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THE REPUBLIC OF THE SUDAN
MINISTRY OF AGRICULTURE

ROSEIRES SOIL SURVEY

REPORT No. 14

WHITE NILE EAST BANK
RABAK TO KHARTOUM
SEMI-DETAILED
SOIL SURVEY AND LAND CLASSIFICATION

ANNEXE

ESH SHAWAL EXTENSION

HUNTING TECHNICAL SERVICES LTD.
LAND USE & AGRICULTURAL CONSULTANTS
6 ELSTREE WAY
BOREHAM WOOD
HERTS.

SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS
HANOVER HOUSE
73 HIGH HOLBORN
LONDON .. W.C.1

DECEMBER 1966

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FIGURE 1
HANOVER HOUSE,
73, HIGH HOLBORN,
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30th December,
1966

Your Ref _____

Our Ref _____

H.E. The Minister of Agriculture,
Ministry of Agriculture,
Khartoum,
REPUBLIC OF THE SUDAN.

Your Excellency,

ROSEIRES SOIL SURVEY REPORT NO.14 (AREA 5a)
WHITE NILE EAST BANK, RABAK TO KHARTOUM
ANNEXE - ESH SHAWAL EXTENSION

We have pleasure in submitting our annexe to Report No.14 for the Roseires Soil Survey, the study of which was entrusted to us by the Contract for Soil Survey of Irrigable Lands in the Sudan signed on 27th September, 1962.

This annexe is in a single volume and the semi-detailed soil survey and land classification maps are included.

The necessary agriculture and soil studies were undertaken on our behalf by Messrs. Hunting Technical Services Ltd. of London.

The Esh Shawal extension area lies in a narrow strip, along the eastern boundary of the existing Managil Scheme and covers an area of some 89,221 feddans. This area was outside of the scope of the original Report No. 14 submitted in November, 1965, and it was not until the spring of this year that the soil survey was carried out when the possibility of providing a supply from an extension of the Fahal canal was proposed.

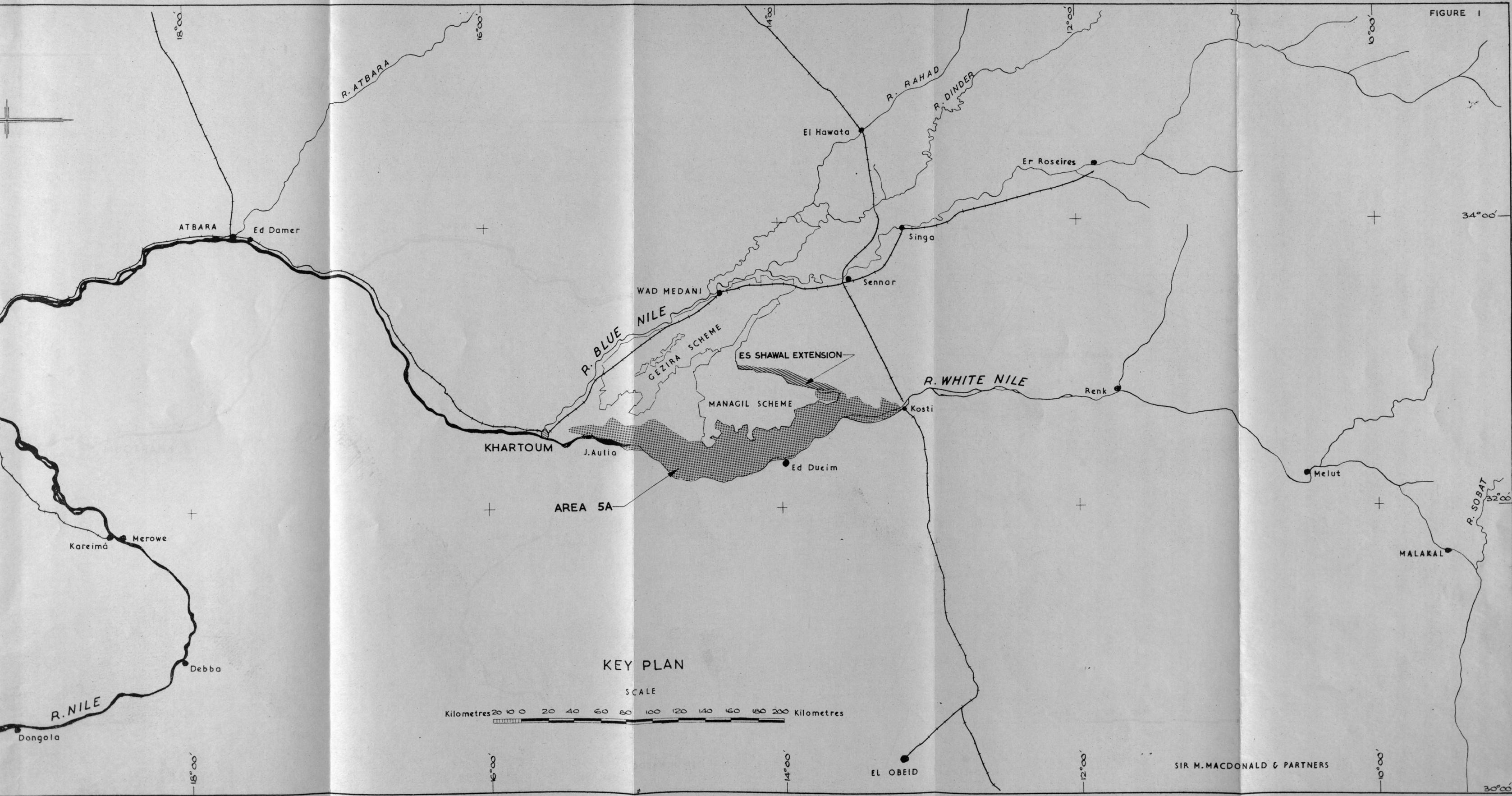
This supplementary report shows that only about 4% of the total number of sites surveyed were classified as Class 6. These occur in the northern part of the area near the sandy ridges and are not recommended for cultivation. The other land classified as Classes 2, 3 and 4 is suitable for long staple cotton cultivation and a rotation of cotton-wheat-fallow-cotton-groundnuts-lubia-dura-Phillipesara-fallow is recommended.

We are, Excellency,

Your obedient servants,

R. H. MacDonald

SIR M. MACDONALD & PARTNERS.



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CHAPTER 2

THE ENVIRONMENT

2.1 Location

The Managil Extension area extends from latitude $14^{\circ}15'$ in the north to $13^{\circ}33'$ in the south. A long, narrow strip, it is bounded on the east by the ACKNOWLEDGEMENTS part of the area lies adjacent to the Shawal extension described in Roseires Soil Survey Report No. 14. In the north, the Kawa major canal forms the western

The compilation of a report of this kind cannot be complete without reference to many organisations and individuals, both in Sudan and the United Kingdom, who have assisted us by providing information, advice or facilities. Among the many who have assisted us in this way are the following, to whom our thanks are due.

The many members of both administrative and technical staff in the Ministry of Agriculture, including the Director of Agriculture and his staff. Also the U.N.S.F. Soil Institute personnel in Wad Medani.

The members of the Ministry of Irrigation and Hydro-Electric Power including the Director of Irrigation and the Assistant Director (Development) with their staff, for their help.

The members of the Survey Department, the Sudan Gezira Board, the Geological Survey Department, the Department of Meteorology, and the officers of local administration and police, for practical help and technical advice in obtaining our results.

At the extreme south of the area, a low ridge also occurs. This is the southern extension of a gravelly ridge which sweeps northwards from Gezira Aha. Within the project area, this ridge is clay covered, but still contains a fairly high sand content and occasional rounded, gravel size stones.

In general, the area slopes downwards from east to west, levelling out somewhat near the Managil scheme. This slope is appreciable in the northern part of the area where it has necessitated a definite alignment of fields parallel to the slope to make the best use of surface run-off during the rainy season.

CHAPTER 2

THE ENVIRONMENT

2.1 Location

The Managil Extension area extends from latitude $14^{\circ}15'$ in the north to $13^{\circ}33'$ in the south. A long, narrow strip, it is bounded on the east by the Managil ridge. The southern part of the area lies adjacent to the Shawal extension described in Roseires Soil Survey Report No. 14. In the north, the Kawa major canal forms the western boundary. The area comprises 89,221 feddans.

2.2 Geology and Geomorphology

The geology and geomorphology of this area is very similar to that of the Shawal area of which it is a natural extension. The geology and geomorphology of the Shawal area are described in some detail in Roseires Soil Survey Report No. 14.

The soils of the Managil extension are developed on clay deposits which are considered to be of Blue Nile origin with considerable dilution in the north by sandy material derived from the Nubian sandstones of the Managil ridge. Within this northern section, small, very low secondary ridges occur. The ridges have relatively high sand content, and upon these the majority of the villages are located.

These rather sandy areas are important in that aspect that the soils developed on them are somewhat different to the soils on the heavier clay alluvium.

In the extreme south of the area, a low ridge also occurs. This is the northern extension of a gravelly ridge which sweeps northwards from Gezira Aba. Within the project area, this ridge is clay covered, but still contains a fairly high sand content and occasional rounded, gravel size stones.

In general, the area slopes downwards from east to west, levelling out somewhat near the Managil scheme. This slope is appreciable in the northern part of the area where it has necessitated a definite alignment of fields parallel to the slope to make the best use of surface run-off during the rainy season.

CHAPTER 3

2.3 Climate

A discussion of the climatological data pertaining to this area is contained in Roseires Soil Survey Report No. 14 and also in Roseires Soil Survey Report No. 6.

2.4 Vegetation

With reference to the 'Ecological Classification of the Vegetation of the Sudan' by Harrison and Jackson, the Managil Extension is classified as Acacia mellifera thornland on dark cracking clay. Within the area the vegetation has been greatly disturbed by the activities of charcoal burning and land clearance for cultivation. Only remnants of the natural vegetation are left and these consist of thickets of Acacia mellifera, A. nubica with Cadaba glandulosa. The herb cover is dominated by Cymbopogon nervatus, Aristida adscensionis, A. hordacea and Schoenefeldia gracilis.

2.5 Population and Land-Use

A considerable proportion of the project area remains under unimproved, rough grassland and scrub. Most of the grassland is seriously overgrazed by stock moving in from the villages situated to the east and west of the area. Cultivation is limited to the area adjacent to the canal and to the vicinity of villages towards the east.

The farming relies entirely upon seasonal rainfall and cultivation is by traditional methods using the ox-drawn plough or "Seluka". Occasionally tractors from the Managil Scheme may plough areas adjacent to the Kawa major canal. Dura (Sorghum vulgare) of the 'Feterita' variety is the dominant crop and only small areas of dukhn (Pennisetum typhoideum) and simsim (Sesamum orientale) are grown. Yields of dura vary from $\frac{1}{2}$ to 3 ardebs/feddan, depending on the rainfall. Most of the grain is consumed locally and any excess is sold in a nearby market.

Livestock numbers have not been assessed, but the few cattle, sheep or goats belonging to each family are grazed with a village herd. Large herds of nomadic camels also pervade the area during the dry season. Water is obtained from villages wells, numerous 'hafirs' or from the irrigation canal.

No assessment of population is made in the Project Area.

CHAPTER 3

SURVEY METHODS

3.1 Aerial Photography

The aerial photography of the project area was flown by the Sudan Survey Department in March 1966. The photography, at scale 1:25,000, was compiled into mosaics at scale 1:50,000.

The procedures employed in using the photography were the same as those described in Report No. 14.

3.2 Soil Survey Procedures

The requirements and procedures of the semi-detailed soil survey were virtually the same as those for Area 5A, described in Report No. 14. There were two exceptions. In this area, obviously sandy areas were delimited by photo-interpretation at the outset, and were not surveyed in detail. Vegetation was not recorded in the same way as described in Report No. 14. A list of occurring species was given for each site without being divided into sections.

No sample areas were used in this area, since this area is regarded as an extension of the Shawal area, where a sample area was studied in the previous season.

The chemical analyses procedures were the same as those described in Report No. 14. It should be noted that the soils of both the Managil and Shawal areas were surveyed in April towards the end of the dry season.

3.3 Map Compilation

The base maps were based on the Sudan Survey contour maps of the Gezira, dated 1929, at scale 1:50,000. The outline of the Managil irrigation scheme was drawn from the 1:50,000 mosaics.

Soil series were shown on the soil maps in the same way as in area 5A. Land class maps were also prepared in the same way, except that the low sandy ridges of the Managil area are indicated separately. Also, the alkali content of these moist soils is higher than the average for the area, especially in the 45-90 cm fixed depth.

The coarser textured soils often possess a firm surface, and this may limit percolation of rain-water into the soil and increase run-off towards the flatter land near the present irrigation scheme.

4.5 Visible Salt Accumulations

As in the Shawal area, the salts visible in the profile are calcium carbonate and calcium sulphate.

CHAPTER 4

The nature and distribution of these salts are described in detail in Report No. 14.

PEDOLOGY

4.1 Parent Material

As stated in Chapter 2, the parent material of this area is Blue Nile alluvium of generally high clay content. In the northern part of the area, the clay is diluted by sand from the Managil ridge immediately to the east.

4.2 Soil Forming Processes

The factors involved in soil formation are discussed in detail in Report No. 14. In this respect there are no differences to be found between the Shawal and Managil areas.

4.3 Structure

The same range of structure is found in the Managil area as in Shawal.

Over the major part of the area, the normal Vertisol structural characteristics are reasonably well developed.

In the northern part of the area, the Vertisol/Entisol intergrades described in Report No. 14 occur. These possess poorly developed Vertisolic structure. It should be noted that the soils of both the Managil and Shawal areas were surveyed in April towards the end of the dry season

A detailed description of the structure is given in report No. 14.

4.4 Soil Consistency

The levels and ranges of consistency are the same in the Managil area as in the Shawal area. In the Managil area, there is a tendency for the soils to be moister and more compact near to the present Managil scheme. This may be due to the fact that the land is flatter and less well drained. Also, the alkali content of these moist soils is higher than the average for the area, especially in the 45-90 cm fixed depth.

The coarser textured soils often possess a firm surface, and this may limit percolation of rain-water into the soil and increase run-off towards the flatter land near the present irrigation scheme.

4.5 Visible Salt Accumulations

As in the Shawal area, the salts visible in the profile are calcium carbonate and calcium sulphate.

The nature and distribution of these salts are described in detail in Report No. 14.

4.6 Colour

The distribution of the main surface horizon colours is shown in Table 4.1.

The top horizons show a marked dominance of the lighter 10YR 4/2 and 2.5Y 4/2 colours. The majority of the 2.5Y hues occur in the northern part of the area, the 10YR hue being markedly dominant in the south.

The second horizon of most of the profiles is the same colour as the top. Below an average depth of about 80 cm, the colour is much darker, normally 10YR 3/1, with tongues of lighter 10YR 4/2 and 2.5Y 4/2 colour occurring in the upper half of this dark coloured horizon. These lighter coloured tongues may be due to the infilling of former cracks by soil material from the surface. In many of the profiles, there is a return to browner colours below about 180 cm, possibly indicating a different depositional horizon.

TABLE 4.1 Percentage Distribution of Soil Colour in Top Horizons

Colour	Number	Per cent
2.5Y 4/2	191	40.3
10YR 4/2	122	25.7
10YR 3/3-4/3	46	10.3
2.5Y 3/2-4/2	35	7.4
2.5Y 4/2-10YR 3/2	18	3.8
10YR 4/2-3/3	17	3.6
10YR 4/2-3/2	10	2.1
2.5Y 3/2	8	1.6
10YR 3/2	7	1.4
10YR 3/3	7	1.4
10YR 4/2-4/3	6	1.2
10YR 3/1-3/2	2	0.4
10YR 4/1-3/1	1	0.2
10YR 3/1	1	0.2
10YR 4/3-2.5Y 4/2	1	0.2
TOTAL	472	99.8
70-75	1	0.2
TOTAL	446	99.9

4.7 Texture Characteristics of the Soil

The occurrence of the various clay percentage ranges is shown in Table 4.2. Within the 0-45 cm fixed depth, 82.8 per cent of the total sites have clay percentages of 50 or over, with 87 per cent of the sites having 50 per cent or more clay in the 45-90 cm fixed depth. This indicates a slight increase in clay percentage with depth in most profiles. The main clay contents are between 50 and 65 per cent in the 0-45 cm depth, and 50 and 70 per cent in the 45-90 cm.

In general terms, the coarser textures occur in the northern and eastern parts of the area. This seems to be due to a higher content of sand derived from the coarse material of the Managil ridge.

Many of the coarser textured soils have been classified as Vertisol/Entisol integrades, but not all by any means. The poor development of Vertisol morphology in many of the soils is not fully understood. Information on the mineralogy of the clay is lacking, but because of the close similarity between clay percentage and cation exchange capacity values, it has been assumed that montmorillonite is the dominant clay mineral. However, since there are soils with over 50 per cent clay content which lack the normal Vertisol morphology, other factors may be active in inhibiting the normal swelling and shrinking of the clay, even if it is predominantly montmorillonite. On the other hand, soils with clay contents of less than 40 per cent have been found to exhibit well developed Vertisol morphology. Therefore, clay content itself is not a reliable guide to the actual morphology except for contents of less than 30 per cent. Such soils are usually Entisolic in this area.

TABLE 4.2 Percentage of total sites within each clay percentage range for fixed depths.

Clay % Range	0 - 45 cms		45 - 90 cms	
	Number	%	Number	%
25-30	1	0.2	-	-
30-35	3	0.6	1	0.2
35-40	13	2.9	12	2.6
40-45	25	5.6	16	3.5
45-50	35	7.8	30	6.7
50-55	81	18.2	47	10.6
55-60	148	33.2	125	27.9
60-65	111	24.9	156	34.9
65-70	28	6.3	59	13.2
70-75	1	0.2	2	0.4
TOTAL	446	99.9	448	100.0

4.8 Chemical Characteristics of the Soil

Soil series analyses were not carried out on the samples as the soils are considered to be similar in chemical characteristics to the ones described in Roseires Soil Survey Report No. 14.

Some of the soils analysed are coarser textured than is normal for the clay plains. Evidence from elsewhere (Report No. 15) suggests that the values for total phosphorus and total potassium will be lower than normal in these coarser textured soils.

1. Salinity

All the soil samples were tested for salinity. The results, summarised in Table 4.3, show that the soils are dominantly non-saline in the upper sampling layer and only a few soils are saline in the lower sampling layer.

2. Exchangeable Sodium

Exchangeable sodium was determined on all samples by extraction with neutral normal ammonium chloride.

3. Cation Exchange Capacity

The CEC was determined on all pit samples. A statistical analysis relating the clay content to the CEC showed that a reasonably good correlation existed ($r^2 = 0.62$).

Therefore the cation exchange capacity was deduced from the clay content for all soil samples originating from the routine bore sites.

4. Exchangeable Sodium Percentage

The exchangeable sodium percentage (ESP) was calculated for all the soils using the relationship:

$$ESP = \frac{\text{Exchangeable sodium (me/100g)} \times 100}{\text{percent clay content}}$$

The values obtained are given in Table 4.4. Most of the soils (92.8 per cent) have an ESP less than fifteen in the 0-45 cm. layer.

The ESP increases in the lower layer (45-90 cm.) but even here 58 per cent of the soils have an ESP less than 15 and 88.5 per cent have an ESP less than 20.

5. pH

Soil pH values decrease down the profile both for the saturation paste and for the 1:5 soil ÷ water suspension.

The pH paste values range from 7.4 to 8.6 with the majority (98.6 per cent) lying between 7.4 and 8.4.

The pH values for the soil suspension are consistently higher by one to one and a half units.

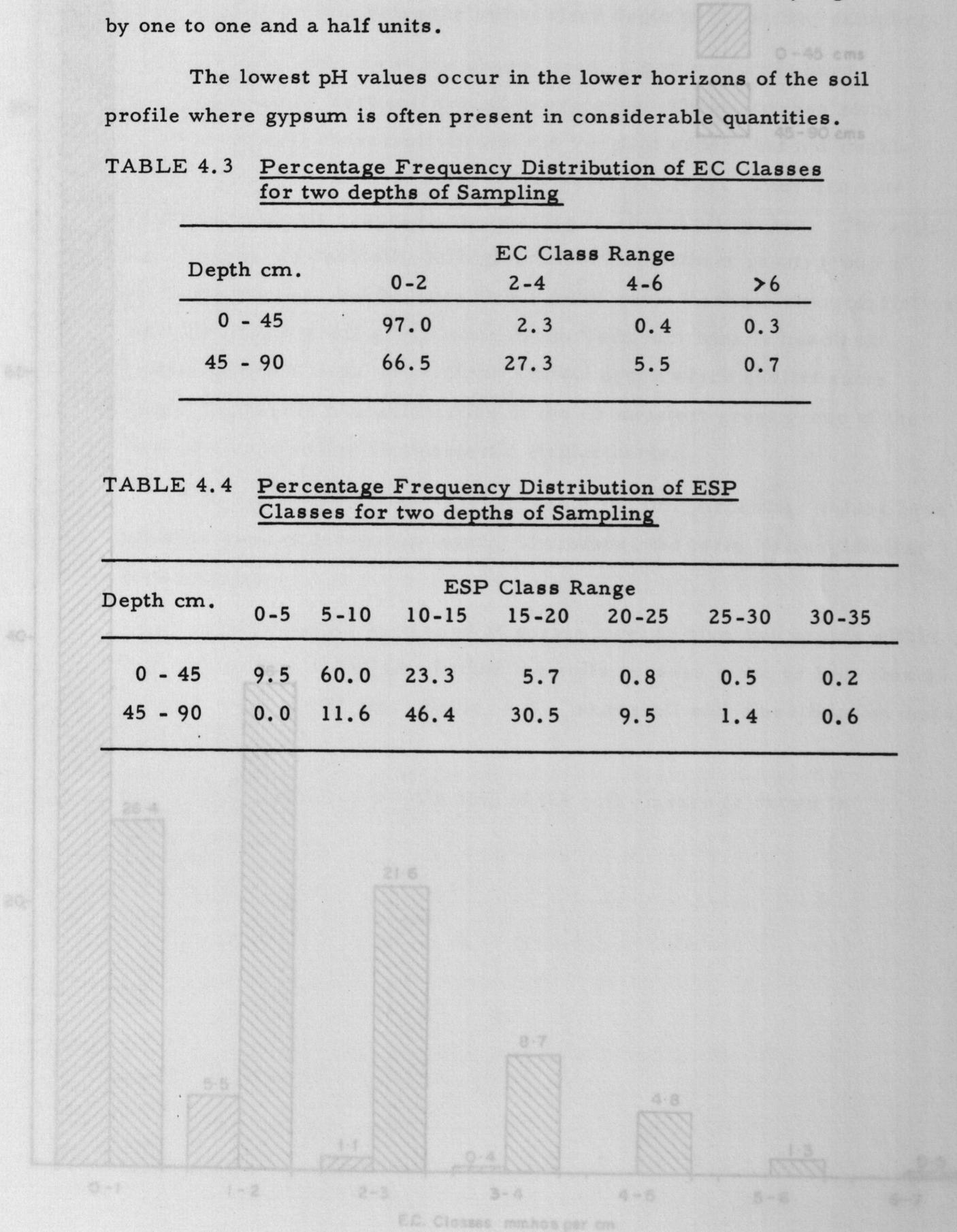
The lowest pH values occur in the lower horizons of the soil profile where gypsum is often present in considerable quantities.

TABLE 4.3 Percentage Frequency Distribution of EC Classes for two depths of Sampling

Depth cm.	EC Class Range			
	0-2	2-4	4-6	>6
0 - 45	97.0	2.3	0.4	0.3
45 - 90	66.5	27.3	5.5	0.7

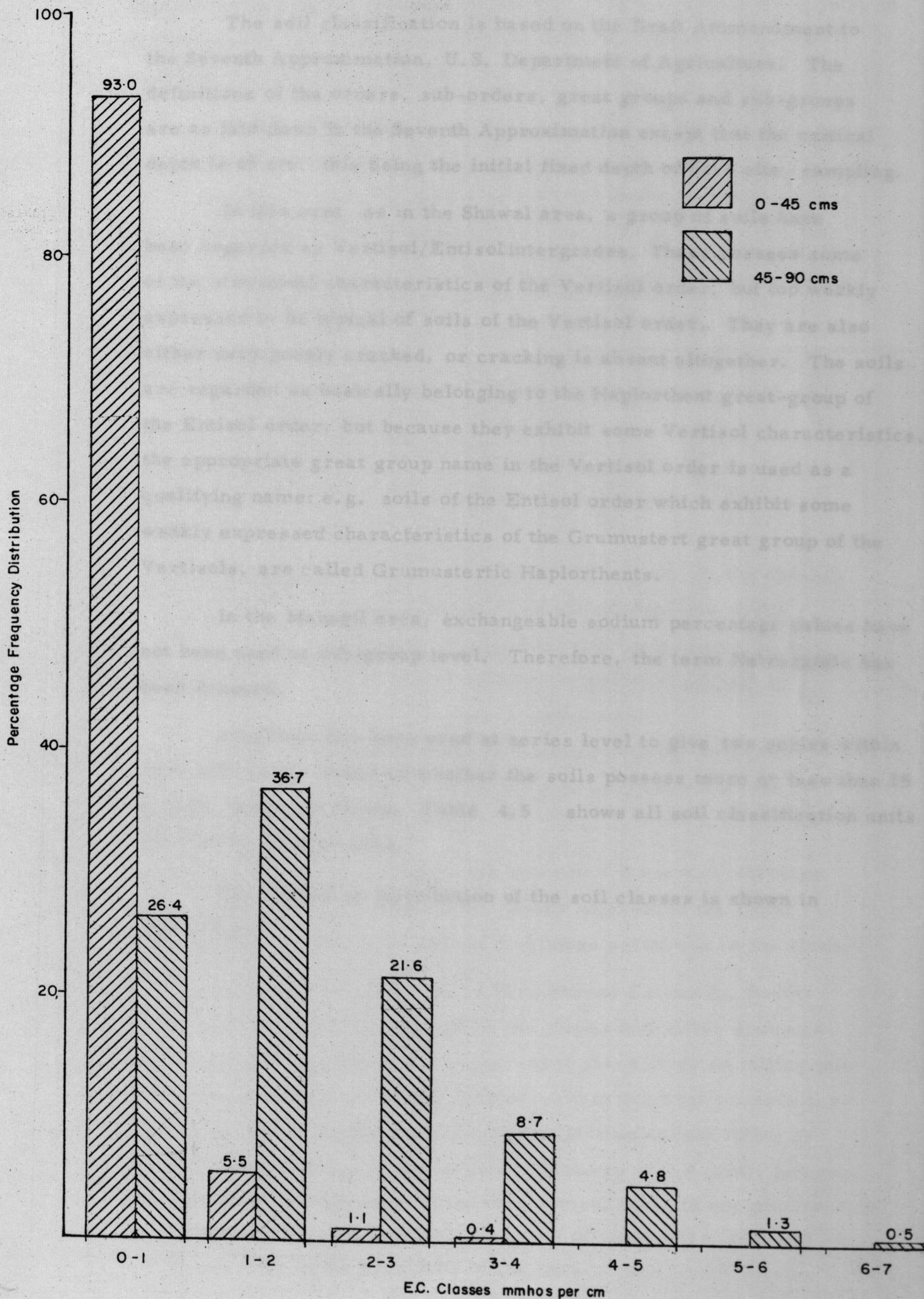
TABLE 4.4 Percentage Frequency Distribution of ESP Classes for two depths of Sampling

Depth cm.	ESP Class Range						
	0-5	5-10	10-15	15-20	20-25	25-30	30-35
0 - 45	9.5	60.0	23.3	5.7	0.8	0.5	0.2
45 - 90	0.0	11.6	46.4	30.5	9.5	1.4	0.6



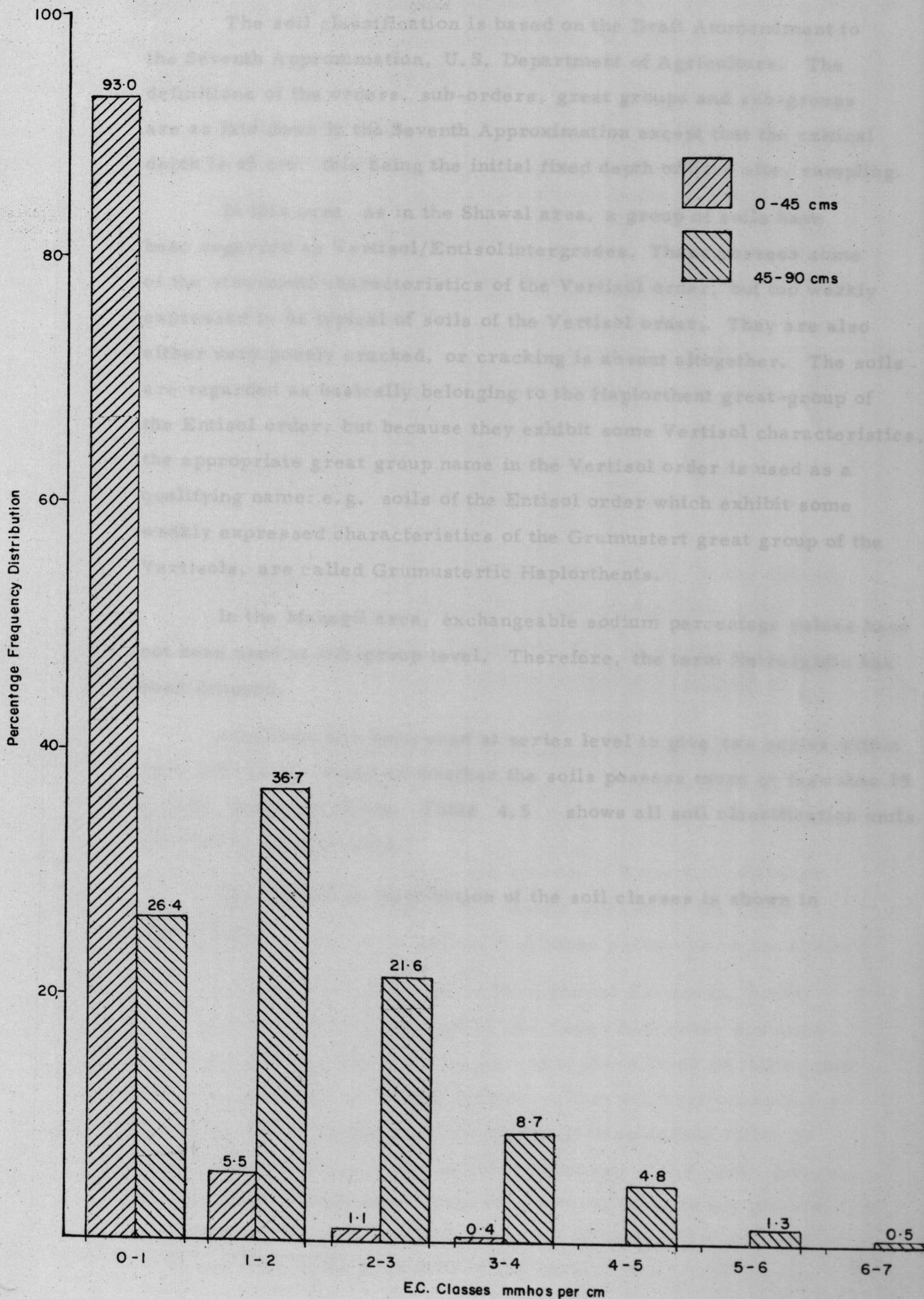
PERCENTAGE FREQUENCY DISTRIBUTION OF E.C.'s BY FIXED DEPTHS

MANAGIL



PERCENTAGE FREQUENCY DISTRIBUTION OF E.C.'s BY FIXED DEPTHS

MANAGIL



4.9 Soil Classification

4.9.1 Definitions

The soil classification is based on the Draft Ammendment to the Seventh Approximation, U.S. Department of Agriculture. The definitions of the orders, sub-orders, great groups and sub-groups are as laid down in the Seventh Approximation except that the critical depth is 45 cm, this being the initial fixed depth of bore site sampling.

In this area, as in the Shawal area, a group of soils have been regarded as Vertisol/Entisol intergrades. These possess some of the structural characteristics of the Vertisol order, but too weakly expressed to be typical of soils of the Vertisol order. They are also either very poorly cracked, or cracking is absent altogether. The soils are regarded as basically belonging to the Haplorthent great-group of the Entisol order, but because they exhibit some Vertisol characteristics, the appropriate great group name in the Vertisol order is used as a qualifying name: e.g. soils of the Entisol order which exhibit some weakly expressed characteristics of the Grumustert great group of the Vertisols, are called Grumustertic Haplorthents.

In the Managil area, exchangeable sodium percentage values have not been used at sub-group level. Therefore, the term Natrargidic has been dropped.

Alkalinity has been used at series level to give two series within each sub-group, based on whether the soils possess more or less than 15 E.S.P. in the top 45 cm. Table 4.5 shows all soil classification units used in the Managil area.

The frequency distribution of the soil classes is shown in Table 4.6.

Reference to Report No. 14 (Esh Shawal Extension, South) suggested that the higher ground on the slopes had better drainage characteristics and the evidence pointed to these lands as falling into land classes 2 and 3a. It was considered that drainage towards the line of the Shawal Major canal might result in an accumulation of salts within a distance of one or two kilometres of the canal, however the final land classification based on chemical data did not confirm this hypothesis, although small isolated areas of classes 4a, 4al and 6a are in evidence in the proximity of the canal.

Interim Draft Land Classification

The Consultants were requested to prepare an interim land classification map for planning purposes. This was submitted in July. In the absence of full chemical analytical data, the interim map was based on the following criteria.

1. Cracking capacity.
2. pH determination.
3. Experience gained from a soil survey in the southern extension of Esh Shawal.

Four land classes were identified, the major emphasis being given to soil cracking capacity:

Classification

- A. Good: Cracking well developed with the likelihood of a high E.S.P. tolerance.
- B. Moderate: Moderately well developed cracking, such soils are considered to have a potential for cotton production.
- C. Doubtful: Cracking only slightly developed. In the absence of full chemical data and information on the behaviour of crops on such soils, these lands could not be recommended for development pending further investigations.
- D. Poor: Total absence of cracking coupled with poor structure which factors preclude soils from development.

The pH values generally lay between 8.0 and 8.5, although a small proportion fell below 8.0. Lands adjacent to the canal appeared to have higher pH values than those pertaining to the slopes.

Reference to Report No. 14 (Esh Shawal Extension, South) suggested that the higher ground on the slopes had better drainage characteristics and the evidence pointed to these lands as falling into land classes 2 and 3a. It was considered that drainage towards the line of the Shawal Major canal might result in an accumulation of salts within a distance of one or two kilometres of the canal, however the final land classification based on chemical data did not confirm this hypothesis, although small isolated areas of classes 4a, 4a1 and 6a are in evidence in the proximity of the canal.

TABLE 4.5 Soil Classification Units

ORDER	SUB-ORDER	GREAT-GROUP	SUB-GROUP	SERIES	SERIES SYMBOL
VERTISOL	USTERTS	GRUMUSTERT	TYPIC GRUMUSTERT	E. S. P. < 15, 0-45 cm	A111
			ENTIC GRUMUSTERT	E. S. P. > 15, 0-45 cm	A121
	AQUERTS	GRUMAQUERT	TYPIC GRUMAQUERT	E. S. P. < 15, 0-45 cm	B111
			ENTIC GRUMAQUERT	E. S. P. > 15, 0-45 cm	B121
ENTISOL	ORTHENT	HAPLORTHENT	GRUMUSTERTIC-	E. S. P. < 15, 0-45 cm	C121
			HAPLORTHENT	E. S. P. > 15, 0-45 cm	C122
OTHER ENTISOLS NOT DIFFERENTIATED.					

CHAPTER 5

TABLE 4.6 Soil Classes. Distribution of Sites in the Soil Classes

LAND CLASSIFICATION

5.1 Specifications

Soil Class	Total Number of sites	Percentage of Total Sites
A111	104	22.4
A112	4	0.9
A121	293	63.1
A122	10	2.2
A121/C121	4	0.9
B111	2	0.4
B121	1	0.2
C121	37	8.0
C122	9	1.9
TOTAL	464	100.0

More information is needed on the relationship and interactions between clay percentage, salt content, exchangeable sodium, pH and cracking capacity and their effects on yields. It is probable that when this information is forthcoming some soils at present downgraded to class 6 and some of the lighter sandy soils may then be considered suitable for irrigated agriculture.

5.2 Land Class Standards

The following is an outline of the U.S.B.R. definitions for each class and a discussion of the criteria used in class limitations.

Class 1

No land was considered suitable for this class, which requires open friable soil capable of producing sustained and relatively high economic yields of a wide range of climatically adapted crops. The clay plains soils are impermeable clays and although well sustained crops of cotton are grown in the Gezira, yields are not high relative to international standards. The range of climatically adapted crops which may be grown on these soils is probably somewhat limited.

CHAPTER 5

LAND CLASSIFICATION

5.1 Specifications

The objective of the survey carried out was to produce a soil map and a land class map delineating areas suitable for irrigation development.

The specifications were based on U.S. Bureau of Reclamation standards for defining land classes using criteria suitable for local conditions.

In devising the classification for Sudan clay plains, U.S.B.R. standards of land classification have been followed, but physical criteria for the limitations applicable to each class have been adopted from international and local knowledge of the behaviour of similar soils under irrigation.

More information is needed on the relationship and interactions between clay percentage, salt content, exchangeable sodium, pH and cracking capacity and their effects on yields. It is probable that when this information is forthcoming some soils at present downgraded to class 6 and some of the lighter sandy soils may then be considered suitable for irrigated agriculture.

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Class 2

TABLE 5.1 Percentage of total sites within each clay percentage range for fixed depths

The definition states "lands of moderate suitability for irrigation farming, being measurably lower than Class 1 in productive capacity, adapted to a somewhat narrower range of crops, more expensive to prepare for irrigation or more costly to farm" ----- "they may be only slowly permeable to water because of clay layers or compaction in the subsoil" ----- "Class 2 lands have intermediate repayment capacity". The above could quite easily be used as a definition of the better blocks in the Gezira scheme. The cost of bush clearance and levelling in preparation for irrigation will be relatively low in the Managil area.

60-65	111	24.9	156	34.9
(i) Clay percentage	28	6.3	59	13.2

It has been shown by Finck and Ochtman (1961) that there is a correlation between cotton yields (long staple) and clay percentage i.e. the higher the clay percentage between 40 and 70 the greater the cotton yield. The average yield of the Gezira being obtained on soils of 58 per cent clay.

In most areas soils of higher clay content would be considered difficult to work and would be downgraded. In the clay plains however the heavier soils have the greater potential.

The cracking capacity of these montmorillonitic clays affects the depth and extent to which water can penetrate. Higher clay percentage does not necessarily result in increased cracking capacity. Where rainfall is higher in some parts of the Gezira, satisfactory cracking occurs in soils with 35-50 per cent clay whilst elsewhere soils of high clay content exhibit more restricted cracking.

The following table shows the distribution of clay content in the top 0-45 cm and in the 45-90 cm zone.

Due to the impermeable nature of the soil, vertical movement of salts is considerably restricted and the upper limits for E.C. in Class 2 lands have been fixed at 4 mmhos in the 0-45 cm zone and 5.3 mmhos in the 45-90 cm zone. Graph 4.1 (see chemical chapter) shows that salinity levels are low, less than 2 mmhos/cm.

TABLE 5.1 Percentage of total sites within each clay percentage range for fixed depths

Clay % Range	0 - 45 cm		45 - 90 cm	
	Number	%	Number	%
25-30	1	0.2	-	-
30-35	3	0.6	1	0.2
35-40	13	2.9	12	2.6
40-45	25	5.6	16	3.5
45-50	35	7.8	30	6.7
50-55	81	18.2	47	10.6
55-60	148	33.2	125	27.9
60-65	111	24.9	156	34.9
65-70	28	6.3	59	13.2
70-75	1	0.2	2	0.4
TOTAL	446	99.9	448	100.0

Most of the soils of the Managil extension have clay percentages between 50 and 70. The coarser textured soils occur near the sandy ridges in the northern part of the area.

(ii) Salinity

Research work at the Gezira Agricultural Research Station Wad Medani has shown that in the Gezira there is only a negligible build up of soluble salts in the rooting zone. There may be a slight leaching of salts to a zone below rooting depth but in general Gezira soils are not inherently saline. The electrical conductivity of the saturation extract is well below the internationally accepted limit of 4.0 mmhos. This level of 4.0 mmhos has been fairly well established in research findings in many parts of the world and it can be assumed that saline sensitive plants grown in a soil with an E.C. greater than 4.0 mmhos would be adversely affected.

Due to the impermeable nature of the soil, vertical movement of salts is considerably restricted and the upper limits for E.C. in Class 2 lands have been fixed at 4 mmhos in the 0-45 cm zone and 5.3 mmhos in the 45-90 cm zone. Graph 4.1 (see chemical chapter) shows that salinity levels are low, less than 2 mmhos/cm.

(iii) Alkali levels

In the absence of structural breakdown of the soil and with an acceptable pH value most plants can grow successfully at exchangeable sodium levels of over 25. In other parts of the world it is found that with E.S.P.'s of over 15 most soils do become deflocculated, compact and extremely impermeable. Plant growth is inhibited by this poor structure which results in lack of air and moisture. An E.S.P. value of 15 has generally been accepted as the upper limit for class 2 soils and any sites with E.S.P.'s greater than 15 in the 45-90 cm zone have been downgraded.

There is however no theoretical justification for considering that E.S.P.'s above 15 have any undesirable effects on the penetration of water into cracking black clays and there is, unfortunately, no field evidence available on the effects of E.S.P.'s above 15 on penetrability of water into these soils. Owing to this lack of field evidence, we have accepted an E.S.P. of 15 as the upper limit for Class 2 soils, although we realise that future work may show that this limit could be raised appreciably.

(iv) Location

(i) Soil Salinity

Class 2 land is distributed throughout the area and amounts to 47,795 feddans or 52.8 per cent of the total number of sites.

Class 3

The U.S.B.R. Manual identifies Class 3 lands as "suitable for irrigation development but approaching marginality for irrigation and are of distinctly restricted suitability because of more extreme deficiencies in the soil than described for Class 2 lands". -----
"because of inferior soils they have restricted crop adaptability".
"The may have uneven topography, moderate to high concentration of salines or restricted drainage, susceptible to correction (but only at relatively high costs."

"Generally greater risk may be involved in farming Class 3 lands than the better classes of land but under proper management they are expected to have adequate repayment capacity."

(i) Clay Percentage Frequency Occurrence (per cent of total sites)
for 0-45 cm and 45-90 cm

Class 3 land has been divided into two clay percentage ranges:
35-50 per cent and over 50 per cent.

The letter 1 in the classification signifies that the clay percentage lies between 35 and 50 and if cotton is grown on these lighter soils a somewhat lower yield must be expected in accordance with the findings of Finck and Ochtman. Soils on some Blue Nile pump schemes have clay percentages of between 40 per cent and 50 per cent and they regularly produce higher yields than the Gezira. This does not preclude the possibility that such soils of comparatively low clay content may be producing yields which are lower than would be obtained on heavier soils in the same geographical location. In the absence of more statistical evidence it is wise to assume that soils with a clay content of between 35 per cent and 50 per cent should be at present downgraded due to reduced production potential. Management of these soils might prove to be a very important factor in obtaining enhanced yields. Such soils may well be more suited to crops such as groundnuts, sisal and kenaf, but to justify this hypothesis extensive trails require to be undertaken.

(ii) Soil Salinity

No structural differences between Classes 2 and 3a were noted. Salinity limitations applicable to Class 3s are as follows:

0-45 cm	4.0-5.3 mmhos
45-90 cm	5.3-8.0 mmhos

This degree of salinity would not render the soil unfit for plant growth and moderately salt tolerant crops would not be affected at all. There should however be some inhibition to the proper growth of sensitive plants probably at germination and in the early stages of growth. Therefore these soils have a reduced yield potential for some crops. Landclass 3s does not occur in the area.

(iii) Alkali levels

The difference between Class 2 and Class 3 in respect of alkali content appears only in the 45-90 cm zone where the permitted level of E.S.P. is extended to 25.

TABLE 5.2 E.S.P. Frequency Occurrence (per cent of total sites)
for 0-45 cm and 45-90 cm

Range	0-45 cm		45-90 cm	
	Number	%	Number	%
0- 5	44	9.5	-	-
5-10	277	60.0	56	12.2
10-15	108	23.4	211	46.3
15-20	26	5.6	139	30.4
20-25	5	0.9	43	9.4
25-30	1	0.2	6	1.1
30-35	-	-	2	0.4

Table 5.2 gives the distribution of varying E.S.P. values. It indicates that a considerable proportion of these areas have been downgraded from Class 2 to 3a due to high E.S.P.'s in the 45-90 cm zone. Sites with high E.S.P. values do tend to show an increased degree of cracking, but a comparison of Class 2 sites with Class 3 sites shows that depth and extent of cracking are very similar.

No structural differences between Classes 2 and 3a were noted. In the top horizon this is to be expected as both classes have E.S.P.'s below 15 in the 0-45 cm zone. It was noted that increased exchangeable sodium in the second horizon tends to give a better development of the wedge structure and a weakening of the angular blocky structure.

A comparison of pH and E.S.P. values failed to reveal any correlation, consequently Class 3a soils are not considered to be inferior to Class 2 soils.

The only notable difference is a higher subsoil E.S.P. and this can be discounted to a large extent as structure, cracking, and pH do not materially differ. It may be argued that Class 3a land has virtually the same productive capacity as Class 2 land. It would certainly have been in the same class by Sodium Value standards.

The fact still remains that by international standards these soils would be viewed with considerable suspicion and if any increase

of alkali did take place under irrigation they would obviously reach the danger limit before less alkali soils. In the initial stages build up of salts would no doubt result in inhibited root growth and reduced yields.

(iv) Extent and Location

The total area mapped as Class 3 for Managil Extension is 40,533 feddans. Class 3 is subdivided as follows:

Landclass	Total Number of Sites	Percentage of total Sites
3 1	30	6.5
3 a	111	23.9
3 al	41	8.8

Land classes 3 1 and 3 al occur as mapping units especially in the northern part of the area.

Class 4

The U.S.B.R. definition states that lands are included in this class only after special economic and engineering studies have shown them to be arable"..... are suitable for irrigation because of existing or contemplated intensive cropping such as truck or fruits; or they may have one or more excessive non-correctible deficiencies thereby limiting their utility to meadow, pasture, orchard or other relatively permanent crops, but are capable of supporting a farm family and meeting water charges if operated in units of adequate size or in association with better lands. The deficiency may be inadequate drainage, excessive salt content requiring leaching.....".

This class is essentially limited arable or special use land. The alkali limitation actually puts a considerable amount of land into this class that would be fully acceptable on Sodium Value standards. On the other hand if the U.S.B.R. standards were followed without a consideration of local conditions then virtually all clay plains soils would be downgraded to this class. As the high clay content and overall alkali content certainly restrict the range of potential crops then the

strictest interpretation of the phrase "limited arable" would thus be applicable to all the large irrigation projects in the Sudan.

The 4 a land class includes soils which have only slightly higher limiting E.S.P.'s than Class 2 in the 0-45 cm zone, 15-20 E.S.P., and have the same E.S.P. range as Class 3 a in the 45-90 cm zone, less than 25 E.S.P. They have therefore been recommended for development, as it is possible they will be found as productive as Class 2 and Class 3 a soils, and it is only the 4 l category with low clay percentages which is considered to be special use land which is not initially recommended as being suitable for irrigation.

(i) Clay Percentage

The 4 l category has clay limits of 5 per cent to 35 per cent which means that the soils in this class are always lighter than clays. The 4 al limitation is 35-50 per cent clay and the 4 a is over 50 per cent which would make them both acceptable for cotton if clay were the only criterion.

Further research may indicate that 4 l lands are suitable for a number of specialised crops as they are not exceptionally alkali. They would however require very different management, particularly regarding cultivation techniques and irrigation practices, from the usual crops of the clay plains. They have not therefore been recommended for inclusion in areas considered for irrigation development at the present time.

(ii) Salinity

The salinity tolerances for this class are identical to those applied to Class 3 s i. e. 5.3 and 8.0 mmhos in the 0-45 cm and 45-90 cm horizons respectively.

When associated with soils of low clay content these levels would be of little significance as leaching would soon reduce them but in the alkaline 4 a lands where leaching is not possible they could be an additional factor in reducing crop yield potential of the more sensitive crops. However the overall soluble salt figures for the area are so low that the number of sites with high E.C.'s is negligible.

(iii) Alkali Levels

The main difference between Class 3a and Class 4a is that the top soil E.S.P. limitation is lifted from 15 to 20. The 45-90 cm zone E.S.P. limit remains the same but in order to include anomalous soils with subsoils having low E.S.P.'s underlying more alkali top soils the classification states "below 25" whereas the 3a classification reads "15-25".

Since the E.S.P. normally increases with depth, 4a lands generally have subsoils which are nearer to the 25 E.S.P. limit than in the 3a lands, which fact in association with their more alkali top soil they would therefore reach danger limits sooner if an alkali build-up under irrigation was a possibility.

Classes 4a and 4al are recommended for inclusion in the irrigable area although Class 4al has a clay content limit of 35-50 per cent. Class 4al only occurs in the northern part of the area and amounts to 2.8 per cent of the total sites.

The distribution and area of Class 4 lands is as follows:

Land class	Total Number of Sites	Percentage of Total Sites
4 a	7	1.5
4 al	13	2.8

Class 4 occurs in two mapping units along the main canal.

Class 5

Under present circumstances this constitutes a non-arable land class. In the light of further research and investigation, re-classification may be possible. It has not been found necessary to make use of Class 5 in the classification of lands under survey in this report.

Class 6

The U.S.B.R. designates this category as non-arable, and

under the criteria used for the project lands any lands which fail to fulfil the requirements for Classes 2, 3 and 4 have been automatically relegated to Class 6. The main criteria for relegation of otherwise usable arable land to Class 6 is high alkalinity and to a very small extent unfavourable topography. The latter category Class 6t has been mapped by photo-interpretation and generally constitutes gullies which are subject to erosion. Generally Class 6 comprises: steep, rough, broken or badly eroded lands: land with soils of very coarse or very fine texture and lands that have inadequate drainage and high concentrations of soluble salts or sodium".

Appreciable differences in alkalinity between top soil and subsoil have resulted in a number of sites with non-alkali top soils and alkali subsoils being downgraded to Class 6a, although they have a low overall soluble sodium level. If the E.S.P. of the 0-45 cm zone lies within acceptable top soil tolerance limits then in these cases the 6a classification has the top soil classification 2, 3, 4a and 4al added to it, e.g. 6a(2). A more detailed explanation is given in the following section.

The alkali limits for this class are those in excess of previous classes and as already explained are associated with the clay content. The suffix 1 indicates a limitation of clay content of less than 50 per cent. Those soils with less than five per cent clay are classified as 6l. This land class has not been found in the area. The classification of soils possessing 5-50 per cent clay is modified by their alkali content and are classed as 6al, which have E.S.P. limits of >15 for the top soil and >20 for the subsoil. A soil with a clay content greater than 50 per cent, would require a top soil E.S.P. greater than 20 and subsoil E.S.P. greater than 25 to cause it to be downgraded i.e. it would then become 6a. Despite the higher alkali content of the 6a subclass it is these lands which might at some future date need re-assessment, since due to their high percentage of clay they would appear to be able to resist the deleterious physical effect of high exchangeable sodium. There is insufficient evidence to warrant extending the level of exchangeable sodium above that used at present. Long term experiments with a variety of crops would be necessary. However, if Gezira results are applicable to this area then soils with clay percentages greater than 50 per cent would have a higher yield potential.

E.S.P. in the 0-45 cm zone yet are downgraded due to alkali in the 45-90 cm. Such sites have been designated as 6a(2), 6a(31),

(ii) Salinity

The number of sites which were downgraded to Class 6s due to excessive salinity are negligible. The E.C. must exceed 5.3 mmhos in the 0-45 cm zone or 8.0 mmhos in the 45-90 cm zone. In fact only eight sites were marginally in excess of these limits. In areas previously surveyed, the salinity of the 90-150 cm zone has never been so high as to be a limiting factor and it is doubtful if salinity at such a depth would have a deleterious effect on crop production. However, in order to confirm that the salinity of this zone was still at the same low level as previously encountered, 25 per cent of the 90-150 cm bore samples were submitted for E.C. estimation. Additional information on the chemical composition of the deeper soil horizons of the area is of course found in the analyses of the natural horizon samples from pits which comprised 1 in 20 of the total sites investigated. From these it can be seen that E.C. values at depth rarely approach even the danger limits set for the top soil.

(iii) Alkali levels

The alkali limits for this class are those in excess of previous classes and as already explained are associated with the clay content. This is because the lower the clay percentage the greater the potential danger of deleterious physical effect of a high alkali content. This is because as the clay percentage falls, the soils are likely to show less well marked cracking and, as the E.S.P. rises, the cracks are more likely to get sealed up by soil particles flaking off the sides of the cracks and blocking them when the soil is wetted. If it is assumed that the cracking and self-mulching capacity of the montmorillonitic clays is the causative factor in maintaining structure despite adverse E.S.P.'s or even some other factor associated with clay content then with lower clay content, a high E.S.P. must exert a greater adverse effect on the soil.

This would presumably remain true until the sand percentage became so high as to dominate the physical condition of the soil.

Due to the greater variation between top soil and subsoil alkali contents there are many sites in this area which have an acceptable

E.S.P. in the 0-45 cm zone yet are downgraded due to alkali in the 45-90 cm. Such sites have been designated as 6 a(2), 6 a(31), 6 a(4a), the second classification symbol being the classification of the top soil alone.

The above dual classifications have been mapped within Class 6 a or as anomalies but it will be noted that they mainly occur in the better class lands.

Land classes 6 a(2), 6 a(31) and 6 a(4a) might well give average yields of cotton under irrigation. The other classes which occur in the Entisols in the Managil extension cannot at present be recommended.

The number of sites and percentage distribution in Class 6 in each sub-division is as follows:-

Land Class	Total Number of Sites	Percentage of Total Sites
6 a	8	1.7
6 a(2)	6	1.3
6 a(31)	2	0.4
6 a(4a)	1	0.3

TABLE 5.3 Land Classification. Proportion of Sites within each Land Class as Percentages of Total Sites

Land Class	Total Number of Sites	Percentage of Total Sites
2	245	52.8
31	30	6.5
3 a	111	23.9
3 a1	41	8.8
4 a	47	1.5
4 a1	13	2.8
6 a	8	1.7
6 a(2)	6	1.3
6 a(31)	2	0.4
6 a(4a)	1	0.3
	<u>464</u>	<u>100.0</u>

5.3 Validity of Classification Criteria

The land classification used is considered to be quite valid in the light of the information available, the main possible criticism being that it may exclude some land which could possibly produce economic yields. With the present state of knowledge of the behaviour of the montmorillonitic clays, both in Sudan and other countries, there is insufficient evidence to justify a relaxation of the adopted criteria.

The clay content limits are based on research and practical knowledge obtained in the Gezira Scheme. Salinity tolerance levels are based upon internationally accepted limits and local research experience. The high quality of Blue Nile water for irrigation is not conducive to a salinity build-up despite the impermeability of the soil.

K.D. Rai observed in the Gezira (VIII Research colloquium, February 1965) that salts have been leached substantially below 120 cm depth, while the distribution of salts over the whole Gezira shows an abrupt increase in salt content around and below 90 cm. This implies that under more intensive irrigation salts in the soil would be leached further down. It was also found that the depth and degree of downward movement of the salts differed between plots.

The alkali limits are those which are most subject to controversy. These limits are based upon the internationally accepted limits with a critical exchangeable sodium percentage of 15 in the case of Class 2 land but have been modified for Classes 3 and 4 land to limits which were more in line with acceptable levels as defined by the previously used 'Sodium Value' classification. The reason for this relaxation from the rather harsh limits of 15 E.S.P. is that this level and even up to 30 per cent exchangeable sodium the clay plain soils are unlikely to

undergo deflocculation. The possible reasons for this favourable characteristic have already been discussed and it may be that the limits could be relaxed still further in the future. The main justification for further relaxation is that even the present expanded limits are still within 'Sodium Value' standards, particularly within the area surveyed, and the fact that high E.S.P.'s do not necessarily result in a high pH.

With only rare exceptions the soil paste pH values vary between 7.0 and 8.5. In the past, land in the Sudan has been considered

unsuitable for irrigated crops if the E.S.P. values have exceeded 20. It would seem probable that a higher E.S.P. limit of perhaps 25 or 30 would be acceptable particularly on clays with good cracking characteristics. Whilst E.S.P. is an important limiting factor, on non-cracking clays, pH becomes the dominant factor where cracking is intensive. It is considered that an upper pH limit of 9 would be a reasonable tolerance level for irrigated crops on such soils, provided that crops did not exhibit chlorosis. Conversely an E.S.P. limit of 10 rather than 15 might be preferable on non-cracking soils. It is recommended that research be initiated to determine whether cracking clays of pH 9 with E.S.P.'s between 20 and 30 are acceptable for irrigated agriculture. This is of very great urgency, because of the large areas of land involved. Moreover the limiting values of E.S.P. on non-cracking soils should be further examined. This is especially important for the coarser soils of the Entisol group on the sandy ridges.

Although evidence to justify the exclusion of these non-cracking soils is lacking the consultants advise against developing these areas in Managil and similar regions until more information is available concerning their behaviour under irrigation. The structure of these coarser textured soils is very weak in the top horizon and there is a danger of sealing up the second horizon. This risk applies to some Vertisols and the Intergrades between the Vertisols and Entisols of the northern part of the Managil area. As the rather sandy mulch of these soils especially in Class 31, 3a1 is not well developed, the risk of sealing up the surface and possibly the 2nd horizon under irrigation is increased. Under careful management these soils may have a good potential.

5.4 The Physical Characteristics in Land Classification

In view of the importance of physical properties, the consultants have made an attempt to classify soils not only on chemical data, but also on the cracking characteristics observed in the field.

Cracking capacity has been sub-divided into four phases:

- | | | | |
|---|------|-----------------------|---------|
| I | Good | Frequent large cracks | (>2 cm) |
| | | Common large cracks | (>2 cm) |
| | | Frequent fine cracks | (<2 cm) |

II	Moderate	Few large cracks	(>2 cm)
		Occasional large cracks	(>2 cm)
		Common fine cracks	(<2 cm)
III	Poor	Few fine cracks	(<2 cm)
		Rare fine cracks	(<2 cm)
		Occasional fine cracks	(<2 cm)
		Rare large cracks	(>2 cm)

IV No cracking.

Phases I and II will probably tolerate pH limits of <9.0 and E.S.P.'s between 20 and 30 for irrigated crops. Phase III will show very limited water percolation and must be considered at present as a soil of low potential, but might improve under irrigation, due to the moisture regime. E.S.P. limits of 10 to 20 are recommended although weak structure might downgrade these soils. These soils are marginal and some have been excluded. Phase IV related to the Entisols; these soils are not recommended for irrigable crops. Another restriction of the clay soils under irrigation might be a platy and/or wedge structure which is very often present in the Vertisols occurring between 20 and 60 cm. This layer which varies in thickness between sites, may prove to be a severe limitation under irrigation. It has been found that roots cannot penetrate the plates or wedges but travel horizontally until a break occurs. There is probably little water percolation through this platy layer and as this occurs mainly at the bottom of the first horizon, little moisture penetrates to the firm second horizon. It is difficult to map these layers at the present survey density and it is suggested that a detailed soil survey be carried out at a mapping scale of 1:5000 or 1:10,000 in Pilot Scheme areas to discover the extent of these layers and to ascertain their effect on crop yields.

This structural element occurs more frequently and is better developed in the southern part of the area than in the northern part. The greatest degree of development is found in areas 2A and 2B, (Blue Nile, east and west bank, Roseires - Abu Hugar - Sennar).

A number of pits were excavated at the beginning of March on the Gezira Research Farm in the continuous cotton plot and in a

TABLE 5.7 Criteria for Determining Land Classification

Land Class	Sample Depth in cms	Clay Content in millimhos	Permeability	Water Penetration
2	0-45	exceeds 50%	less than 4.0	less than 15
	45-90	not limiting	less than 5.3	less than 15
31	0-45	exceeds 50%	less than 4.0	less than 15
	45-90	not limiting	less than 5.3	less than 15
3a	0-45	exceeds 50%	less than 4.0	less than 15
	45-90	not limiting	less than 5.3	15-25
3al	0-45	35-50%	less than 4.0	less than 15
	45-90	not limiting	less than 5.3	15-25
3s	0-45	exceeds 50%	4.0-5.3	less than 15
	45-90	not limiting	5.3-8.0	less than 15
3al	0-45	35-50%	4.0-5.3	less than 15
	45-90	not limiting	5.3-8.0	less than 15
3as	0-45	exceeds 50%	4.0-5.3	less than 15
	45-90	not limiting	5.3-8.0	15-25
3asl	0-45	35-50%	4.0-5.3	less than 15
	45-90	not limiting	5.3-8.0	15-25
4a	0-45	exceeds 50%	less than 5.3	15-20
	45-90	not limiting	less than 8.0	less than 25
4al	0-45	35-50%	less than 5.3	15-20
	45-90	not limiting	less than 8.0	less than 25
4l	0-45	5-35%	less than 5.3	less than 15
	45-90	not limiting	less than 8.0	less than 20
6a	0-45	exceeds 50%	less than 5.3	exceeds 20
	45-90	not limiting	less than 8.0	exceeds 25
6s	0-45	exceeds 5%	exceeds 5.3	less than 15 or 20
	45-90	not limiting	exceeds 8.0	less than 20 or 25
6as	0-45	exceeds 5%	exceeds 5.3	exceeds 15 or 20
	45-90	not limiting	exceeds 8.0	exceeds 20 or 25
6l	0-45	less than 5%	not limiting	not limiting
	45-90	not limiting	not limiting	not limiting
6al	0-45	5-50	less than 5.3	exceeds 15
	45-90	not limiting	less than 8.0	exceeds 15 or 20
6t	unsuitable due to adverse topography.			



Not recommended for any cultivation based on structural deficiency.

NOTE:

Not all these classes occur in the area investigated.

TABLE 5.7 Criteria for Determining Land Classification

TABLE 5.8 Areas of Land Classes Mapped

Land Class	Sample Depth in cms	Clay Content	E.C. in millimhos	E.S.P.
2	0-45	exceeds 50%	less than 4.0	less than 15
	45-90	not limiting	less than 5.3	less than 15
31	0-45	35-50%	less than 4.0	less than 15
	45-90	not limiting	less than 5.3	less than 15
3a	0-45	exceeds 50%	less than 4.0	less than 15
	45-90	not limiting	less than 5.3	15-25
3a1	0-45	35-50%	less than 4.0	less than 15
	45-90	not limiting	less than 5.3	15-25
3s	0-45	exceeds 50%	4.0-5.3	less than 15
	45-90	not limiting	5.3-8.0	less than 15
3s1	0-45	35-50%	4.0-5.3	less than 15
	45-90	not limiting	5.3-8.0	less than 15
3as	0-45	exceeds 50%	4.0-5.3	less than 15
	45-90	not limiting	5.3-8.0	15-25
3as1	0-45	35-50%	4.0-5.3	less than 15
	45-90	not limiting	5.3-8.0	15-25
4a	0-45	exceeds 50%	less than 5.3	15-20
	45-90	not limiting	less than 8.0	less than 25
4a1	0-45	35-50%	less than 5.3	15-20
	45-90	not limiting	less than 8.0	less than 25
41	0-45	5-35%	less than 5.3	less than 15
	45-90	not limiting	less than 8.0	less than 20
6a	0-45	exceeds 50%	less than 5.3	exceeds 20
	45-90	not limiting	less than 8.0	exceeds 25
6s	0-45	exceeds 5%	exceeds 5.3	less than 15 or 20
	45-90	not limiting	exceeds 8.0	less than 20 or 25
6as	0-45	exceeds 5%	exceeds 5.3	exceeds 15 or 20
	45-90	not limiting	exceeds 8.0	exceeds 20 or 25
61	0-45	less than 5%	not limiting	not limiting
	45-90	not limiting	not limiting	not limiting
6a1	0-45	5-50	less than 5.3	exceeds 15
	45-90	not limiting	less than 8.0	exceeds 10 or 25
6t	unsuitable due to adverse topography.			



Not recommended for any cultivation based on structural deficiency.

NOTE:

Not all these classes occur in the area investigated.

TABLE 5.8 Areas of Land Classes Mapped

Land Class	Total Feddan	Percentage
2	47794.6	53.5
3 a	27617.3	31.0
6.1 <u>Arable Lands</u> 3 a 1	7321.0	8.2
3 1	5594.9	6.3
4 a	535.7	0.6
4 a 1	178.6	0.2
6 a	178.6	0.2
Total:	89220.7	100.0
2	47794.6	53.5
3	40533.2	45.5
4	714.3	0.8
6	178.6	0.2
Total:	89220.7	100.0
<u>6.2 Non-arable Lands</u>		

Only 3.7 per cent of the total number of sites has been classified as Class 6. They occur in the northern part of the area adjacent to the sandy ridges, on which the villages are situated. The sandy ridges are not recommended for cultivation.

The consultants recommend that Class 6 lands be reserved for irrigated pastures, where the herds of cattle belonging to the village communities could graze.

CHAPTER 6

RECOMMENDATIONS

6.1 Arable Lands

The lands classified as Class 2, 3 and 4 are situated along the Kawa Main Canal and the Esh Shawal extension and are suitable for long staple cotton. A rotation of cotton - wheat - fallow - cotton - groundnuts - lubia - dura - Phillipesera - fallow is recommended. This rotation is quite adequate for the Vertisols, and Vertisols - Entisols intergrades. Any decrease in the fallow on the latter should not be considered without the necessary research. These soils have a restricted cracking capacity and are likely to be affected by a salinity build-up under irrigation.

Groundnuts on the coarser textured soils would probably improve their physical structure, although more research is required.

6.2 Non-arable Lands

Only 3.7 per cent of the total number of sites has been classified as Class 6. They occur in the northern part of the area adjacent to the sandy ridges, on which the villages are situated. The sandy ridges are not recommended for cultivation.

The consultants recommend that Class 6 lands be reserved for irrigated pastures, where the herds of cattle belonging to the village communities could graze.

Pit No.	Depth (cm)	pH 1:5	pH Paste	E.C. mmhos/cm at 25°C.	Sat %	Mechanical Analysis						Sol. Na. Meq. 100g.	Ex. Na Meq. 100g.	C.E.C. E.S.P.
						Sand			Silt 0.02-0.002 mm	Clay 0.002 mm				
						CS 2.0-0.2 mm	FS 0.2-0.02 mm	FS 0.02 mm						
2868	0-40	9.4	8.2	0.6	56	2	20	11	57	0.27	3.90	62	6	
	40-85	9.5	8.0	1.5	65	7	24	9	60	0.75	7.25	67	11	
	85-155	9.4	7.9	3.5	73	5	19	12	64	1.91	7.49	64	12	
	155-200	8.5	7.7	6.7	65	0	21	13	56	2.94	6.80	57	12	
2893	0-50	9.6	8.3	1.0	57	0	21	10	59	0.45	7.21	61	12	
	50-80	9.4	8.0	2.7	67	8	29	9	54	1.43	11.79	55	21	
	80-135	9.0	7.7	6.8	73	9	44	4	63	4.25	10.35	59	18	
	135-205	8.6	7.8	7.6	64					3.62	7.18	63	11	
3768	0-70	9.6	7.9	2.2	61	7	7	7	59	1.00	7.00	62	11	
	70-120	9.7	8.0	1.3	59	0	3	12	55	0.57	8.83	63	14	
	120-175	9.4	7.8	2.4	66	6	22	17	55	1.20	7.15	61	12	
	175-200	9.3	7.7	4.7	63	10	23	11	56	2.05	5.95	59	10	
3794	0-75	9.7	8.1	1.1	57	12	21	8	59	0.47	9.95	62	16	
	75-160	9.2	7.8	4.9	66	6	22	12	60	2.69	7.73	63	12	
	160-200	8.7	7.6	6.8	64	14	21	12	53	3.34	8.86	53	17	
4777	0-45	9.4	8.0	0.7	62	10	20	11	59	0.29	6.32	60	11	
	45-85	9.4	7.8	3.6	68	7	12	10	71	1.78	11.12	65	17	
	85-170	8.9	7.7	4.9	67	9	15	14	62	2.36	10.84	64	17	
	170-200	9.2	7.7	3.5	67	9	17	13	61	1.75	7.98	67	12	

APPENDIX

ANALYSES FROM AUGER BORINGS AND PITS

Pit No.	Depth (cm)	pH 1:5	pH Paste	E.C. mmhos/cm at 25°C.	Sat %	Mechanical Analysis					Sol. Na. Meq. 100g.	Ex. Na. Meq. 100g.	C.E.C.	E.S.P.
						Sand		Silt 0.02-0.002 mm	Clay 0.002 mm					
						CS 2.0-0.2 mm	FS 0.2-0.02 mm							
2868	0-40	9.4	8.2	0.6	56	12	20	11	57	0.27	3.90	62	6	
	40-85	9.5	8.0	1.5	65	7	24	9	60	0.75	7.25	67	11	
	85-155	9.4	7.9	3.5	73	5	19	12	64	1.91	7.49	64	12	
	155-200	8.5	7.7	6.7	65	10	21	13	56	2.94	6.80	57	12	
2893	0-50	9.6	8.3	1.0	57	10	21	10	59	0.45	7.21	61	12	
	50-80	9.4	8.0	2.7	67	8	29	9	54	1.43	11.79	55	21	
	80-135	9.0	7.7	6.8	73	9	24	4	63	4.25	10.35	59	18	
	135-205	8.6	7.8	7.6	64	9	20	16	55	3.62	7.18	63	11	
3768	0-70	9.6	7.9	2.2	61	7	27	17	59	1.00	7.00	62	11	
	70-120	9.7	8.0	1.3	59	10	23	12	55	0.57	8.83	63	14	
	120-175	9.4	7.8	2.4	66	6	22	17	55	1.20	7.15	61	12	
	175-200	9.3	7.7	4.7	63	10	23	11	56	2.05	5.95	59	10	
3794	0-75	9.7	8.1	1.1	57	12	21	8	59	0.47	9.95	62	16	
	75-160	9.2	7.8	4.9	66	6	22	12	60	2.69	7.73	63	12	
	160-200	8.7	7.6	6.8	64	14	21	12	53	3.34	8.86	53	17	
4777	0-45	9.4	8.0	0.7	62	10	20	11	59	0.29	6.32	60	11	
	45-85	9.4	7.8	3.6	68	7	12	10	71	1.78	11.12	65	17	
	85-170	8.9	7.7	4.9	67	9	15	14	62	2.36	10.84	64	17	
	170-200	9.2	7.7	3.5	67	9	17	13	61	1.75	7.98	67	12	

Pit No.	Depth (cm)	pH 1:5	pH Paste	E.C. mmhos/cm at 25°C.	Sat %	Mechanical Analysis					Sol. Na. Meq. 100g.	Ex. Na Meq. 100g.	C.E.C.	E.S.P.
						Sand		Silt 0.02-0.002 mm	Clay 0.002 mm					
						CS 2.0-0.2 mm	FS 0.2-0.02 mm							
4810	0-50	9.4	7.9	1.0	53	14	14	9	63	0.36	3.47	52	7	
	50-95	9.3	7.7	4.2	58	11	14	10	65	1.76	6.59	69	10	
	95-145	9.0	7.6	5.3	65	9	20	10	61	2.26	7.14	69	10	
	145-190	8.8	7.6	5.7	68	10	24	15	51	2.43	6.27	57	11	
	190-200	9.2	7.6	5.5	60	20	14	11	55	2.24	5.42	60	9	
4828	0-50	9.2	8.0	0.6	53	13	16	15	56	0.17	2.61	62	4	
	50-90	9.2	8.0	0.8	48	14	17	13	56	0.28	6.33	68	9	
	90-200	9.2	7.8	2.2	61	11	20	13	56	1.03	8.71	65	13	
4839	0-50	9.0	7.8	4.2	62	9	20	16	55	1.75	6.25	65	10	
	50-170	9.1	7.8	3.2	63	10	20	14	56	1.37	6.29	63	10	
	170-200	8.8	7.8	5.6	64	7	18	19	56	2.22	5.78	60	10	
4854	0-35	9.4	8.2	0.7	53	14	23	10	53	0.22	4.65	57	8	
	35-90	9.6	8.1	0.8	54	12	20	13	55	0.30	3.18	60	5	
	90-145	9.5	8.1	4.4	65	12	25	8	55	2.29	3.28	62	5	
	145-200	8.5	7.7	8.3	66	13	21	10	56	4.30	10.00	63	16	
4862	0-75	9.6	7.9	4.3	53	24	10	20	45	1.80	5.86	48	12	
	75-160	9.4	7.9	7.5	57	19	18	10	53	3.61	10.69	60	18	
	160-200	8.6	7.9	8.1	55	25	22	8	45	3.68	8.82	53	17	
	45-90	9.6	8.2	0.8	50	26	19	5	48	0.25	6.36	45	14	
90-150	9.5	7.9	2.8	57	29	9	11	51	1.31	7.40	44	17		

Pit No.	Depth (cm)	pH 1:5	pH Paste	E.C. mmhos/cm at 25°C.	Sat %	Mechanical Analysis						Sol. Na. Meq. 100g.	Ex. Na Meq. 100g.	C.E.C.	E.S.P.
						Sand		Silt 0.02-0.002 mm	Clay 0.002 mm	FS 0.2-0.02 mm					
						CS 2.0-0.2 mm	FS 0.2-0.02 mm								
5836	0-50 50-95 95-165 165-200	9.5 9.4 9.2 8.4	8.2 8.0 7.9 7.8	0.5 2.0 4.0 6.8	57 67 60 63	9 10 11 14	22 21 20 19	13 12 12 11	56 57 57 56	0.23 1.05 1.72 2.95	5.67 9.37 7.68 2.62	60 61 63 63	9 15 12 4		
5865	0-30 30-95 95-195	9.6 9.3 9.0	8.4 7.9 7.8	0.6 4.8 7.1	51 61 60	14 15 16	21 21 21	15 12 11	50 52 52	0.27 2.65 3.44	6.35 10.55 9.06	50 60 55	13 18 16		
5880	0-40 40-110 110-200	9.5 9.7 8.4	8.3 7.9 7.7	0.6 1.9 8.3	52 54 58	13 16	18 17	15 10	54 57 57	0.24 0.81 3.78	3.24 6.85 9.12	63 65 63	5 10 14		
5894	0-45 45-90 90-150	9.6 9.5 9.3	8.0 8.2 7.9	0.4 1.3 5.2	38 48 53	18 31 24	34 18 20	10 7 9	38 44 47	0.10 0.52 2.32	2.68 6.09 8.10	52 41 43	5 15 19		
5895	0-45 45-90 90-150	9.4 9.6 9.3	8.4 8.6 7.8	0.5 0.9 7.2	37 46 48	39 38 29	16 16 12	8 7 7	37 39 52	0.13 0.39 2.88	3.00 7.61 7.18	36 37 43	8 21 17		
5903	0-45 45-90 90-150	9.4 9.6 9.5	8.3 8.2 7.9	2.1 0.8 2.8	57 50 57	25 28 29	14 19 9	14 5 11	47 48 51	0.88 0.25 1.30	3.29 6.36 7.40	47 45 44	7 14 17		

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class	Land Class
		Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
2875	0-45	27	8	65	0.9	62	0.52	5.39	8	A111	2
	45-90	29	9	62	3.3	65	2.12	7.64	12		
	90-150										
2876	0-45	24	16	60	0.4	49	0.18	3.99	7	A111	2
	45-90	24	14	62	1.6	62	0.97	7.73	12		
	90-150										
2877	0-45	29	9	62	0.4	48	0.15	6.81	11	A121	3a
	45-90	28	10	62	1.1	57	0.59	10.21	16		
	90-150				5.2	57					
2878	0-45	27	14	59	0.4	49	0.19	5.72	10	A121	3a
	45-90	28	10	62	2.7	56	1.29	9.51	15		
	90-150										
2879	0-45	28	15	57	0.5	48	0.23	3.94	7	A121	2
	45-90	28	10	62	1.5	59	0.68	7.67	12		
	90-150										
2880	0-45	29	17	54	0.2	48	0.08	5.48	10	A121	3a
	45-90	29	11	60	1.4	61	0.65	9.09	15		
	90-150				3.6	66					
2881	0-45	34	13	53	0.4	63	0.19	5.37	10	A111	3a
	45-90	30	11	59	1.6	55	0.69	9.05	16		
	90-150										
2882	0-45	27	15	58	0.3	57	0.17	5.39	9	A121	2
	45-90	27	8	65	0.5	58	0.23	8.47	13		
	90-150										
2883	0-45	29	14	57	0.5	52	0.19	5.37	9	A121	3a
	45-90	29	9	62	1.4	60	0.61	9.81	16		
	90-150										
2884	0-45	29	9	62	0.4	49	0.16	9.24	15	A121	3a
	45-90	30	8	62	0.8	58	0.36	12.84	20		
	90-150				7.5	67					
2885	0-45	32	9	59	0.4	48	0.16	6.46	11	A111	2
	45-90	27	11	62	1.1	48	0.41	8.99	14		
	90-150										
2886	0-45	31	10	59	0.5	49	0.19	7.47	13	A121	3a
	45-90	27	11	62	0.7	59	0.32	12.88	20		
	90-150										
2887	0-45	30	11	59	0.4	48	0.16	7.84	13	A121	3a
	45-90	32	9	59	0.8	55	0.35	11.85	20		
	90-150										
2888	0-45	32	9	59	0.4	65	0.19	6.77	11	A121	2
	45-90	27	11	62	0.9	58	0.39	8.95	14		
	90-150				4.0	64					

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class	Land Class
		Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
2890	0-45	30	12	58	0.4	49	0.17	8.18	14	A121	3a
	45-90	36	9	55	0.7	50	0.29	12.61	23		
	90-150										
2891	0-45	28	12	60	0.4	48	0.19	7.81	13	A121	3a
	45-90										
	90-150										
2892	0-45	29	14	57	0.4	48	0.16	8.54	15	A121	3a
	45-90	29	11	60	0.9	56	0.41	14.59	24		
	90-150				7.5	67					
2893	0-45	27	10	63	0.3	49	0.13	7.53	12	A121	3a
	45-90	28	12	60	2.0	58	0.97	14.73	24		
	90-150										
2894	0-45	28	17	55	0.4	48	0.16	5.75	10	A111	3a
	45-90	30	12	58	2.6	63	1.26	11.64	20		
	90-150										
2895	0-45	27	15	58	0.4	53	0.15	3.33	6	A121	3a
	45-90	30	12	58	1.1	60	0.51	8.89	15		
	90-150										
2896	0-45	33	12	55	0.3	53	0.08	1.66	3	A121	2
	45-90	31	9	60	0.8	58	0.30	4.57	8		
	90-150				2.9	64					
2897	0-45	31	9	60	0.3	53	0.09	1.65	3	A111	2
	45-90	29	8	63	1.6	60	0.68	6.98	11		
	90-150										
2898	0-45	29	6	65	0.3	50	0.11	4.06	6	A111	2a
	45-90	29	8	63	0.4	49	0.14	6.48	13		
	90-150										
2899	0-45	31	9	60	0.3	49	0.12	3.36	6	A111	2
	45-90	35	7	58	0.4	48	0.17	6.45	11		
	90-150				4.1	64					
2900	0-45	29	8	63	0.3	52	0.13	3.70	6	A121	2
	45-90	29	8	63	0.4	56	0.19	5.38	9		
	90-150										
2901	0-45	28	7	65	0.3	51	0.12	4.05	6	A121	2
	45-90	27	5	68	0.4	55	0.17	9.23	13		
	90-150										
2902	0-45	20	16	64	0.3	55	0.14	4.03	6	A111	2
	45-90	23	11	66	1.1	58	0.56	6.40	10		
	90-150										
2903	0-45	25	14	61	0.4	54	0.12	1.96	3	A121	2
	45-90	25	9	66	0.5	55	0.18	5.33	8		
	90-150				1.90	64					

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class	Land Class
		Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
2918	0-45	24	13	63	0.4	50	0.17	8.18	13	A121	3a
	45-90	21	13	66	2.2	62	1.21	11.69	18		
	90-150				4.3	76					
3739	0-45	28	11	61	0.4	52	0.15	2.29	4	C121	2
	45-90	29	8	63	1.0	60	0.52	6.44	10		
	90-150										
3740	0-45	31	8	61	0.4	52	0.20	3.28	5	C121	2
	45-90	26	8	66	2.0	61	1.03	6.97	11		
	90-150				6.4	65					
3741	0-45	26	13	61	0.5	57	0.23	2.21	4	C121	2
	45-90	26	11	63	4.1	61	1.94	6.77	10		
	90-150										
3742	0-45	25	14	61	0.3	53	0.15	3.33	5	C121	2
	45-90	23	13	64	2.6	59	1.36	8.38	13		
	90-150				6.0	65					
3743	0-45	30	13	57	0.7	51	0.26	3.22	6	A121	2
	45-90	25	15	60	3.9	67	2.10	6.61	11		
	90-150				5.0	74					
3744	0-45	26	16	58	0.6	54	0.29	3.54	6	C121	2
	45-90	23	15	62	2.0	64	1.07	7.64	12		
	90-150										
3745	0-45	26	12	62	0.6	55	0.24	2.89	5	A121	2
	45-90	23	13	64	2.5	66	1.29	6.37	10		
	90-150										
3746	0-45	24	11	65	0.7	55	0.20	1.54	2	A121	2
	45-90	25	11	64	2.1	63	0.86	4.71	7		
	90-150				4.8	70					
3747	0-45	25	14	61	0.5	56	0.18	2.60	4	A111	2
	45-90	23	13	64	1.3	66	0.58	3.94	6		
	90-150				7.0	72					
3748	0-45	24	14	62	0.4	53	0.15	6.12	10	A111	2
	45-90	24	12	64	1.6	60	0.77	8.28	13		
	90-150										
3749	0-45	29	14	57	0.3	48	0.12	5.80	10	A111	2
	45-90	26	14	60	1.1	58	0.52	8.19	14		
	90-150										
3750	0-45	29	14	57	0.4	52	0.14	3.69	6	A111	3a
	45-90	30	10	60	1.6	60	0.79	9.71	16		
	90-150				3.0	73					
3751	0-45	24	13	63	0.5	53	0.21	5.01	8	A111	2
	45-90	26	13	61	2.7	62	1.35	8.05	13		
	90-150				3.8	68					
3766	0-45	22	12	66	0.3	53	0.12	4.40	7	A111	2

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class	Land Class
		Sand 2.0- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay 0.002 mm.							
3752	0-45	33	11	56	0.5	48	0.20	4.32	8	C121	3a
	45-90	31	12	57	2.2	56	1.02	12.88	23		
	90-150										
3753	0-45	25	15	60	0.5	48	0.17	4.35	7	C121	2
	45-90	25	15	60	4.2	60	1.83	6.84	11		
	90-150										
3754	0-45	23	18	59	0.4	50	0.16	4.36	7	A111	2
	45-90	26	9	65	2.6	60	1.15	6.15	9		
	90-150				6.4	65					
3755	0-45	23	16	61	0.4	48	0.15	5.42	9	A111	3a
	45-90	25	14	61	1.3	60	0.67	9.43	15		
	90-150										
3756	0-45	26	12	62	0.4	49	0.17	1.57	3	A111	3a
	45-90	26	13	61	0.8	54	0.41	10.39	17		
	90-150										
3757	0-45	24	15	61	0.3	52	0.10	10.00	16	C122	4a
	45-90	25	11	64	2.1	59	0.99	14.01	22		
	90-150				5.0	74					
3758	0-45	21	14	65	0.2	50	0.08	7.22	11	A121	2
	45-90	22	10	68	0.9	56	0.38	9.72	14		
	90-150				3.2	66					
3759	0-45	20	15	65	0.3	53	0.12	6.49	10	A111	3a
	45-90	21	10	69	2.5	58	1.03	11.47	17		
	90-150										
3760	0-45	21	10	65	0.5	55	0.20	5.37	8	A111	2
	45-90	22	13	65	0.9	50	0.30	9.10	14		
	90-150										
3761	0-45	24	12	64	0.4	52	0.11	4.41	7	A111	2
	45-90	25	9	66	2.0	63	0.92	7.79	12		
	90-150				7.0	72					
3762	0-45	47	9	44	0.5	50	0.20	5.37	12	A111	31
	45-90	24	13	63	2.6	61	1.08	8.32	13		
	90-150										
3763	0-45	26	10	64	0.5	51	0.18	3.30	5	A111	2
	45-90	30	13	57	2.1	61	0.87	7.48	13		
	90-150										
3764	0-45	31	10	59	0.5	50	0.13	2.65	4	C121	2
	45-90	27	12	61	1.9	56	0.67	5.60	9		
	90-150										
3765	0-45	23	11	66	0.4	48	0.13	5.09	8	C121	2
	45-90	24	10	66	1.9	59	0.75	7.96	12		
	90-150				3.8	68					
3766	0-45	22	12	66	0.3	53	0.12	4.40	7	A111	2

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class	Land Class
		Sand 2.0- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay 0.002 mm.							
3767	0-45	30	13	57	0.4	50	0.13	3.35	6	A111	2
	45-90	30	13	57	1.5	59	0.61	7.05	12		
	90-150										
3768	0-45	32	10	58	0.4	52	0.13	3.70	6	A111	2
	45-90	31	12	57	0.7	51	0.16	7.84	14		
	90-150										
3769	0-45	28	13	59	0.3	51	0.08	3.75	6	A111	2
	45-90	37	12	51	0.8	61	0.31	6.65	13		
	90-150				3.3	70					
3770	0-45	31	11	58	0.4	57	0.16	2.67	5	A111	2
	45-90	30	8	62	0.8	60	0.34	8.01	13		
	90-150				4.4	74					
3771	0-45	33	12	55	0.4	48	0.11	5.46	10	A111	3a
	45-90	32	6	62	0.5	61	0.21	9.53	15		
	90-150										
3772	0-45	30	10	60	0.5	42	0.12	6.15	10	A111	3a
	45-90	34	8	58	2.9	50	1.04	9.06	16		
	90-150										
3773	0-45	32	8	60	0.4	59	0.15	6.46	11	A111	3a
	45-90	33	10	57	1.8	52	0.68	11.12	20		
	90-150				3.2	66					
3774	0-45	32	5	63	1.3	50	0.87	4.35	7	A111	2
	45-90	29	11	60	1.7	60	0.71	7.29	12	12	
	90-150				3.1	73					
3775	0-45	33	9	58	0.4	52	0.13	2.31	4	A111	2
	45-90	32	8	60	2.5	60	0.91	6.39	11		
	90-150										
3776	0-45	32	10	58	0.4	48	0.13	4.74	8	A111	3a
	45-90	31	9	60	0.5	60	0.20	9.54	16		
	90-150				4.6	65					
3777	0-45	31	9	60	1.0	57	0.42	5.15	9	A111	2
	45-90	30	10	60	2.5	54	1.02	8.72	14		
	90-150										
3778	0-45	34	8	58	0.4	51	0.16	4.02	7	A111	3a
	45-90	30	13	57	2.5	55	0.98	8.76	15		
	90-150				7.5	70					
3779	0-45	32	14	54	0.5	51	0.12	3.36	6	A111	2
	45-90	30	12	58	1.4	62	2.63	5.37	9		
	90-150										
3780	0-45	29	12	59	0.5	48	0.19	5.38	9	A111	2
	45-90	29	10	61	1.7	57	0.70	8.01	13		
	90-150				3.7	70					

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class	Land Class
		Sand 2.0- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay 0.002 mm.							
3781	0-45	31	10	59	3.1	60	1.33	9.17	16	A112	4a
	45-90	29	12	59	1.2	58	0.52	8.53	14		
	90-150				4.8	72					
3782	0-45	32	9	59	0.4	49	0.14	5.43	9	A111	2
	45-90	31	10	59	1.8	60	0.81	8.59	15		
	90-150				3.7	72					
3783	0-45	30	13	57	0.5	57	0.21	3.62	6	A111	2
	45-90	30	9	61	3.3	59	1.41	9.09	15		
	90-150										
3784	0-45	29	12	59	0.5	53	0.17	4.70	8	A111	3a
	45-90	30	9	61	1.3	60	0.52	10.28	17		
	90-150				4.4	74					
3785	0-45	29	12	59	0.4	49	0.09	5.48	9	A111	3a
	45-90	31	7	62	1.0	57	0.35	10.45	17		
	90-150										
3786	0-45	31	10	59	0.5	49	0.09	3.39	6	A111	2
	45-90	31	7	62	2.8	59	1.29	8.11	13		
	90-150				4.5	64					
3787	0-45	29	12	59	1.9	58	0.69	3.83	6	A111	2
	45-90	29	9	62	1.7	60	0.76	8.29	13		
	90-150										
3788	0-45	32	6	62	0.4	48	0.13	4.05	7	A111	2
	45-90	32	6	62	3.7	58	1.41	6.94	11		
	90-150				3.1	73					
3789	0-45	32	9	59	0.5	48	0.15	4.37	7	A111	2
	45-90	28	10	62	1.3	59	0.49	8.32	13		
	90-150										
3790	0-45	34	9	57	0.4	48	0.13	3.70	6	C121	2
	45-90	30	10	60	1.2	61	0.53	7.47	12		
	90-150										
3791	0-45	32	14	54	0.7	54	0.30	3.53	7	C121	2
	45-90	32	9	59	2.1	61	1.03	8.71	15		
	90-150										
3792	0-45	27	13	60	0.7	54	0.23	3.60	6	C121	2
	45-90	28	12	60	1.3	60	0.60	6.36	11		
	90-150				7.5	70					
3793	0-45	33	12	55	0.5	50	0.15	4.72	9	A111	2
	45-90	25	10	65	2.2	62	0.98	6.61	10		
	90-150				4.4	74					
3794	0-45	30	11	59	0.6	54	0.16	2.97	5	A111	2
	45-90	30	10	60	2.2	61	0.99	5.97	10		
	90-150				4.8	72					

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class	Land Class
		Sand 2.0- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay 0.002 mm.							
3795	0-45	30	11	59	0.6	54	0.16	2.97	5	A111	2
	45-90	30	10	60	2.2	61	0.99	5.97	10		
	90-150				4.8	72					
3796	0-45	30	10	60	0.5	54	0.17	2.96	5	A111	2
	45-90	30	11	59	1.9	60	0.85	8.55	14		
	90-150				3.7	72					
3797	0-45	30	11	59	0.6	56	0.26	2.87	5	A111	2
	45-90	29	11	60	2.7	63	1.18	4.39	7		
	90-150				3.4	72					
3798	0-45	34	12	54	0.5	48	0.12	1.97	4	A111	2
	45-90	32	8	60	1.9	61	0.79	4.08	7		
	90-150										
3799	0-45	29	14	57	0.9	56	0.32	2.46	4	A111	2
	45-90	29	11	60	3.2	61	1.40	3.12	5		
	90-150										
3800	0-45	26	14	60	0.7	56	0.27	2.51	4	A111	2
	45-90	26	9	65	3.6	60	1.56	4.36	7		
	90-150				4.5	64					
3801	0-45	27	13	60	0.5	55	0.15	1.24	2	A111	2
	45-90	22	12	66	1.4	64	0.78	9.18	14		
	90-150										
3802	0-45	23	12	65	0.4	52	0.17	2.96	5	A111	2
	45-90	23	12	65	1.1	59	0.47	5.80	9		
	90-150										
3803	0-45	28	10	62	0.4	51	0.14	2.30	4	A111	2
	45-90	27	11	62	2.3	60	0.98	5.29	9		
	90-150										
3804	0-45	28	15	57	0.4	56	0.14	1.25	2	A111	2
	45-90	28	10	62	1.9	61	0.74	4.48	7		
	90-150				3.0	73					
3805	0-45	27	13	60	0.6	52	0.21	4.66	8	A111	2
	45-90	28	10	62	3.8	62	1.70	6.65	11		
	90-150										
4756	0-45	27	16	57	0.6	54	0.19	1.90	3	A111	2
	45-90	26	10	64	1.6	61	0.82	6.78	11		
	90-150										
4757	0-45	28	10	62	0.7	57	0.25	2.53	4	A111	2
	45-90	25	10	65	2.2	62	0.98	6.62	10		
	90-150				4.4	74					
4758	0-45	22	11	67	0.7	59	0.29	3.89	6	A121	2
	45-90	24	9	67	3.4	66	1.66	7.74	12		
	90-150				4.0	75					

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class	Land Class
		Sand 2.0- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay 0.002 mm.							
4759	0-45	24	12	64	0.5	55	0.21	5.01	8	A121	2
	45-90	24	9	67	3.6	64	1.67	9.13	14		
	90-150										
4760	0-45	23	10	67	0.5	56	0.18	4.13	6	A121	2
	45-90	22	9	69	2.7	63	1.26	8.74	13		
	90-150										
4761	0-45	23	10	67	0.5	53	0.16	5.55	8	A121	2
	45-90	21	10	69	1.8	62	0.78	8.55	12		
	90-150				3.4	72					
4762	0-45	23	13	64	1.1	58	0.39	3.51	5	A121	2
	45-90	24	12	64	3.1	64	1.47	8.13	13		
	90-150				4.5	79					
4763	0-45	23	13	64	1.0	60	0.38	4.92	8	A121	2
	45-90	24	9	67	3.4	67	1.63	9.36	14		
	90-150										
4764	0-45	23	10	67	0.5	48	0.18	4.41	7	A121	2
	45-90	24	7	69	1.6	65	0.87	7.34	11		
	90-150										
4765	0-45	26	10	64	1.4	60	0.69	3.76	6	A121	2
	45-90	22	12	66	1.4	64	0.74	9.15	14		
	90-150										
4766	0-45	22	12	66	0.6	55	0.22	4.37	7	A121	2
	45-90	20	11	69	3.0	65	1.52	10.18	15		
	90-150				4.1	70					
4767	0-45	20	11	69	0.7	53	0.25	3.37	5	A121	2
	45-90	19	14	67	2.3	61	1.07	7.70	11		
	90-150										
4768	0-45	22	13	65	0.5	51	0.21	4.80	7	A121	2
	45-90	22	11	67	2.7	61	1.32	9.40	14		
	90-150				3.0	73					
4769	0-45	22	11	67	0.7	58	0.30	5.54	8	A121	3a
	45-90	19	14	67	2.4	66	1.25	10.45	16		
	90-150				4.4	70					
4770	0-45	22	11	67	0.8	57	0.28	5.43	8	A121	3a
	45-90	22	11	67	1.4	64	0.68	11.02	16		
	90-150										
4771	0-45	24	9	67	0.5	55	0.19	5.65	8	A121	2
	45-90	21	12	67	2.0	62	0.98	9.04	13		
	90-150										
4772	0-45	21	12	67	0.5	54	0.22	5.62	8	A121	3a
	45-90	21	12	67	2.4	64	1.17	10.94	16		
	90-150				4.0	75					

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class	Land Class
		Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
4787	0-45	25	12	63	0.5	51	0.17	5.40	9	A121	3a
	45-90	24	11	65	2.0	57	0.87	10.41	16		
	90-150				3.9	75					
4788	0-45	23	13	64	0.5	55	0.18	6.78	10	A121	3a
	45-90	23	12	65	2.1	65	1.02	10.39	16		
	90-150				6.3	61					
4789	0-45	27	14	59	0.6	53	0.24	9.23	16	A122	4a
	45-90	24	12	64	1.3	61	0.61	11.92	19		
	90-150										
4790	0-45	29	16	55	0.5	55	0.22	4.93	9	A121	3a
	45-90	28	10	62	2.2	63	1.05	9.67	16		
	90-150										
4791	0-45	26	14	60	0.6	55	0.22	4.10	7	A121	2
	45-90	24	11	65	3.8	66	1.55	6.66	10		
	90-150				4.6	62					
4792	0-45	28	13	59	0.5	55	0.17	3.03	5	A121	2
	45-90	28	10	62	1.2	61	0.45	5.85	9		
	90-150				5.2	63					
4793	0-45	28	14	58	0.4	52	0.15	3.61	6	A111	2
	45-90	29	11	60	3.8	60	1.56	7.91	13		
	90-150										
4794	0-45	28	13	59	2.9	57	1.24	10.04	17	A112	4a
	45-90	28	15	57	0.4	48	0.11	5.60	10		
	90-150										
4795	0-45	30	13	57	0.4	48	0.12	2.39	4	A111	2
	45-90	28	13	59	2.5	60	1.10	6.00	10		
	90-150				3.1	60					
4796	0-45	29	14	57	0.4	50	0.12	2.39	4	A111	2
	45-90	26	15	59	1.4	60	0.60	6.78	11		
	90-150				4.5	64					
4797	0-45	29	12	59	0.5	54	0.17	2.89	5	A121	2
	45-90	29	12	59	0.7	56	0.25	6.98	12		
	90-150										
4798	0-45	31	15	54	0.5	50	0.14	3.76	7	A121	2
	45-90	26	15	59	4.1	64	1.94	8.08	14		
	90-150										
4799	0-45	28	13	59	0.4	48	0.11	4.63	8	A121	2
	45-90	26	10	64	1.8	62	0.89	8.71	14		
	90-150				3.9	61					
4800	0-45	31	12	57	0.4	50	0.13	5.58	10	A121	2
	45-90	34	7	59	1.0	62	0.38	8.80	15		
	90-150				5.6	64					

Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class	Land Class
		Sand 2.0- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay 0.002 mm.							
4801	0-45	30	13	57	0.5	61	0.14	1.57	3	A121	2
	45-90	25	13	62	0.8	61	0.33	5.24	8		
	90-150										
4802	0-45	31	15	54	0.4	48	0.12	2.66	5	A121	2
	45-90	32	9	59	0.8	56	0.32	5.52	9		
	90-150				6.3	61					
4803	0-45	30	11	59	1.2	60	0.50	4.92	8	A121	2
	45-90	32	9	59	1.2	58	0.49	7.30	12		
	90-150										
4804	0-45	32	9	59	0.4	48	0.10	3.52	6	A121	2
	45-90	32	9	59	0.4	53	0.12	6.15	11		
	90-150				7.4	64					
4805	0-45	37	11	52	1.0	53	0.30	2.48	5	A121	2
	45-90	32	9	59	0.8	59	0.34	6.62	11		
	90-150										
4806	0-45	32	11	57	0.4	59	0.14	1.81	3	A121	2
	45-90	27	9	64	1.3	69	0.66	6.44	10		
	90-150				5.2	63					
4807	0-45	37	10	53	0.4	48	0.12	3.22	6	A121	2
	45-90	35	6	59	0.3	48	0.09	6.45	11		
	90-150				6.0	62					
4808	0-45	34	13	53	0.3	48	0.09	1.86	4	A121	2
	45-90	36	7	57	0.3	48	0.09	3.11	6		
	90-150										
4809	0-45	37	11	52	0.8	55	0.29	3.20	6	A121	2
	45-90	35	11	54	1.4	57	0.48	5.96	11		
	90-150										
4810	0-45	34	12	54	0.4	48	0.13	2.93	5	A121	2
	45-90	35	8	57	4.0	62	1.70	6.51	11		
	90-150				4.5	64					
4811	0-45	31	10	59	0.6	51	0.17	5.40	9	A121	2
	45-90	29	7	64	2.4	63	1.15	9.30	15		
	90-150				6.9	66					
4812	0-45	29	12	59	0.6	48	0.16	6.11	10	A121	3a
	45-90	29	7	64	3.8	63	1.69	10.69	17		
	90-150										
4813	0-45	29	17	54	0.5	51	0.17	4.57	8	A121	3a
	45-90	26	13	61	2.1	67	0.84	9.18	15		
	90-150										
4814	0-45	30	13	57	0.6	51	0.17	5.67	10	A121	3a
	45-90	28	14	58	3.4	64	1.39	13.78	24		
	90-150				5.6	65					

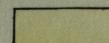
Site No.	Depth (cm.)	Mechanical Analysis			E.C. mmhos/cm at 25°C.	Sat. %	Sol. Na Meq 100 g.	Exch. Na Meq 100 g.	E.S.P.	Soil Class	Land Class
		Sand 2.0-0.02 mm.	Silt 0.02-0.002 mm.	Clay 0.002 mm.							
4843	0-45	42	14	44	0.7	48	0.14	1.11	3	A121	31
	45-90	37	13	50	0.8	51	0.37	4.37	18		
	90-150										
4844	0-45	49	9	42	0.3	42	0.08	1.46	3	A121	31
	45-90	42	11	47	0.4	48	0.10	1.29	13		
	90-150				3.4	58					
4845	0-45	31	10	59	0.4	48	0.13	4.19	17	A121	2
	45-90	32	11	57	1.5	56	0.64	7.15	13		
	90-150				6.5	55					
4846	0-45	27	11	62	0.5	51	0.20	3.70	6	A121	2
	45-90	30	11	59	3.1	59	1.43	7.48	13		
	90-150										
4847	0-45	32	11	57	2.3	55	0.97	7.24	13	A121	2
	45-90	32	13	55	0.6	50	0.23	4.51	18		
	90-150										
4848	0-45	27	16	57	0.8	50	0.28	5.43	10	A121	3a
	45-90	28	15	57	1.9	60	0.92	10.07	18		
	90-150				5.2	67					
4849	0-45	28	15	57	0.5	51	0.22	7.01	12	A121	3a
	45-90	32	11	57	2.5	62	1.32	10.09	18		
	90-150										
4850	0-45	47	15	38	0.4	41	0.10	3.10	8	A121	3a1
	45-90	39	13	48	2.0	51	0.85	8.75	18		
	90-150										
4851	0-45	41	11	48	0.4	42	0.15	3.88	9	A121	31
	45-90	47	7	46	0.5	43	0.16	5.82	13		
	90-150										
4852	0-45	49	11	40	0.5	37	0.15	2.91	7	A121	31
	45-90	47	8	45	1.0	44	0.33	6.21	13		
	90-150				6.8	57					
4853	0-45	34	11	55	0.6	48	0.19	2.87	5	A121	2
	45-90	31	11	58	4.8	43	1.46	7.60	13		
	90-150										
4854	0-45	34	12	54	0.5	46	0.18	5.12	9	A121	3a
	45-90	33	11	56	0.8	53	0.30	8.88	16		
	90-150										
4855	0-45	56	3	41	0.4	42	0.13	2.65	6	C121	31
	45-90	56	3	41	0.6	33	0.17	6.10	15		
	90-150										
4856	0-45	49	7	44	0.4	35	0.11	4.48	10	C121	3a1
	45-90	49	5	46	0.6	42	0.16	7.63	16		
	90-150				5.8	59					

LEGEND FOR SOILS MAPS

AFTER U.S.D.A. 1964 SYSTEM THE SEVENTH APPROXIMATION

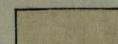
VERTISOLS (CRACKING CLAYS)

A 111 Typic Grumusterts with Exchangeable Sodium Percentages < 15
A 112 Typic Grumusterts with Exchangeable Sodium Percentages > 15
A 122 Entic Grumusterts with Exchangeable Sodium Percentages > 15



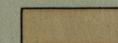
AQUERTS (Colour chromas of 1.5 or less throughout the upper 45 cm.)

B 111 Typic Grumaquerts with Exchangeable Sodium Percentages < 15
B 121 Entic Grumaquerts with Exchangeable Sodium Percentages < 15



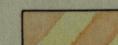
ENTISOLS (SOILS WITHOUT WELL DEFINED GENETIC HORIZONS)

C 121 Grumustertic Haplothents with clay percentages > 30 and Exchangeable Sodium Percentages < 15
C 122 Grumustertic Haplothents with clay percentages > 30 and Exchangeable Sodium Percentages > 15



COMPLEX

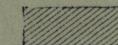
A 121 + C 121 Complex of Entic (E.S.P. < 15) and Grumustertic (E.S.P. < 15; clay < 30%) Haplothent.



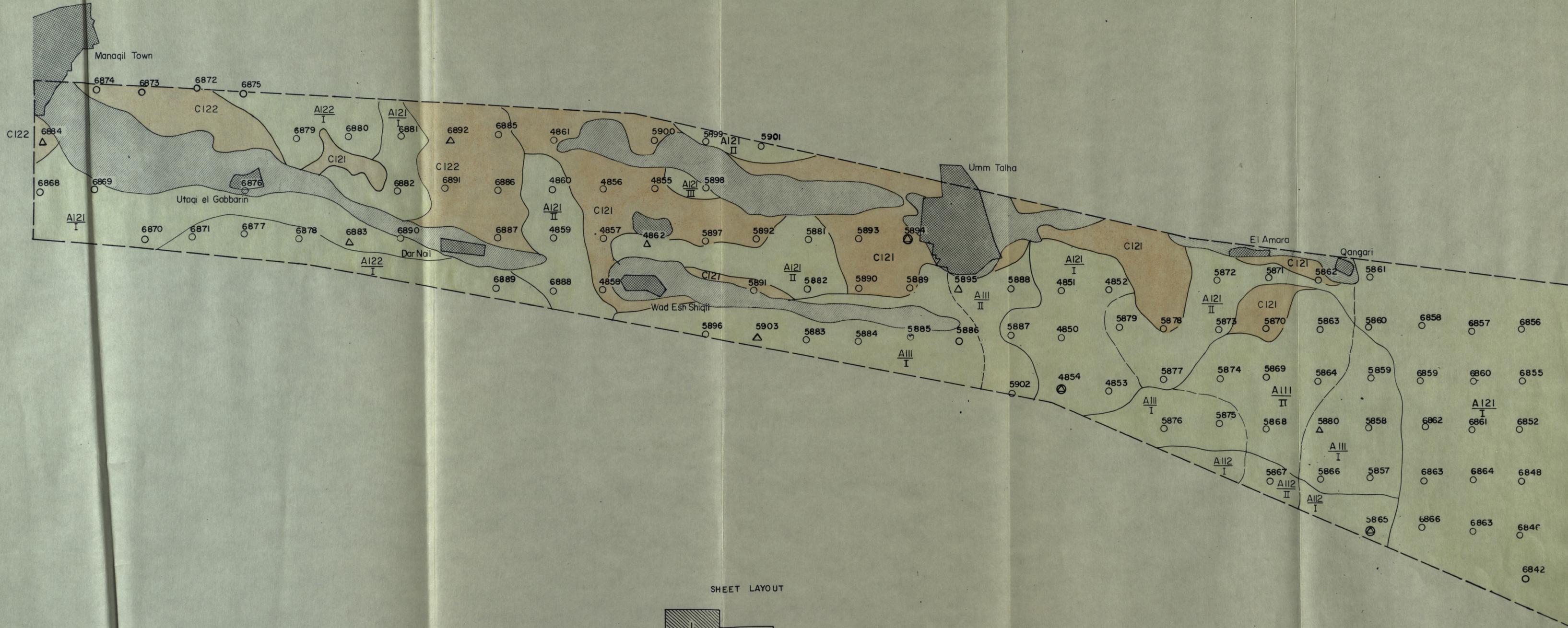
SURFACE CRACKING PHASES

I Good
II Moderate
III Poor
IV No Cracking

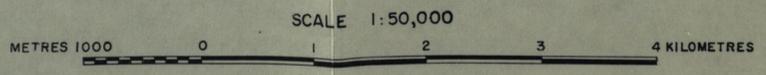
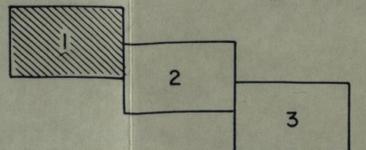
Undifferentiated Entisols.



SOILS MAP



SHEET LAYOUT

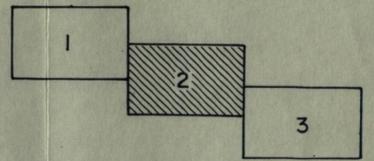


COMPILATION NOTE
 Soil survey carried out
 on behalf of the Consulting Engineers
 by
 HUNTING TECHNICAL SERVICES LTD.,
 4 Albemarle Street London, W1

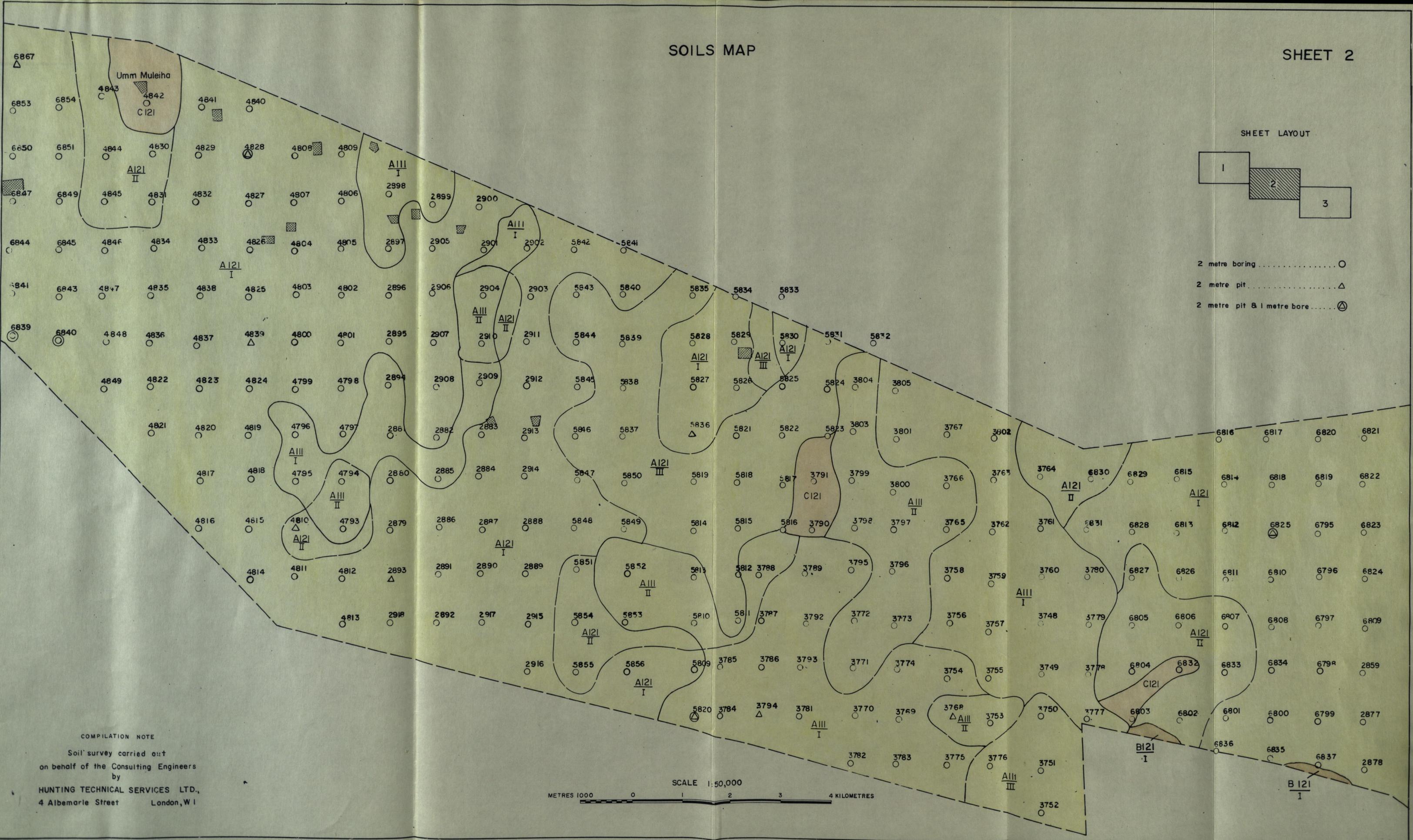
2 metre boring ○
 2 metre pit △
 2 metre pit & 1 metre bore ⊙

SOILS MAP

SHEET LAYOUT



- 2 metre boring ○
- 2 metre pit △
- 2 metre pit & 1 metre bore ⊕

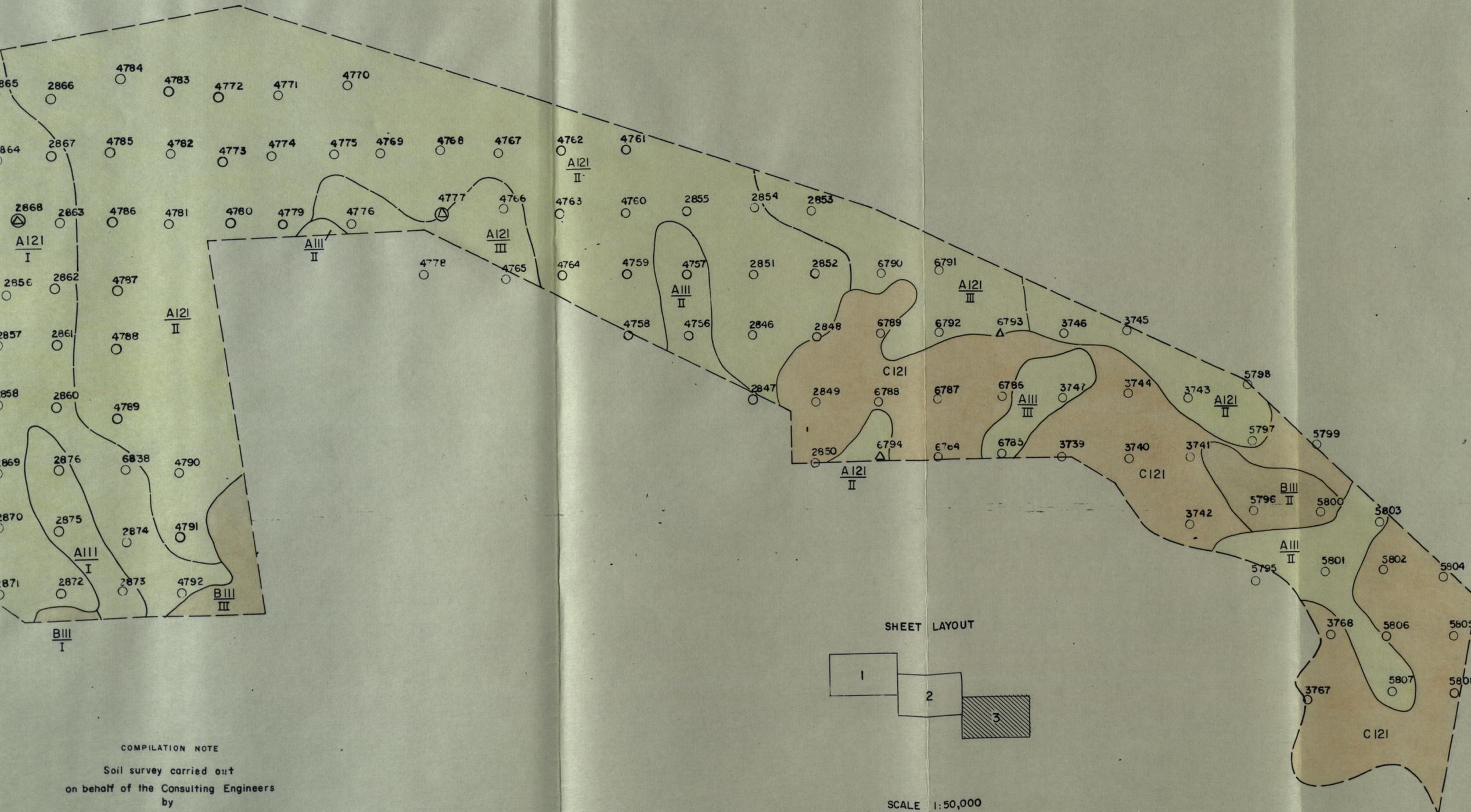


COMPILATION NOTE

Soil survey carried out
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HUNTING TECHNICAL SERVICES LTD.
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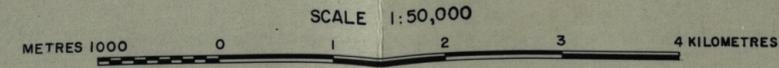
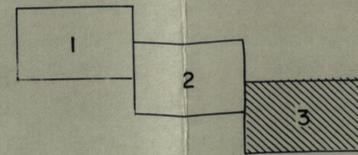
SCALE 1:50,000

METRES 1000 0 1 2 3 4 KILOMETRES



COMPILATION NOTE
 Soil survey carried out
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 by
HUNTING TECHNICAL SERVICES LTD.,
 4 Albemarle Street London, W1

SHEET LAYOUT



- 2 metre boring ○
- 2 metre pit △
- 2 metre pit & 1 metre bore ⊙

LEGEND FOR LAND CLASSIFICATION MAPS

Land classes in accordance with U.S. Bureau of Reclamation Standards with criteria adjusted for Sudan conitions

ARABLE

Class 2 - Good lands	}	-----	}	2
Class 3 - Moderate lands				3

LIMITED ARABLE

Class 4 - Special use lands	-----	4
-----------------------------	-------	---

NON ARABLE

Class 6 - Unsuitable lands	-----	6
----------------------------	-------	---

Land sub-classes are shown on the map in areas of class 2,3,4 and 6 lands by the following subscripts :

Land downgraded due to excess sandiness	-----	↓
Land downgraded due to alkalinity	-----	a
Land downgraded due to salinity	-----	s
Unsuitable topography	-----	†
Land downgraded due to poor structure	-----	

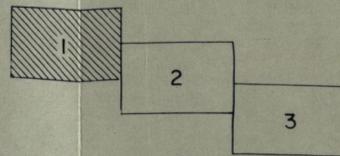
Some sites have been downgraded to class 6a due to high E.S.P values (see report chapter 5) in lower horizon (45-90cm) Where re-classification from further investigations is a possibility the present classification of the upper horizon alone is indicated after the overall classification. e.g. 6a/2 ©

LAND CLASSIFICATION MAP

SHEET 1



SHEET LAYOUT



SCALE 1:50,000

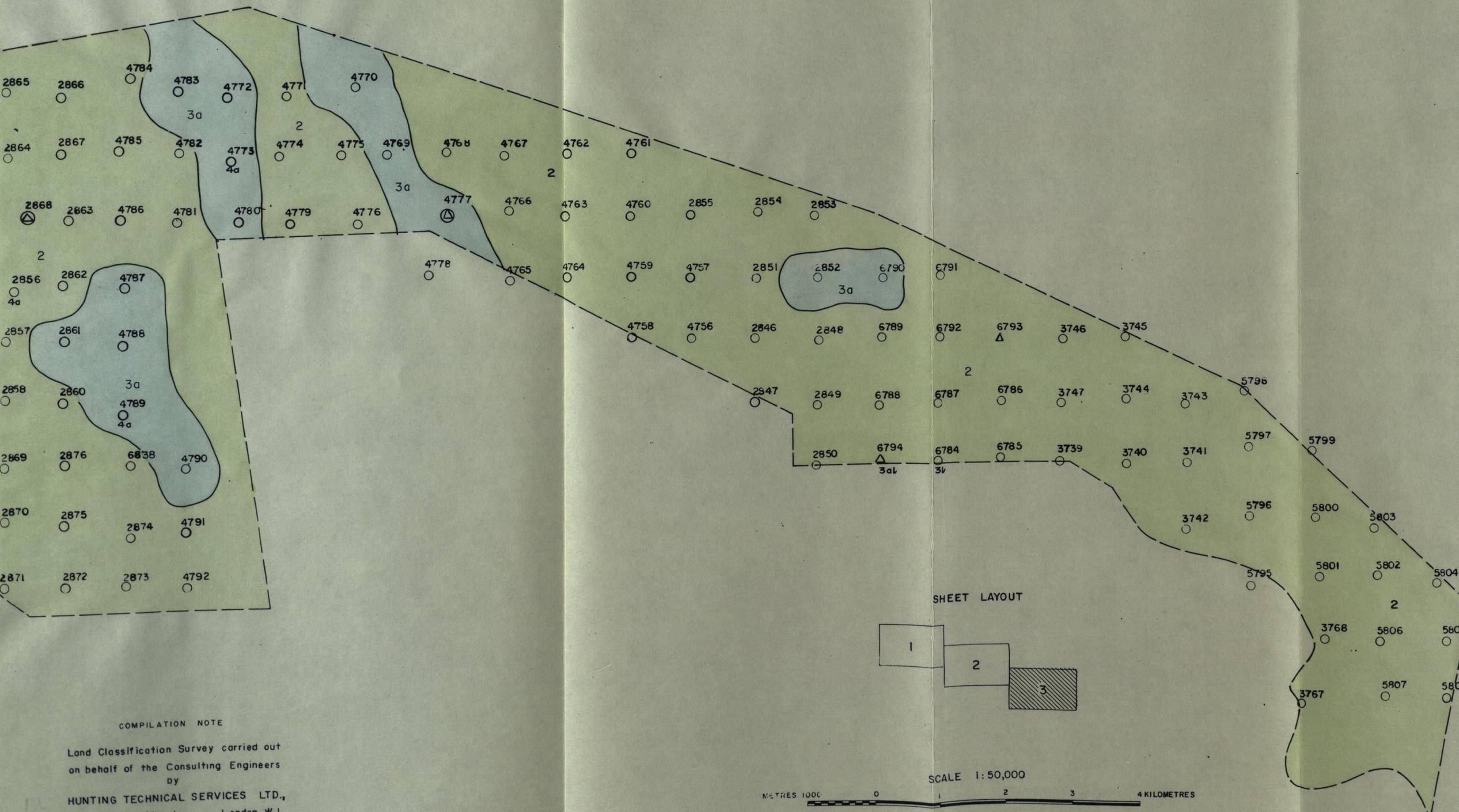
METRES 1000 0 1 2 3 4 KILOMETRES

COMPILATION NOTE

Land Classification Survey carried out on behalf of the Consulting Engineers by HUNTING TECHNICAL SERVICES LTD., 4 Albemarle Street London, W.1.

- 2 metre boring ○
- 2 metre pit △
- 2 metre pit & 1 metre bore ⊕

LAND CLASSIFICATION MAP



COMPILATION NOTE

Land Classification Survey carried out on behalf of the Consulting Engineers by HUNTING TECHNICAL SERVICES LTD., 4 Albemarle Street London, W.1.

- 2 metre boring ○
- 2 metre pit △
- 2 metre pit & 1 metre bore ⊗