RECCONNAISSANCE SOIL SURVEY OF A SECTION OF TANDJIESKOPPE, NORTH-WEST OF NOORDOEWER ALONG THE ORANGE RIVER

by

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APPENDIXES

1 TERMS OF REFERENCE

The soil survey of a section of the farm Tandjieskoppe north-west of Noordoewer, Namibia, along the Orange River, was instructed by the firm Murray, Biesenbach & Badenhorst (MBB), Stellenbosch, Republic of South Africa.

The terms of reference regarding the form of the survey and report were as follow:

i) A reconnaissance soil survey of the specified section of land to determine the dominant soils and their inherent physical and morphological properties.

ii) Compilation of a reconnaissance soil map at a scale of 1:25 000, to describe the natural distribution of broad soil groups.

iii) Description of the soils in the different map units in terms of their general physical, morphological and chemical properties.

iv) Evaluation of the soils in terms of their salinity hazard and plant available water holding capacity.

v) Description of the important limitations of the soils in the different map units in terms of crop production.

vi) General recommendations for amelioration of soil limitations.

vii) Evaluation of the relative suitability of the soil units for the production of grapes, mangos, date, vegetables and lucerne under irrigation.

2 ALLOCATION OF RESPONSIBILITIES

The following individuals and organizations were responsible for the following actions:

i) MBB (Stellenbosch) will supply the topographic background map of the area. This map, enlarged to an approximate scale of 1 : 25 000, will serve as a base map.

ii) The soil surveyors will site profile positions on the 1 : 25 000 maps. MBB will be responsible for actual field siting and digging of the profile pits.

iii) The surveyors will be responsible for description and classification of the soil profiles.

iv) The surveyors will be responsible for compilation of the soil map and a report on the properties, limitations, amelioration practices and relative suitability of the soils.

SOIL CLASSIFICATION WORKING GROUP, 1991. Soil classification: a Taxonomic system for South Africa. *Mem. nat. Agric. Resources S.Afr.* Nr. 15.

3 SITING OF SOIL PITS

A reconnaissance soil survey is defined as a survey with a low intensity of field observations. The intensity however should be such that the dominant soils can be identified, and to broadly subdivide the area in relatively uniform soil-terrain map units.

Because of the restraints in terms of time for field work, assistance to dig pits etc., it was decided to follow the following operational procedure:

i) Instead of a fixed grid system for profile pitting, nine north-south traverses, 2,5 km apart, were defined on the 1 : 25 000 topographic map to cross all expected variation in terms of terrain types, parent materials and soils.

ii) Along these traverses, profiles were sited at a constant linear interval of 500 m, for a total of 118 pits.

iii) The pits were sited in the field by trigonometric interprelation using the global positioning system (GPS).

iv) A mechanical digger was used for digging the pits. Due to mechanical failure as well as the rocky nature of certain sites, only 81 pits were finally made.

4 DESCRIPTION AND CLASSIFICATION OF SOIL PROFILES

4.1 General

A total of 81 soil profiles were investigated in the field. The profiles were described according to standard procedures.

Based on recognisable properties as well as inferred properties, the soils were classified according to **Soil Classification: A Taxonomic system for South Africa** (Soil Classification Working Group, 1991) in **SOIL FORMS** and **SOIL FAMILIES**. This system is based on the recognition of diagnostic soil horizons and materials (see **Appendix 1: Horizons and Properties diagnostic for the Soil Forms**).

Soil Forms are defined in terms of the type and vertical sequence of diagnostic horizons or materials. For communication, Soil Forms are given locality names, eg. Augrabies. These names are abbreviated to two-letter symbols, eg. Ag for Augrabies form.

Soil Forms are subdivided into Soil Families using properties that are not used in the definition of diagnostic horizons or materials (see **Appendix 2: Properties diagnostic for the Soil Families**). Reference to a Soil Family is by combining the Soil Form abbreviation and a four-digit symbol, eg. Ag 2110 is Family number 2110 of the Augrabies form.

Depending on the purpose of the soil survey, Soil Families can be subdivided on an *ad hoc* basis into Soil Phases using properties such as soil and horizon depths, stoniness etc. Phase subdivision is achieved by detail coding of individual soil profiles (see **Appendix 3: Structure of Soil Code and Explanation of Symbols**).

4.2 Soil Forms and Families

Three Soil Forms and 11 Soil Families were identified during the survey.

The Soil Forms, listed alphabetically according to the two-letter Form abbreviation as used in the soil code (see **Table 2**) and Families identified in the survey area, are given in **Table 1**.

5 SOIL MAP LEGEND

A comprehensive map legend was developed to define the spatial distribution of soils in the survey area.

The following principles were followed:

i) Map units should as far as possible consist of only one soil form.

ii) Depending on the uniformity of a soil form unit, soil families should be separated.

iii) The texture of soils in a unit must be similar.

iv) Non-gravelly and non-stony soils were separated from gravelly/stony soils; particularly soils with coarse fragments in the upper 20-30 cm depth of soil.

v) The presence of rock outcrops in terms of type of rock and percentage cover, were used to separate map units.

vi) The terrain (percentage slope and slope form) of a map unit should be fairly uniform.

Map units are characterised by the abbreviation of the dominant soil form in the unit, followed by an arabic number (eg. Au 1) for specific combinations of texture, depth, stoniness, rockiness and/or terrain. The map legend is defined in **Table 3**. **Table 4** is a complete list of all the profiles and codes in the different map units.

6 SOIL PROPERTIES OF MAP UNIT INDIVIDUALS

The properties of the soils in any map unit individual can be abstracted from:

i) the definition of Soil Forms in terms of diagnostic horizons and materials,

ii) the properties of diagnostic horizons and materials,

iii) differentiating Family criteria, and

iv) addisional information (eg. horizon/soil depth, coarse fragments, etc.) specified in the soil code (**Table 4**).

7 PHYSICAL AND CHEMICAL SOIL LIMITATIONS

The soil properties that may limit root penetration and development, water and nutrient retention, aeration, and therefore affecting crop growth and production, can be one or more of the the following:

7.1 Physical

i) Low clay content

The potential of soils, especially those with a low organic carbon content ($\leq$1,0% organic carbon), to store water and plant nutrients for use by plants, is primarily determined by the clay content. At a clay content of approximately 8 - 10 % (clay class symbol 2), the water retention is already so low that it can be considered as a limitation for crop production; the lower the clay content the greater the limitation.

A low clay content is considered a limitation because it is difficult, especially during the dry summer months, to maintain the plant available water at an optimum level. With a properly designed irrigation system, regularly monitoring the soil water content, and an above average level of irrigation management, this limitation can be overcome.

The same comments are applicable to fertilisation.

Another limitation of soils with a sandy topsoil, low in organic carbon, is their susceptability to water and wind erosion; the latter particularly during warm, dry periods and with no plant cover. Wind transported sand grains can cause severe mechanical damage to young trees.

It is recommended that all soils with less than 5 - 8 % clay in the topsoil, practices should be followed that will ensure that the soil surface is permanently covered with an organic mulch (eg. permanent cover crop, or straw or wood chip/bark mulch). This will ensure that the soil surface temperatures and evaporation rates will be lower, and the risk of wind erosion and mechanical damage will smaller.

ii) Underlying weathering rock

Rock in different stages of weathering, from completely unweathered (codes Ro) to slightly weathered (codes so) to moderately weathered (codes lo), is present in many soils as a diagnostic horizon (eg. Glenrosa), or as an unspecified underlying material (eg. Augrabies). It is usually dense and relatively impervious to air, water and plant roots. The shallower, less weathered and harder the rock, the more severe the negative effect will be on crop production.

The limitations associated with weathering rock can be ameliorated by deep ripping or shift ploughing during soil preparation for the establishment of fruit trees or vines; the harder the weathering rock, the more difficult it is to get it loose, but the more permanent the amélioration effect.

The weathering rock in most of the soils in the survey area is of such a nature that it can be mechanically broken. Depending on the depth of the weathering rock below the soil surface, mechanical loosening may result in a very stony surface layer, and is not suitable for row crops and even alfalfa for hay. It is physically however very suitable for fruit and vines.

Another limitation associated with these gravelly/stony loosened soils, is their extremely low plant available waterholding capacity. Although similar soils are successfully used for fruit production in the Western Cape, the extremely warm and dry condition at Noordoewer, will require an exceptionally high level of irrigation management for economically viable crop production.

A should be stressed that loosened weathered rock has a very rapid hydraulic conductivity. Free water will tend to flow freely from higher to lower lying positions. It is therefore essential that cutoff drains are installed after loosening to remove accumulated free drainage water and free salts.

iii) **Coarse fragments in top- and upper subsoils**

Coarse fragments, as specified in the soil code, include fine gravel (*f*; 2-25 mm diameter), gravel (*g*; 25-75 mm diameter), stones (*k*; 75-250 mm diameter) and rock (*r*; >250 mm diameter). The greater the volume content of coarse fragments in a soil, the lower the content of fine soil material (<2mm).

Since water retention capacity is determined by the fine soil material, gravelly or stony soils will have less plant available water than similar soils with no coarse fragments, and would require more frequent but lighter irrigations. Nutrient retention is affected in a similar way as water retention with an increase in coarse fragments.

Gravelly and/or stony soils would require more regular, but lighter irrigations than similarly textured, non-gravelly/stony soils. Fertiliser programmes should also be modified, especially on those soils with a coarse sandy topsoil texture.

Extremely coarse fragments (eg. stones and rocks) in surface horizons also affect soil cultivation, and are therefore not suitable for row crops. It can however be used for fruit trees and vines.

iV) **Water holding capacity**

To determine the combined effect of low clay content and coarse fragments on the potential of the soils to retain water, representative profiles were samples on a horizon basis. A total of 25 samples were collected.

After removal of the ≥2,0 mm fraction by dry sieving, the water retention at 5, 10, 100 and 200 kPa suction were determined on the fine soil (<2 mm fraction) by Infruitec, Stellenbosch. The water retention in mm water per sample depth were calculated and corrected for volume-% coarse fragments (**Table 5**).

From **Table 5** it is evident that the water retention between 10 kPa and 100 kPa suction ranged from as low as 2,9 mm $10cm^{-1}$ to as high as 9,6 mm $10cm^{-1}$. The total water held between these suctions on a profile basis (down to underlyin weathering rock) ranged from as low as 25 mm on shallow, stony soils with a low clay content, to as high as 60 mm on deep, non-stony, loamy soils.

7.2 Chemical

Soil samples collected during the survey from representative profiles, were analysed for pH, salinity and free lime (Table 6).

i) pH and Free lime

With the exception of sample 68B, the pH (measured in a 1:2,5 soil to 1M KCl solution) of all the sampes ranged from 7,5 to 8,5. The reason for these high pH values is the presence of finely divided free lime ($CaCO_3$) in all the samples.

The free lime will improve the physical nature of the soils in terms of stabilising the clay, improving aeration and lower soil density.

Chemically however the lime and associated alkaline pH, may lead to low phosphorous availability, and trace elements, paricularly zinc and iron, will be insoluble.

Different means are available to partially overcome these limitations. One is by selecting crops that are tolerant to high pH values and low iron and zinc levels. Other practices are foliar trace element sprays, acidifying fertilizers etc.

ii) Gypsum

Gypsum crystals is a common feature in many subsoil horizons in the survey area. The presence of gypsum is typical of soils in dry environments and is an indication of the low degree of leaching that the soils experience under those particular climatic conditions.

Although gypsum is a poorly soluble salt that may influence the salinity of the soils, it has a stabilising effect on clay particles. These soils should therefore remain open and porous.

iii) Salinity

Based on resistance of saturated soil pastes (measured in a standard USDA soil cup and expressed in ohms), the soils vary from non-saline to extremely saline. Soil paste resistance values of approximately >400 ohms are considered non-saline for most crops. Values of between 150-400 ohms are limiting for a large range of crops, while values of <150 ohms are considered too saline for most crops.

The resitance values are typical of soils of arid regions. Most soils appear to be non-saline in the surface horizon, with increasing salinity values with depth. This increase in salts is due to the inefficiency of rain to leach salts completely out of soil profiles. In landscape positions where laterally draining soil water tends to concentrate, the soils have low resistance values right through the profile.

Although many soils are saline under the prevailing climatic conditions, it is a limitation that could be improved. The soils are generally fairly low in clay, without any restricting subsoil clay pans. The drainage restriction of underlying weathering rock can be improved by deep ripping. Under irrigation with fresh water from the Orange River, it is therefore expected that these salts could fairly easily be leached from the soils. The presence of free lime, as well as gypsum in particular soils, it is expected that most of the soils will retain its fairly high degree of drainage as the more soluble salts are leached.

It is extremely important that, if the survey area is developed for irrigation, sufficient attention is paid to a well designed drainage system for the removal of all leaching soil water with its component of soluble salts. If a drainage system is not installed, it is predicted that large areas of low lying ground will be salinised to such an extent that it cannot be used for agricultural crops.

7.3 Degree of limitation

The following classes and symbols were used to qualify the physical and chemical limitations of the soils in the various map units (see **Table 7**):

LIMITATION CLASS	ABBREVIATION
None	(no symbol)
Low	Low
Moderate	Mod
Severe	Sev

8 SOIL SUITABILITY

The suitability of the map units for the production of crops was determined in the following manner:

i) Individual physical and morphological limitations of the soils in the map units were evaluated. The greater the number of limitations and the more severe the individual limitations in a particular unit, the less suitable the unit is for crop production.

ii) The general tolerance of crops for any particular soil limitation was taken into account for final assessment of the suitability of a soil map.

iii) Soil cultivation practices used for a paricular crop was also taken into consideration.

The soil requirements and tolerances of the crops that were specified in the terms of reference, are briefly the following:

Grapes	Mangos	Dates	Vegetables	Lucerne
1 Potential rooting depth (cm)				
100	100	150	60	200
2 Minimum effective depth				
60	60	75	30	60
3 Textural requirements				
Variable	Loamy	Sand-loam	Variable	Loam
4 pH_{KCl} requirements				
5,0-7,0	4,5-6,5	>6,0	Variable	5,5-8,0
5 Salinity tolerance				
Medium	Low	High	Medium	Medium
6 Wetness tolerance				
Low-medium	Low	Medium	Low	Medium
7 Tolerance for free lime (iron and other trace element deficiencies)				
High	Low	High	Variable	Medium-high
8 Mechanical limitations stones and/or boulders				
Low-medium	Low-medium	Low	Severe	Medium-Severe

The suitability of the map units for the production of the selected crops after physical amelioration **(Table 8)** were rated according to the following qualitative classification:

SUITABILITY CLASS	RELATIVE SUITABILITY
High (H)	80 - 100 %
Medium-high (MH)	60 - 80 %
Medium (M)	40 - 60 %
Medium-low (ML)	20 - 40 %
Low (L)	0 - 20 %

Soils with a **Low** to **Medium-low** suitability are generally not recommended for development.

Medium-high to **High** suitable soils are usually recommended for development of climatically adapted crops following standard practices.

Medium suitable soils are recommended with the *proviso* that the correct soil cultivation and amelioration practices are followed. A high management level is required to ensure that optimum practices in terms of irrigation and fertilisation are followed.

9 SUMMARY

A soil survey of a section of land ($\pm$3 000 ha) on the farm Tandjieskoppe, was undertaken to determine, at reconnaissance level, the soil distribution and some its important chemical and physical properties. A total of 81 soil profiles were investigated and described in the field.

The soil variation was fairly small, and only three soil forms were identified. On soil familiy and phase levels however, 15 different map units were described and mapped.

Twenty-five soil samples collected from 10 representative profiles were analysed to determine the water-holding capacities, as well as some chemical properties.

The water-holding capacity of the soils on Tandjieskoppe range from 27 mm on shallow (<50 mm deep), light textured soils, to as high as 58 mm on deeper (>90 cm) loamy soils. pH values (measured in 1M KCl) are generally high (>7,5) and fine lime occurs in virtually all the subsoil horizons, as well as in certain topsoils. In all the soils salinity increases with depth

Proper drainage management and a well designed irrigation system are therefore prerequisites for successful irrigation farming on Tandjieskoppe.

TABLE 1

SOIL FORMS, LISTED ALPHABETICALLY ACCORDING TO THE TWO-LETTER FORM ABBREVIATION, AND FAMILIES IDENTIFIED ON TANDJIESKOPPE

ABBRE-VIATION	FORM AND VERTICAL SEQUENCE OF DIAGNOSTIC HORIZONS AND/OR MATERIALS

Ag — AUGRABIES FORM

Orthic A
Neocarbonate B
Unspecified material

SOIL FAMILIES

2000 A horizon bleached
- 2100 Non-red B horizon
  - 2110 Non-luvic B1 horizon
  - 2120 Luvic B1 horizon
- 2200 Red B horizon
  - 2210 Non-luvic B1 horizon
  - 2220 Luvic B1 horizon

Du — DUNDEE FORM

Orthic A
Stratified alluvium

SOIL FAMILIES

1000 Non-red stratified alluvium
- 1100 Signs of wetness absent
  - 1110 Non-calcareous within 1500mm of the soil surface
  - 1120 Calcareous within 1500mm of the soil surface

2000 Red stratified alluvium
- 2100 Signs of wetness absent
  - 2110 Non-calcareous within 1500mm of the soil surface
  - 2120 Calcareous within 1500mm of the soil surface

Gs

GLENROSA FORM

Orthic A
Lithocutanic B

SOIL FAMILIES

2000 A horizon bleached
- 2100 B1 horizon not hard
  - 2110 No signs of wetness in B1 horizon
    - 2112 Calcareous B horizon
- 2200 B1 horizon hard
  - 2210 No signs of wetness in B1 horizon
    - 2211 Non-calcareous B horizon
    - 2212 Calcareous B horizon

TABLE 2

NUMERICAL LIST OF PROFILES AND SOIL CODES

Profile number	ABOVE THE LINE		SUBSOIL LIMITATIONS			BELOW THE LINE				
	Depth codes	Soil Form & Family	Upper	Lower	Coarse frag-ments	Coarse frag-ments	Sand grade	Clay class	Changes	Transitional form & other features
1	2 8 2	Ag 2220	so		f1+g1	f1	co	1/2		
2	2 2-4 5 2	Gs 2112	lo	so	f2	f1/2	fi/co	3/4		
3	3	Gs 2212	so			f1/2	fi/co	3	nc	Few low ridges
4	3	Gs 2212	so			f1/2	fi/co	3	nc	Low ridges
5	3 6 3	Ag 221/20	so		f1	f1	co	2		+ Gs 2211
6	2 5/6 2	Ag 2120	so		f1+g1	f1+g1	co	2	nc	Low ridges + Gs 2212
7	2 6 2	Ag 2120	so		f1+g1	f1+g1	co	2	nc	Low ridges + Gs 2212
8	2 4/5 2	Ag 2120	so		f1+g1	f1+g1	co	2	nc	Lae riwwe met Gs2212
9	3 6 3	Ag 2120	so		f2	f1+g1	fi/co	2		Ag 2220; + Gs2211
10	1-2	Gs 2212	so+Ro			f1/2	fi/co	3	nc	
11	2	Gs 2212	so/Ro			f2	fi/co	2		Low rocky terrace
12	2	Gs 2212	so/Ro			f1	fi/co	3	nc	+ Low rocky ridges
13	2 5 2 2	Gs 2112	Ro	cs	f2	f1/2	fi/co	3	nc	+ Gs 2212
14	3	Gs 2212	so			f2	co	2	nc	Commen surface stones
15	2 5 2	Ag 211/20	so		f1	f1	fi/co	3	nc	+ Gs 2212
16	2 4 2	Gs 21/212	lo/so	so	g2	f1	fi/co	3	nc	Red B
17	2	Gs 2211	so+Ro			f1+g/k1	fi/co	2/3		Rock ridges; uneven terrain
18	2 5 2	Ag 211/20	so		f2	f1/2	fi/co	3		Uneven terrain
19	2	Gs 2211	so+Ro			f1+g/k1	fi/co	2/3		Rock ridges; uneven terrain
20	3	Gs 2211	so+Ro			f1+g/k1	fi/co	2/3		Rock ridges; uneven terrain
21	3	Gs 2211	so+Ro			f1+g/k1	fi/co	2/3		Rock ridges; uneven terrain
22	2 5 2	Ag 211/20	so		f2	f2	fi/co	2/3		+ Gs 2211
23	2 2-4 2	Gs 2112	so		f2/3	f1	fi/co	3		
24	2 2-4 2	Gs 2112	so		f2/3	f1	fi/co	3		+ Dolomite ridges
25	2 2-4 2	Gs 2112	so		f2/3	f1	fi/co	3		+ Dolomite ridges
26	2 2-4 2	Gs 2112	so		f2/3	f1	fi/co	3		+ Dolomite ridges
27	2 6 2	Ag 2110	so		f1+g1	f1	fi/co	3		
28	3 3	Du 1/2120	U5		f1+k1	f1	me/co	2		
29	3 6 7 3	Du 1/2110	U5	xp	f2		co	1/2		
30	2 7 2	Ag 2220	so		f1+g1	f1+k1	co	2		Rocky terrace
31	2 8 6	Ag 2220	so	cs	f1+g1	f1+k/r1	co	3		
32	2 6 2	Ag 2120	so/Ro		f1+g1	f2	co	1/2		
33	2 6 2	Gs 2112	so		g1+k1	f2/3	co	1/2		
34	2 5/6 2	Ag 2120	so		f2	f1+g1	co	2		
35	2 6 2	Gs 2112	so		g1+k1	f1+k1	co	1/2		
36	1	Gs 2211	so+Ro			g1+k1	co	1/2		Rock; surface stones
37	1	Gs 2211	so+Ro			g1+k1	co	1/2		Rock; surface stones
38	1	Gs 2211	so+Ro			g1+k1	co	1/2		Rock; surface stones
39	2/3 6 2 2	Gs 2112	so	cs	f2+g1	f1	fi/co	2/3	nc	
40	2/3 6 2 2	Gs 2112	so	cs	f2+g1	f1	fi/co	2/3	nc	
41	4	Gs 2211	so+Ro			f2	co	2		Dolomite ridges
42	4	Gs 2211	so+Ro			f2	co	2		Dolomite ridges
43	3	Gs 2211	so+Ro			f2	co	2		
44	2 6 2	Ag 2110	so		f2	f1/2	fi/co	2/3	nc	Dolomite+ Quartsite ridges
45	2 2-6 2	Gs 21+212	so		f1		fi/co	3	nc	

Table 2- 2

	ABOVE THE LINE					BELOW THE LINE				
			SUBSOIL LIMITATIONS							
Profile number	Depth codes	Soil Form & Family	Upper	Lower	Course frag-ments (above)	Course frag-ments (below)	Sand grade	Clay class	Changes	Transitional form & other features
46	3 3-7 3 3	Gs 21+212	lo+so	cs	f2	f1+g1	co	1/2		
47	2 6 2	Ag 2120	so		f2	f/g1	co	2	nc	Ag 2220
48	2 4-6 2	Ag 2120	so		f2	f/g1	co	2	nc	Ag 2220
49	4 6 4	Ag 2120	nc		f1+g1	f/g1	co	2		Ag 2220
50	2 2	Ag 2110			f1+g1	f1/2	co	2		
51	2 2	Ag 2110			f/g1	f/g1	co	2		
52	2 2	Ag 2110			f/g1	f/g1	co	2		
53	4 4	Ag 2120			f/g1	f/g1	co	2	nc	
54	4 4	Ag 2120			f/g1	f/g1	co	2	nc	
55	2 2	Ag 2110			f/g1	f/g1	co	2		
56	1 4 1	Gs 2212	so	so/Ro	g1+k1	f2/3	fi/co	2		
57	2 2-7 2	Gs 2112	so		f2	f1	co	2	nc	
58	2 4	Gs 2212	so	so/Ro	f1+g2	f2	fi/co	1		
59	2 2-7 2	Gs 2112	so		f2	f1	co	2	nc	Rock ridges
60	2 6 2	Ag 2110	so		f1+g1	f1/2	fi/co	2/3	nc	
61	3	Gs 2212	so			f2	f1/co	2/3		Rock ridges
62	3	Gs 2212	so+Ro			f2	co	1/2		
63	2 6/7 2	Ag 2110	so		f1+g1	f2	fi/co	2		
64	2 5 2	Ag 2110	so		f2	f2	co	2		
65	2 4 2	Gs 2112	so		f2/3	f1	fi/co	3		Red B
66	2 5 2 2	Gs 2112	so	cs	f2/3	f1	fi/co	2		
67	2 2-4 2	Gs 2112	so		f2	f2	fi/co	2/3		
68	3 6 3 3	Gs 2112	so	cs	f1+g2	f2	fi/co	2		
69	2 6/7 2 2	Gs 2112	so/Ro	cs	f1+g2	f2	fi/co	1/2		
70	3 6 3 3	Gs 2112	so+Ro	cs	f2/3	f2	fi/co	2/3		
71	1 4	Gs 2212	so	so/Ro		f2	fi/co	2		
72	1 2-4 1	Gs 2112	so	Ro	f1	f2	fi/co	2	nc	
73	3 6 3 3	Gs 2112	so	cs	f2	f1	fi/co	3		
74	2 6	Gs 2212	so	so/Ro		f2	co	1/2		
75	2 6	Gs 2212	so	so/Ro		f2	co	1/2		
76	2 2-4 2	Gs 2112	so		f2	f1/2	co	2		
77	2 2-6 2	Gs 2112	so		f1	f1+g1	fi/co	2		
78	2	Gs 2212	so			f1	fi/co	2		Rock ridges
79	2-3	Gs 2212	so			f1	fi/co	2		
80	2 6 2 2	Gs 2112	lo+cs	so/Ro	f1+g2		co	1/2		
81	1 3	Gs 2212	so	Ro			co	1/2		

TABLE 3

SOIL MAP LEGEND

Ag	AUGRABIES FORM SOILS				
Soils with an Orthic A horizon on a Neocarbonate B horizon on Unspecified material without signs of wetness (usually weathering rock)					
Map symbol	**Colour of neocarbonate B**	**Clay increase from A to B**	**Coarse fragments below the topsoil**	**Type and depth (cm) underlying material**	**Clay (%) topsoil**
Ag 1	Non-red	Usually non-luvic	Fine gravelly	Hard saprolite 50-65	8-12
Addisional features:	Topsoil non-calcareous; low incidence of rock outcrops				
Ag 2	Non-red	Non-luvic	Gravelly	Deeper 120cm	5-10
Addisional features:	Topsoil non-calcareous; low incidence of rock outcrops				
Ag 3	Non-red	Luvic	Gravelly	Hard saprolite 55-65	5-10
Addisional features:	Topsoil non-calcareous; low incidence of rock outcrops				
Ag 4	Red	Luvic	Gravelly	Hard saprolite 65-80	5-10
Addisional features:	Topsoil non-calcareous; low incidence of rock outcrops				
Ag 5	Non-red	Luvic	Gravelly	Hard saprolite 50-65	5-12
Addisional features:	Topsoil calcareous; high incidence of rock outcrops				
Ag 6	Red	Luvic	Gravelly	Hard saprolite 50-65	5-12
Addisional features:	Topsoil non-calcareous; low incidence of rock outcrops; abundant stones and rocks of soil surface				
Ag 7	Non-red	Luvic	Gravelly	Deeper 120cm	5-10
Addisional features:	Topsoil calcareous; low incidence of rock outcrops				

Table 3-2

Du	DUNDEE FORM SOILS				
Soils with an Orthic A horizon directly on Stratified alluvium					
Map symbol	Colour of alluvium	Signs of wetness in alluvium	Presence carbonates in alluvium	Coarse fragments below the topsoil	Clay (%) topsoil
Du 1	Yellowish red	Absent	Variable	Gravelly to stony	5-10

Gs	GLENROSA FORM SOILS				
Soils with an Orthic A horizon on a Lithocutanic B horizon					
Map symbol	Hardness of upper lithocutanic B	Presence carbonates in B horizon	Depth to hard saprolite/rock	Presence gypsum in B horizon	Clay (%) topsoil
Gs 1	Soft	Present	40-60	Absent	5-12
Addisional features:	Topsoil non-calcareous; low incidence of rock outcrops				
Gs 2	Soft	Present	Tonguing 20-85	Absent	5-10
Addisional features:	Topsoil calcareous; low to moderate incidence of rock outcrops				
Gs 3	Soft	Present	50-65	Present	5-10
Addisional features:	Topsoil non-calcareous; low incidence of rock outcrops				
Gs 4	Soft	Present	45-65	Present	10-15
Addisional features:	Topsoil calcareous; low incidence of rock outcrops				
Gs 5	Hard	Absent	20-40	Absent	5-10
Addisional features:	Topsoil non-calcareous; very high incidence of rock outcrops				
Gs 6	Hard	Present	20-40	Absent	5-13
Addisional features:	Topsoil usually calcareous; moderate incidence of rock outcrops				
Gs 7	Soft	Present	20-40	Absent	10-15
Addisional features:	Topsoil non-calcareous; high incidence of rock outcrops				

TABLE 4

MAP UNITS WITH A COMPLETE LIST OF PROFILES AND SOIL CODES

		ABOVE THE LINE					BELOW THE LINE			
				SUBSOIL LIMITATIONS						
Map unit	Profile number	Depth codes	Soil Form & Family	Upper	Lower	Coarse frag-ments	Coarse frag-ments	Sand grade	Clay class	Surface features
Ag			**AUGRABIES FORM SOILS**							
Soils with an Orthic A horizon on a Neocarbonate B horizon on Unspecified material without signs of wetness (usually weathering rock)										
Ag 1	18	2 5 2	Ag 211/20	so		f2	f1/2	fi/co	3	
Ag 1	22	2 5 2	Ag 211/20	so		f2	f2	fi/co	2/3	
Ag 1	27	2 6 2	Ag 2110	so		f1+g1	f1	fi/co	3	
Ag 1	63	2 6/7 2	Ag 2110	so		f1+g1	f2	fi/co	2	
Ag 1	64	2 5 2	Ag 2110	so		f2	f2	co	2	
Ag 2	50	2 2	Ag 2110			f1+g1	f1/2	co	2	
Ag 2	51	2 2	Ag 2110			f/g1	f/g1	co	2	
Ag 2	52	2 2	Ag 2110			f/g1	f/g1	co	2	
Ag 2	55	2 2	Ag 2110			f/g1	f/g1	co	2	
Ag 3	9	3 6 3	Ag 2120	so		f2	f1+g1	fi/co	2	
Ag 3	32	2 6 2	Ag 2120	so/Ro		f1+g1	f2	co	1/2	
Ag 3	34	2 5/6 2	Ag 2120	so		f2	f1+g1	co	2	
Ag 3	49	4 6 4	Ag 2120	nc		f1+g1	f/g1	co	2	
Ag 4	1	2 8 2	Ag 2220	so		f1+g1	f1	co	1/2	
Ag 4	5	3 6 3	Ag 221/20	so		f1	f1	co	2	
Ag 5	6	2 5/6 2	Ag 2120	so		f1+g1	f1+g1	co	2	nc
Ag 5	7	2 6 2	Ag 2120	so		f1+g1	f1+g1	co	2	nc
Ag 5	8	2 4/5 2	Ag 2120	so		f1+g1	f1+g1	co	2	nc
Ag 5	15	2 5 2	Ag 211/20	so		f1	f1	fi/co	3	nc
Ag 5	44	2 6 2	Ag 2110	so		f2	f1/2	fi/co	2/3	nc
Ag 5	47	2 6 2	Ag 2120	so		f2	f/g1	co	2	nc
Ag 5	48	2 4-6 2	Ag 2120	so		f2	f/g1	co	2	nc
Ag 5	60	2 6 2	Ag 2110	so		f1+g1	f1/2	fi/co	2/3	nc
Ag 6	30	2 7 2	Ag 2220	so		f1+g1	f1+k1	co	2	
Ag 6	31	2 8 6	Ag 2220	so	cs	f1+g1	f1+k/r1	co	3	
Ag 7	53	4 4	Ag 2120			f/g1	f/g1	co	2	nc
Ag 7	54	4 4	Ag 2120			f/g1	f/g1	co	2	nc

Table 4- 2

Map unit	Profile number	Depth codes	Soil Form & Family	ABOVE THE LINE — SUBSOIL LIMITATIONS: Upper	Lower	Coarse frag-ments	BELOW THE LINE: Coarse frag-ments	Sand grade	Clay class	Surface features
Du			DUNDEE FORM SOILS							
Soils with an Orthic A horizon directly on Stratified alluvium										
Du 1	28	3 3	Du 1/2120	U5		f1+k1	f1	me/co	2	
Du 1	29	3 6 7 3	Du 1/2110	U5	xp	f2		co	1/2	
Gs			GLENROSA FORM SOILS							
Soils with an Orthic A horizon on a Lithocutanic B horizon										
Gs 1	23	2 2-4 2	Gs 2112	so		f2/3	f1	fi/co	3	
Gs 1	33	2 6 2	Gs 2112	so		g1+k1	f2/3	co	1/2	
Gs 1	35	2 6 2	Gs 2112	so		g1+k1	f1+k1	co	1/2	
Gs 1	65	2 4 2	Gs 2112	so		f2/3	f1	fi/co	3	
Gs 1	67	2 2-4 2	Gs 2112	so		f2	f2	fi/co	2/3	
Gs 1	76	2 2-4 2	Gs 2112	so		f2	f1/2	co	2	
Gs 1	77	2 2-6 2	Gs 2112	so		f1	f1+g1	fi/co	2	
Gs 2	45	2 2-6 2	Gs 21+212	so		f1		fi/co	3	nc
Gs 2	57	2 2-7 2	Gs 2112	so		f2	f1	co	2	nc
Gs 2	59	2 2-7 2	Gs 2112	so		f2	f1	co	2	nc
Gs 2	72	1 2-4 1	Gs 2112	so	Ro	f1	f2	fi/co	2	nc
Gs 3	46	3 3-7 3 3	Gs 21+212	lo+so	cs	f2	f1+g1	co	1/2	
Gs 3	66	2 5 2 2	Gs 2112	so	cs	f2/3	f1	fi/co	2	
Gs 3	68	3 6 3 3	Gs 2112	so	cs	f1+g2	f2	fi/co	2	
Gs 3	69	2 6/7 2 2	Gs 2112	so/Ro	cs	f1+g2	f2	fi/co	1/2	
Gs 3	70	3 6 3 3	Gs 2112	so+Ro	cs	f2/3	f2	fi/co	2/3	
Gs 3	73	3 6 3 3	Gs 2112	so	cs	f2	f1	fi/co	3	
Gs 4	2	2 2-4 5 2	Gs 2112	lo	so	f2	f1/2	fi/co	3/4	
Gs 4	13	2 5 2 2	Gs 2112	Ro	cs	f2	f1/2	fi/co	3	nc
Gs 4	16	2 4 2	Gs 21/212	lo/so	so	g2	f1	fi/co	3	nc
Gs 4	39	2/3 6 2 2	Gs 2112	so	cs	f2+g1	f1	fi/co	2/3	nc
Gs 4	40	2/3 6 2 2	Gs 2112	so	cs	f2+g1	f1	fi/co	2/3	nc
Gs 4	80	2 6 2 2	Gs 2112	lo+cs	so/Ro	f1+g2		co	1/2	

		ABOVE THE LINE					BELOW THE LINE			
				SUBSOIL LIMITATIONS						
Map unit	Profile number	Depth codes	Soil Form & Family	Upper	Lower	Coarse frag- ments	Coarse frag- ments	Sand grade	Clay class	Surface features
Gs 5	17	2	Gs 2211	so+Ro			f1+g/k1	fi/co	2/3	
Gs 5	19	2	Gs 2211	so+Ro			f1+g/k1	fi/co	2/3	
Gs 5	20	3	Gs 2211	so+Ro			f1+g/k1	fi/co	2/3	
Gs 5	21	3	Gs 2211	so+Ro			f1+g/k1	fi/co	2/3	
Gs 5	36	1	Gs 2211	so+Ro			g1+k1	co	1/2	
Gs 5	37	1	Gs 2211	so+Ro			g1+k1	co	1/2	
Gs 5	38	1	Gs 2211	so+Ro			g1+k1	co	1/2	
Gs 5	41	4	Gs 2211	so+Ro			f2	co	2	
Gs 5	42	4	Gs 2211	so+Ro			f2	co	2	
Gs 5	43	3	Gs 2211	so+Ro			f2	co	2	
Gs 6	3	3	Gs 2212	so			f1/2	fi/co	3	nc
Gs 6	4	3	Gs 2212	so			f1/2	fi/co	3	nc
Gs 6	10	1-2	Gs 2212	so+Ro			f1/2	fi/co	3	nc
Gs 6	11	2	Gs 2212	so/Ro			f2	fi/co	2	
Gs 6	12	2	Gs 2212	so/Ro			f1	fi/co	3	nc
Gs 6	14	3	Gs 2212	so			f2	co	2	nc
Gs 6	56	1 4 1	Gs 2212	so	so/Ro	g1+k1	f2/3	fi/co	2	
Gs 6	58	2 4	Gs 2212	so	so/Ro	f1+g2	f2	fi/co	1	
Gs 6	61	3	Gs 2212	so			f2	f1/co	2/3	
Gs 6	62	3	Gs 2212	so+Ro			f2	co	1/2	
Gs 6	71	1 4	Gs 2212	so	so/Ro		f2	fi/co	2	
Gs 6	74	2 6	Gs 2212	so	so/Ro		f2	co	1/2	
Gs 6	75	2 6	Gs 2212	so	so/Ro		f2	co	1/2	
Gs 6	78	2	Gs 2212	so			f1	fi/co	2	
Gs 6	79	2-3	Gs 2212	so			f1	fi/co	2	
Gs 6	81	1 3	Gs 2212	so	Ro			co	1/2	
Gs 7	24	2 2-4 2	Gs 2112	so		f2/3	f1	fi/co	3	
Gs 7	25	2 2-4 2	Gs 2112	so		f2/3	f1	fi/co	3	
Gs 7	26	2 2-4 2	Gs 2112	so		f2/3	f1	fi/co	3	

TABLE 5.a & 5.b

CLAY CONTENT, COARSE FRAGMENTS AND WATER RETENTION OF REPRESENTATIVE SOIL PROFILES

5.a

Profile number	Map unit	Soil form & family	Master horizon	Depth (cm)	Estimated clay (%)	Coarse fragments (mass %)	Coarse fragments (volume %)	Fine soil (volume %)
1	Ag 4	Ag 2220	A B1 B2	20 65 90	3 8 15	26 43 56	16 29 41	83 70 58
15	Ag 5	Ag 211/20	A B	20 50	10 18	33 25	21 16	78 83
27	Ag 1	Ag 2110	A B	20 65	6 8	38 36	25 23	74 76
31	Ag 6	Ag 2220	A B1 B2	20 65 90	20 25 25	6 35 27	3 22 16	96 77 83
32	Ag 3	Ag 2120	A B	20 65	5 13	34 24	21 15	78 84
35	Gs 1	Gs 2112	A B C	20 65 90	5 13 35	26 10 84	16 6 75	83 93 24
40	Gs 4	Gs 2112	A B	25 65	22 18	6 61	3 46	96 53
48	Ag 5	Ag 2120	A B C/R	20 50 80	6 13 20	28 37 79	17 24 67	82 75 32
55	Ag 2	Ag 2110	A B1 B2	20 60 90	7 8 10	27 30 40	17 18 27	82 81 72
68	Gs 3	Gs 2112	A B	30 65	7 35	24 55	14 40	85 59

Table 5- 2

5.b

Profile number	Lower depth (cm)	Mass percent water of fine soil with increased suction in kPa				Volume percent water* of fine soil with increased suction in kPa				Available water between 10 kPa and 100kPa (mm/10cm soil)		Available water between 10 kPa and 100kPa (mm)	
		5	10	100	200	5	10	100	200	Fine soil	Plus** coarse frag-ments	Per horizon	Total for profile
1	20	13,1	8,3	3,5	2,8	19,7	12,5	5,3	4,3	7,2	6,1	12,1	
	65	17,2	13,9	6,8	5,4	25,8	20,9	10,3	8,2	10,6	7,6	34,2	
	90	17,0	14,2	8,1	6,0	25,5	21,4	12,3	9,0	9,1	5,4	13,4	59,8
15	20	9,6	7,2	3.9	3,4	14.4	10.9	5,9	5,2	5.0	3,9	7,9	
	50	15,8	12.4	7.3	6.7	23,7	18.7	11,0	10,1	7,7	6.4	19,3	27,2
27	20	16,8	12,2	4,8	3,6	25,2	18,3	7,3	5,5	11,0	8,3	16,6	
	65	14,9	13,1	4.9	3,9	22,5	19,7	7,5	5,9	12,2	9,4	42,1	58,7
31	20	20,3	16.4	11.4	8.9	30.6	24.7	17,2	13,4	7,5	7,3	14,5	
	65	17,8	15,0	9,7	8,0	26,8	22,5	14,7	12,0	7,9	6,1	27,3	
	90	17,6	13.9	8,7	6,5	26.5	20.9	13,1	9,8	7,8	6,5	16,2	58,1
32	20	15,1	9.0	6,3	4.6	22,7	13.5	9,6	7,0	4,0	3,1	6,3	
	65	17.3	13,5	8,3	7.1	26.0	20.3	12,6	10,7	7,7	6,6	29,5	35,8
35	20	11,3	8,1	5,7	4.6	17.0	12.3	8,6	6,9	3.7	3,1	6.2	
	65	18,1	13.0	8,4	6.6	27.2	19.6	12,7	10,0	6,9	6,5	29,3	
	90	23,8	21,3	13,5	10.9	35.8	32.0	20,3	16,5	11,7	2,9	7,2	42,6
40	25	20,1	16.3	11,0	10,1	30.2	24.6	16,5	15,3	8,0	7,8	19,4	
	65	29,9	19,7	10.2	8.6	45.0	29.6	15,3	13,0	14.3	7,6	30,5	49,8
48	20	19,2	9.7	4,4	3.8	28.9	14,6	6,7	5,8	7,9	6,5	13,0	
	50	16.1	12.3	6.8	5.0	24.2	18.5	10,3	7,5	8.2	6,2	18,6	
	80	19.2	15.0	8.5	6.5	28.9	22.6	12.8	9,8	9,8	3.2	9,5	28,1
55	20	15,5	11.4	3.7	3.4	23,3	17.1	5,6	5,2	11,6	9.6	19,2	
	60	12.2	8.1	4,1	3.1	18.3	12.2	6,3	4,8	5,9	4,8	19,2	
	90	14.0	10.7	4.8	4.0	21.1	16.1	7,2	6,1	8,9	6,5	19,4	38,6
68	30	12.4	10.0	5.3	4.6	18.7	15,1	8,1	7,0	7,0	6,0	18,0	
	65	26,2	21,0	14,7	11.9	39,3	31,6	22,2	17,9	9,4	5,6	19,6	37,5

* Bulk density of soil was taken as as 1500 kg m^{-3}

** Density of coarse fragments was 2550 kg m^{-3}

TABLE 6

SELECTED CHEMICAL PROPERTIES OF REPRESENTATIVE SOIL PROFILES

Profile number	Map Unit	Soil form & family	Master horizon	Depth (cm)	pH (KCl)	Resistance soil paste (ohms)	Free lime	Gypsum
1	Ag 4	Ag 2220	A B1 B2	20 65 90	8,1 8,1 8,1	2270 365 166	* *** ***	
15	Ag 5	Ag 211/20	A B	20 50	8,0 7,9	850 610	* ***	
27	Ag 1	Ag 2110	A B	20 65	8,0 8,0	1240 410	* *	
31	Ag 6	Ag 2220	A B1 B2	20 65 90	8,0 7,7 7,7	54 24 28	*** ** **	 ***
32	Ag 3	Ag 2120	A B	20 65	8,0 7,9	520 45	** *	
35	Gs 1	Gs 2112	A B C	20 65 90	8,0 7,9 7,5	860 278 278	* ** ***	
40	Gs 4	Gs 2112	A B	25 65	7,8 7,6	134 136	** *	 ***
48	Ag 5	Ag 2120	A B C/R	20 50 80	8,3 8,0 8,0	780 114 125	* *** ***	
55	Ag 2	Ag 2110	A B1 B2	20 60 90	8,0 8,2 8,3	1620 405 128	* * ***	
68	Gs 3	Gs 2112	A B	30 65	7,7 6,7	395 56	* *	 ***

* Weak effervescence with acid
** Moderate effervescence with acid
*** Strong effervescence with acid/Common gypsum crystals

TABLE 7

SOIL LIMITATIONS OF MAP UNITS

Note: The following classes and symbols were used to qualify the physical soil limitations of the map units.

LIMITATION CLASS	ABBREVIATION
None	(no symbol)
Low	Low
Moderate	Mod
Severe	Sev

Map unit	Low clay content	Depth underlying rock	Stones boulders surface	Rock outcrops	Lime surface horison	Salinity
Ag	**AUGRABIES FORM SOILS**					
Soils with an Orthic A horizon on a Neocarbonate B horizon on Unspecified material without signs of wetness (usually weathering rock)						
Ag 1		Mod 50-65				Low
Ag 2	Low	None >120				Low
Ag 3		Mod 55-65				Low-Mod
Ag 4	Low	Low 65-80				Low
Ag 5		Mod 50-65		Mod-Sev	Mod	Mod
Ag 6		Mod 50-65	Mod-Sev			Mod-Sev
Ag 7	Low	None >120			Mod	Mod
Du	**DUNDEE FORM SOILS**					
Soils with an Orthic A horizon directly on Stratified alluvium						
Du 1	Low-Mod		Low-Mod			Low

Table 7- 2

Map unit	Low clay content	Depth underlying rock	Stones boulders surface	Rock outcrops	Lime surface horison	Salinity
Gs	**GLENROSA FORM SOILS**					
Soils with an Orthic A horizon on a Lithocutanic B horizon						
Gs 1		Mod 40-60	None-Low			Low-Mod
Gs 2	Low	Mod 20-85				Low-Mod
Gs 3	Low	Mod 50-65				Mod-Sev
Gs 4		Mod 45-65			Mod	Mod-Sev
Gs 5	Low	Sev 20-40	Mod-Sev	Sev		Low-Mod
Gs 6		Sev 20-40		Mod-Sev	Mod	Mod
Gs 7		Sev 20-40		Sev		Low-Mod

TABLE 8

SUITABILITY OF MAP UNITS FOR VARIOUS CROPS

Note:

The following five classes were used to rate the suitability

SUITABILITY CLASS	SYMBOL	RELATIVE SUITABILTY
Low	L	0-20%
Medium-Low	ML	20-40%
Medium	M	40-60%
Medium-high	MH	60-80%
High	H	80-100%

Map unit	Suitability				
	Grapes	Mangos	Dates	Vegetables	Lucerne
Ag	**AUGRABIES FORM SOILS**				
Soils with an Orthic A horizon on a Neocarbonate B horizon on Unspecified material without signs of wetness (usually weathering rock)					
Ag 1	MH	M	MH	MH	MH
Ag 2	MH-H	M-MH	H	MH	H
Ag 3	M-MH	ML-M	MH	M-MH	MH
Ag 4	MH-H	M-MH	H	MH	H
Ag 5	M	ML	M-MH	L	M
Ag 6	M	ML	MH	L	L
Ag 7	MH	ML-M	H	M	MH
Du	**DUNDEE FORM SOILS**				
Soils with an Orthic A horizon directly on Stratified alluvium					
Du 1	M-MH	M	MH	MH	MH

Table 8- 2

Map unit	Suitability				
	Grapes	Mangos	Dates	Vegetables	Lucerne
Gs	GLENROSA FORM SOILS				
Soils with an Orthic A horizon on a Lithocutanic B horizon					
Gs 1	M-MH	M	M-MH	MH	MH
Gs 2	M	ML	M-MH	ML	M
Gs 3	ML-M	L	M	M	M-MH
Gs 4	ML	L	M-MH	ML-M	M
Gs 5	L-ML	L	ML	L	L
Gs 6	ML-M	L	M	L	ML
Gs 7	ML-M	ML	M	L	L

APPENDIX 1

HORIZONS AND PROPERTIES DIAGNOSTIC FOR THE SOIL FORMS

INTRODUCTION

To be diagnostic, an horizon must occur wholly or in part within 1,5 m of the soil surface. In some instances, a classifiable soil has been buried by a recent aeolian, alluvial or manmade soil deposit. When the recent deposit is less than 500 mm thick, it is the buried soil which is classified. When the deposit is thicker than 500 mm, it is the recent deposit which is classified. Further, it is the recent deposit which is classified if it is less than 500 mm thick, but overlies material which is not classifiable soil. When no diagnostic horizon or material, either topsoil or subsoil, other than an orthic A horizon, can be identified, then, if less than 100 mm thick and if no marked pedogenesis (such as organic matter accumulation) has taken place, inclusion in a land class such as "rock and lithosols" is usually appropriate.

Subsoil horizons and materials occur beneath diagnostic topsoil horizons unless they have been exposed at the surface by truncation of the soil. At least part of a diagnostic subsoil horizon or material must occur within 1500 mm of the soil surface. The following subsoil horizons and materials have been defined as diagnostic.

TOPSOIL HORIZONS

Orthic A horizon

i) is a surface horizon that does not qualify as any other diagnostic surface horizon (eg. organic, humic, vertic or melanic), although it may have been darkened by organic matter.

SUBSOIL HORIZONS AND MATERIALS

Lithocutanic B horizon

i) underlies a diagnostic topsoil horizon, either directly or via a stoneline, or an E horizon;
ii) merges into underlying weathering rock;
iii) has, at least in part, a general organization in respect of colour, structure or consistence which has distinct affinities with the underlying parent rock;
iv) has cutanic character expressed usually as tongues or prominent colour variegations caused by residual soil formation and illuviation resulting in the localization of one or more of clay, iron and manganese oxides, and organic matter in a non-homogenized matrix of geological material saprolite) in a variable but generally youthful stage of weathering.
v) lacks a laterally continuous horizon which would qualify as either a diagnostic pedocutanic B or prismacutanic B;
vi) does not qualify as a diagnostic podzol B, a neocarbonate B, a soft or hardpan carbonate horizon, or diagnostic dorbank;
vii) if the horizon shows signs of wetness, then more than 25% by volume has saprolite character.

Neocarbonate B horizon

i) directly underlies a diagnostic topsoil or E horizon;
ii) contains, within 1500 mm of the surface, sufficient calcium or calcium-magnesium carbonate to effervesce visibly when treated with cold 10% hydrochloric acid;
iii) does not have the morphology required to qualify as a diagnostic soft or hardpan carbonate horizon;
iv) occurs in unconsolidated material, usually transported, which has undergone pedogenesis to an extent which excludes the horizon from diagnostic stratified alluvium, regic sand and man-made soil deposit, and which has caused the presence of carbonates, but which has been insufficient to produce any other diagnostic horizon;
examples are:
- horizons which, but for the presence of carbonates, would have qualified as diagnostic red apedal or yellow-brown apedal B horizons;
- disappearance of fine stratifications and the presence of carbonates in a deposit which was initially stratified contrast with an underlying stratified C);
- aggregation of soil particles in the presence of carbonates to the extent that it is no longer loose, but insufficient to qualify as a diagnostic pedocutanic or prismacutanic B.

Stratified alluvium

i) is unconsolidated and contains stratifications caused by alluvial or colluvial deposition;
ii) directly underlies a diagnostic orthic or melanic A horizon, or occurs at the surface.

Saprolite

i) is an horizon of weathering rock with a general organization in respect of colour, structure or consistence, which still has distinct affinities with the parent rock;
ii) grades into relatively unweathered and, eventually, fresh rock;
iii) does not qualify as a diagnostic soft or hardpan carbonate horizon, dorbank or hard rock;
iv) underlies a diagnostic podzol B or pedocutanic B horizon.

Soft carbonate horizon

i) has morphology which is largely that of the calcium and/or calcium-magnesium carbonates present, whether in powder here the colour of the carbonates dominates the colour of any non-carbonates present), nodular, honeycomb, or boulder form;
ii) unless exposed by erosion, occurs beneath a melanic or orthic A, a red apedal B, a yellow-brown apedal B, a neocutanic B or a neocarbonate B horizon;
iii) does not qualify as diagnostic dorbank or as a diagnostic hardpan carbonate horizon.

Unconsolidated material without signs of wetness

i) underlies a diagnostic podzol B or pedocutanic B horizon;
ii) may be any combination of organic matter, clay, silt sand and coarse fragments;
iii) does not qualify as diagnostic hard rock or saprolite weathering of coarse fragments in an unconsolidated matrix can give a false impression of saprolite);
iv) lacks grey, low chroma colours, with or without sesquioxide mottles that are evidence of wetness as defined for G and E horizons.

APPENDIX 2

PROPERTIES DIAGNOSTIC FOR THE SOIL FAMILIES

The following sets of properties are used to distinguish soil families.

Bleached orthic A horizon

Many A horizons have a bleached "grey" colour in the dry state, as defined for the diagnostic E horizon. Some of these A horizons are underlain by diagnostic subsoil horizons (e.g. E horizon, G horizon) which themselves have undergone reduction and removal of iron. In these soils, the reduced nature of the A horizon is covariant with that of the accompanying subsoil horizon. However, in many cases, these bleached A horizons overlie diagnostic subsoil horizons (e.g. pedocutanic, lithocutanic) which have not suffered marked reducing conditions. In these soils, a distinction is made at family level between members which have and which do not have, bleached A horizons. Bleached A horizons often have moist state colours that are darker (very dark grey 10YR 3/1 is a common moist colour) than the "grey" dry state colours of the diagnostic E horizon. In some cases this diagnostic A horizon has an overall bleached appearance while parts retain the original unbleached colour, presenting a mottled appearance on close inspection. Important to note is that the bleached A is an A (i.e. a topsoil horizon) and not a subsoil horizon as are E and G horizons.

Non-red and red colours in B horizons and stratified alluvium

Where iron oxides have imparted a red colour (hues of 5YR, 2.5YR, 10R, 7.5R) to the greater part of an horizon, the resultant soil structure is usually more water stable than similar soil which is not red. In many soil forms the non-red and red distinction is made at family level.

Luvic B horizon

A soil has a luvic B in the following circumstances:

- when any part of the A or E horizon has 15% or less, the B1 horizon must contain at least 5% more clay than the A, O or E;
- when any part of the A or E horizon has more than 15% clay, the ratio of clay percentage in the B1 to that in the A or E must be 1,3 or greater.

The presence of more clay in the B than in the A or E horizon is implicit in the definitions of many soil forms (e.g. Sterkspruit, Estcourt). However, there are several forms (with red apedal, yellow-brown apedal, neocutanic and neocarbonate B horizons) where this is not so, and it is considered necessary to distinguish between members which have markedly more clay in the B than in the A or E horizon from those which do not. The luvic concept is used for this purpose.

Hard and not hard lithocutanic B horizons and saprolite

More than 70% by volume of a hard lithocutanic B or saprolite horizon is bedrock, fresh or partly weathered, with at least a hard consistence in the dry, moist and wet states. Horizons which do not meet these requirements are not hard. The latter often occur in higher rainfall areas where weathering has often taken place to considerable depth.

Signs of wetness

These signs consist of grey, low chroma colours, sometimes with blue or green tints, with or without sesquioxide mottles. The latter, if present, may be yellowish brown, olive brown, red or black. The signs of wetness must occur within 1500 mm of the surface and must not be of such a nature or in such a profile position as to qualify as a diagnostic E, G or soft plinthic B horizon or as undifferentiated material with signs of wetness.

Calcareous horizons and layers

An horizon or layer is calcareous if, in some part, it contains sufficient calcium carbonate or calcium-magnesium carbonate to effervesce visibly when treated with cold 10% hydrochloric acid. It is not considered calcareous if it contains discrete, relict lime nodules in a non-calcareous matrix. It does not qualify as a diagnostic neocarbonate B, or as a soft or hardpan carbonate horizon.

APPENDIX 3

STRUCTURE OF SOIL CODE AND EXPLANATION OF SYMBOLS

1 STRUCTURE OF SOIL CODE

The code consists of two series of letter-number symbols, separated by a horizontal line, arranged in the following order:

ABOVE THE LINE
Depth of horizons and/or materials
    Soil form
        Soil family
            Subsoil limitations or properties

BELOW THE LINE
Coarse fragments in the topsoil horizon and outcrops
    Texture of the topsoil horizon
        Soil water conditions
            Changes in soil properties and conditions

In uncultivated soils the term topsoil horizon refers to the natural A horizon, while for cultivated soils it refers to the upper 200 - 300 mm of the soil profile affected by tillage.

2 CLASSES AND SYMBOLS FOR PROPERTIES ABOVE THE LINE

2.1 Horizon and/or effective depths

The depths of all diagnostic as well as non-diagnostic horizons and/or materials are coded with a number symbol in front of the soil form symbol. Depth classes and symbols used are:

DEPTH CLASS (mm)	SYMBOL
0 - 150	1
150 - 250	2
250 - 350	3
350 - 450	4
450 - 550	5
550 - 750	6
750 - 950	7
950 - 1150	8
1150 - 1350	9
1350 - 1550	0
> 1550	no symbol

Depth symbols for diagnostic horizons or materials specified in a particular soil form are arranged from shallow (topsoil transition) to deep (subsoil transition) before the form symbol (e.g. 3 5 Ag 2120, where 3 refers to the A/B transition and 5 to the B/C transition). Depth symbols for subsoil limitations or properties (arranged from shallow to deep) appear between the depth symbols for diagnostic horizon transitions and the form symbol (e.g. 3 5 3 Ag 2120; the second 3 indicates the depth of a subsoil limitation or property, eg abundant fine gravel (*code symbol f2*).)

2.2 Soil Form

The soil forms that were identified, as well as the abbreviations used in the code are explained in Table 1.

2.3 Soil family

The soil family is coded by means of a four-digit symbol directly after the form symbol. See Table 1 for an explanation of the four-digit symbols in the different soil forms.

2.4 Subsoil limitations and properties

The depth of soil utilised by plant roots is determined by several soil materials and factors. For example, in the Estcourt soil form the maximum effective root depth is determined by the prismacutanic B. In the Avalon form the depth is restricted seasonally by a fluctuating free water table which leads to the development of the soft plinthic B horizon. In other forms, e.g. Mispah, weathering rock determines the effective depth. In those forms where the limiting horizon is part of the defined sequence of **horizons which are diagnostic of the soil form,** the symbol for the limiting material or horizon is **not coded.** If the limiting horizon or material **is not included in the sequence of diagnostic horizons, the symbol for the horizon or material must be specified after the family number in the code symbol.** The depth symbol for such horizons is written between the depth symbol for diagnostic horizons and the soil form symbol (see 2 above).

The more important materials that may affect root penetration and water infiltration to a greater or lesser extent are one or more of the following:

- **Non-diagnostic hardpans; reversibly cemented**

  These are pans which appears cemented when dry, but which softens if left in water overnight.

  xp - Fragipan (Afr. *brosbank*): a subsurface material, usualy mottled, low in organic material with a high bulk density. It appears cemented when dry. It is usually polygonal with bleached fracture planes. It is slowly permeable to water. When moist it shows a moderate to weak brittleness.

- **Weaker than moderately structured, non-diagnostic unconsolidated materials without signs of wetness**

  nc - Calcareous unconsolidated material with signs of soil development, e.g. aggregation, clay illuviation and/or disappearance of original stratification. It largely meets the requirements of a neocarbonate B horizon. Red as well as non-red variants occur.

- **Textural stratification in diagnostic and non-diagnostic unconsolidated materials**

  Depending on the mode of transport and deposition, certain unconsolidated materials can be texturally stratified. With time soil development results in the disappearance of the stratification. However, in certain young soils stratification can still be detected. Since textural stratification is an important characteristic in soil use, it has to be indicated in the code in the following way:

Textural stratification non-prominent or absent

SYMBOL	DESCRIPTION
U5	Predominantly sandy

- **Predominantly gravelly, stony, or bouldery diagnostic and non-diagnostic horizons or materials**

Coarse fragments (>2 mm) can occur in varying quantities either in a part of or throughout a horizon or layer. Such coarse material can seriously affect root development, water infiltration and water holding capacity and must be indicated in the soil code in terms of ***size***, ***quantity*** (volume percentage) and ***shape***.

The predominant size and quantity of coarse fragments are qualified in the code as follows:

MATERIAL NAME	SIZE (mm)	QUANTITY (volume-%)	SYMBOL
Fine gravel	2 - 25	20 - 50 50 - 90 >90	f1 f2 f3
Coarse gravel	25 - 75	20 - 50 50 - 90 >90	g1 g2 g3
Stones	75 - 250	20 - 50 50 - 90 >90	k1 k2 k3
Boulders	>250	5 - 25 25 - 50 >50	r1 r2 r3

- **Non-diagnostic materials with signs of weathering residual rock**

lo - Material in different stages of weathering which varies from hard rock to fully homogenized soil with cutanic properties in the form of tongues of prominent variegation because of residual soil formation and illuviation. There are no signs of wetness. It largely meets the requirements of a non-hard lithocutanic B horizon or saprolite.

so - Weathering rock which, although unconsolidated, still has distinct geogenic properties. No signs of wetness occur. It largely meets the requirements of a hard lithocutanic B horizon or saprolite.

Ro - Hard rock without signs of wetness.

- **Additional properties in diagnostic and non-diagnostic horizons or materials**

In some diagnostic as well as non-diagnostic horizons or materials, properties occur which are important for soil use, but which cannot be inferred from the definition of such horizons or materials.

cs An accumulation of calcium sulphate, usually in the form of gypsum crystals.

3 CLASSES AND SYMBOLS FOR PROPERTIES BELOW THE LINE

3.1 Coarse fragments in topsoil horizon and outcrops

The presence of coarse fragments (>2 mm) in the topsoil horizon or rock outcrops has an important effect on several physical (e.g. water holding capacity) and chemical (e.g. exchangeable cation content) properties, as well as on tillage and landuse. The size, quantity, and form of coarse fragments in the topsoil horizon (or plough layer) are indicated with the same symbols as those used to describe such materials as **Subsoil limitations or properties.**

3.2 Texture of topsoil horizon

The texture of the upper part (usually to a depth of 200 to 300 mm) of the profile is coded in terms of:

i) the **sand grade** for soils with less than 20% clay and

ii) the **clay content** (percentage).

Classes and abbreviations for sand grade and clay content are the following:

SAND GRADE	
SIZE	SYMBOL
coarse	co
medium	me
fine	fi

CLAY CONTENT	
PERCENTAGE	SYMBOL
0 - 5	1
5 - 10	2
10 - 15	3
15 - 20	4
20 - 35	5

3.3 Phenomena on or in the A horizon

Soils as natural phenomena are subjected at their surface to recent geological processes, such as erosion by wind or water, as well as the deposition of material transported by water, wind or gravity. As a natural agricultural resource soil is also affected by man for shorter or longer periods. Activities such as grazing of natural veld, normal soil tillage, deep soil preparation and drainage, etc., can cause soils to change to a greater or lesser extent. The changes can vary in permanence and can benefit or adversely affect crop production. It is therefore essential that such phenomena be described and indicated in the soil code.

nc - A topsoil that largely meets the requirements of a neocarbonate B horizon in terms of the presence of free lime and colour. Red as well as non-red variants occur.

4 EXAMPLE

In the following paragraph a soil code is given to illustrate the structure and composition:

Code:

2[6] 6[7] 2[8] Ag[1] 2[2]1[3]1[4]0 so[5] f2[8]
----
f2[9] co[10] 2[11]

Description:

Augrabies form soil[1] with a bleached orthic A horizon[2], a non-red[3], non-luvic[4] neocarbonate B horizon, on hard saprolite without signs of wetness[5]. The A/B transition is at 20cm[6], and the B/C transition at 65cm[7]. The B horizon has 20-50% fine gravel[8]. The topsoil has 20 - 50 % fine gravel[9], a coarse sand grade[10] and 5 - 10 %[11] clay.