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ROSEIRES SOIL SURVEY

REPORT No. 12

BLUE NILE
EAST BANK ROSEIRES TO SENNAR
WEST BANK ABU HUGAR TO SENNAR
SEMI-DETAILED
SOIL SURVEY AND LAND CLASSIFICATION

VOLUME III

WEST BANK ABU HUGAR TO SENNAR
THE REPORT

HUNTING TECHNICAL SERVICES LTD.
4 ALBEMARLE STREET
LONDON, W.1

SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS
LION HOUSE
RED LION STREET
LONDON .. W.C.1

JANUARY 1966

THE REPUBLIC OF THE SUDAN

MINISTRY OF AGRICULTURE

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ROSEIRES SOIL SURVEY

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REPORT No. 12.

Volume III

West Bank Abu Hugar to Sennar
Semi-detailed Soil Survey and
Land Classification

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ROSEIRES SOIL SURVEY.

Report NO 12.

VOLUME II.

Sir M. MacDonald & Partners
CONSULTING ENGINEERS

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30th January, 1966.

His Excellency the Minister of Agriculture,
Ministry of Agriculture,
Khartoum,
REPUBLIC OF THE SUDAN.

Your Excellency,

ROSEIRES SOIL SURVEY REPORT NO.12(AREAS 2A & 2B)
BLUE NILE EAST BANK ROSEIRES TO SENNAR
WEST BANK ABU HUGAR TO SENNAR

We have pleasure in submitting our Report No. 12 for the Roseires Soil Survey Project, 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 semi-detailed soil survey and land classification report, accompanied by an album of maps, is in three volumes :-

Volume I East Bank Roseires to Sennar - The Report
Volume II East Bank Roseires to Sennar - Appendix III
Volume III West Bank Abu Hugar to Sennar - The Report

These areas, Roseires to Sennar and Abu Hugar to Sennar, are referred to as Areas 2a and 2b respectively in the Contract and for convenience are reported upon separately below :-

a) East Bank Roseires to Sennar (Area 2a)

The semi-detailed survey of this area shows that the soils are eminently suitable for development as an irrigation project. The clay soils are non-saline and of moderate alkalinity. Because they lie on a slightly dissected old flood plain these lands include local basins with occluded drainage which suffer from surface flooding during the rainy season but the area affected does not exceed 25 per cent of the lands examined. In the southern sector of the project area the vegetative cover increases in density with the increasing rainfall but, because tree-clearing trials have shown that the densest vegetation can be cleared at reasonable cost, land clearing operations have not been considered limiting on any of the project lands. The overall pattern shows that two thirds of the area examined can be classed as arable and limited arable lands. This is a very satisfactory ratio although not quite reaching the high standard of excellence of the Rahad right bank lands.

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The economic suitability of the crops to be grown in the project area was the subject of a separate study carried out under the terms of the Roseires Pre-investment Survey by the Agreement signed on 25/10/1964. Of the crops climatically adapted to the project area the Consultants consider that the most promising are medium staple cotton (variety Acala 4-42), groundnuts (varieties Ashford and Barberton) and dura to be grown in rotation as follows :-

First Year	groundnuts
Second Year	cotton
Third Year	groundnuts
Fourth Year	cotton
Fifth Year	fallow
Sixth Year	dura

In addition, the Consultants suggest that in the extreme south of the project area an alternative cropping pattern could be based on sugar and rice cultivation in association with a beef fattening enterprise utilising by-products such as molasses and ricestraw as well as grazing on non-arable lands.

We must make it clear that the engineering proposals for Area 2a put forward in this report were the result of fieldwork carried out in 1963/4. These proposals have now been superseded by the Roseires Project reported upon in the Roseires Pre-investment Survey, Report No. 3, prepared for the Ministry of Finance and Economics in late 1965.

b) West Bank Abu Hugar to Sennar (Area 2b)

The Blue Nile west bank between Abu Hugar and Sennar has been partially developed by pump scheme projects growing long staple cotton in rotation with dura and a little lubia. The 37 existing private pump schemes and the Government Dairy Scheme at Umm Benein together occupy about half the total land between the river and the western boundary of the project area so that the lands selected for semi-detailed soil survey are mostly in separate blocks at some distance from the river.

The semi-detailed soil survey shows that, after excluding alkali lands, about 56 per cent of the 60,000 feddans of land examined is suitable for irrigation development. It is recommended that 7,000 feddans of this land should be developed as extensions to existing pump schemes and that 25,000 feddans should be incorporated into 4 new pump schemes.

The engineering surveys show that from a pump site near Abu Hugar some 37,000 feddans of additional land to the west of the project area would be commanded by a static pump lift of 19.5 metres. Further surveys show that from the Maiurno West pump site some 40,000 feddans of additional undeveloped land north of Sennar could be commanded by a static pump lift of about 14 metres. Our preliminary studies indicate that, if these additional lands were shown to be arable, their development with the project lands would enhance the economic feasibility of development on the Blue Nile west bank.

The economic suitability of the crops to be grown in the project area was the subject of a separate study carried out under the terms of the Rosaires Pre-Investment Survey by the Agreement signed on 25/10/1964. Of the crops climatically adapted to the project area the Consultants consider that the most promising are medium staple cotton (variety Acala 4-42), groundnuts (varieties Ashford and Barberton) and dura to be grown in rotation as follows :-

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b) West Bank Abu Nuger to Sennar (Area 2b)

The Blue Nile west bank between Abu Nuger and Sennar has been partially developed by pump schemes projects growing long staple cotton in rotation with dura and a little lubia. The 37 existing private pump schemes and the Government Dairy Scheme at Umm Benein together occupy about half the total land between the river and the western boundary of the project area so that the lands selected for semi-detailed soil survey are mostly in separate blocks at some distance from the river.

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The engineering surveys show that from a pump site near Abu Nuger some 37,000 feddans of additional land to the west of the project area would be commanded by a static pump lift of 19.5 metres. Further surveys show that from the Maiurno West pump site some 40,000 feddans of additional undeveloped land north of Sennar could be commanded by a static pump lift of about 14 metres. Our preliminary studies indicate that, if these additional lands were shown to be arable, their development with the project lands would enhance the economic feasibility of development on the Blue Nile west bank.

Because of the existing extensive irrigation development on the Blue Nile west bank we recommend that the project lands should be developed to the same type of long staple cotton rotation as that used on the private pump schemes. We suggest, however, that the rotation should be intensified by the inclusion of groundnuts as a second cash crop.

The interpretation of land classes as agreed with the World Bank, is that Classes 2, 3a and 4a are all suitable for a long staple cotton rotation of the Managil type. These land classes have self-mulching soils of high clay content which Finck and Ochtman show to be capable of producing high cotton yields; at the same time the level of exchangeable sodium does not have a depressive effect on the yields of long staple cotton which is one of the more alkali-tolerant of the arable crops. Class 3l and 4l lands may be used for forage crops, truck crops, forestry plantations or village sites.

The necessary soil studies were undertaken on our behalf by Messrs. Hunting Technical Services Limited of London who retained Professor E.W. Russell, C.M.G., of the University of Reading as their Soil Consultant. Dr. Robert Smith, Scientific Consultant, has reviewed the Report.

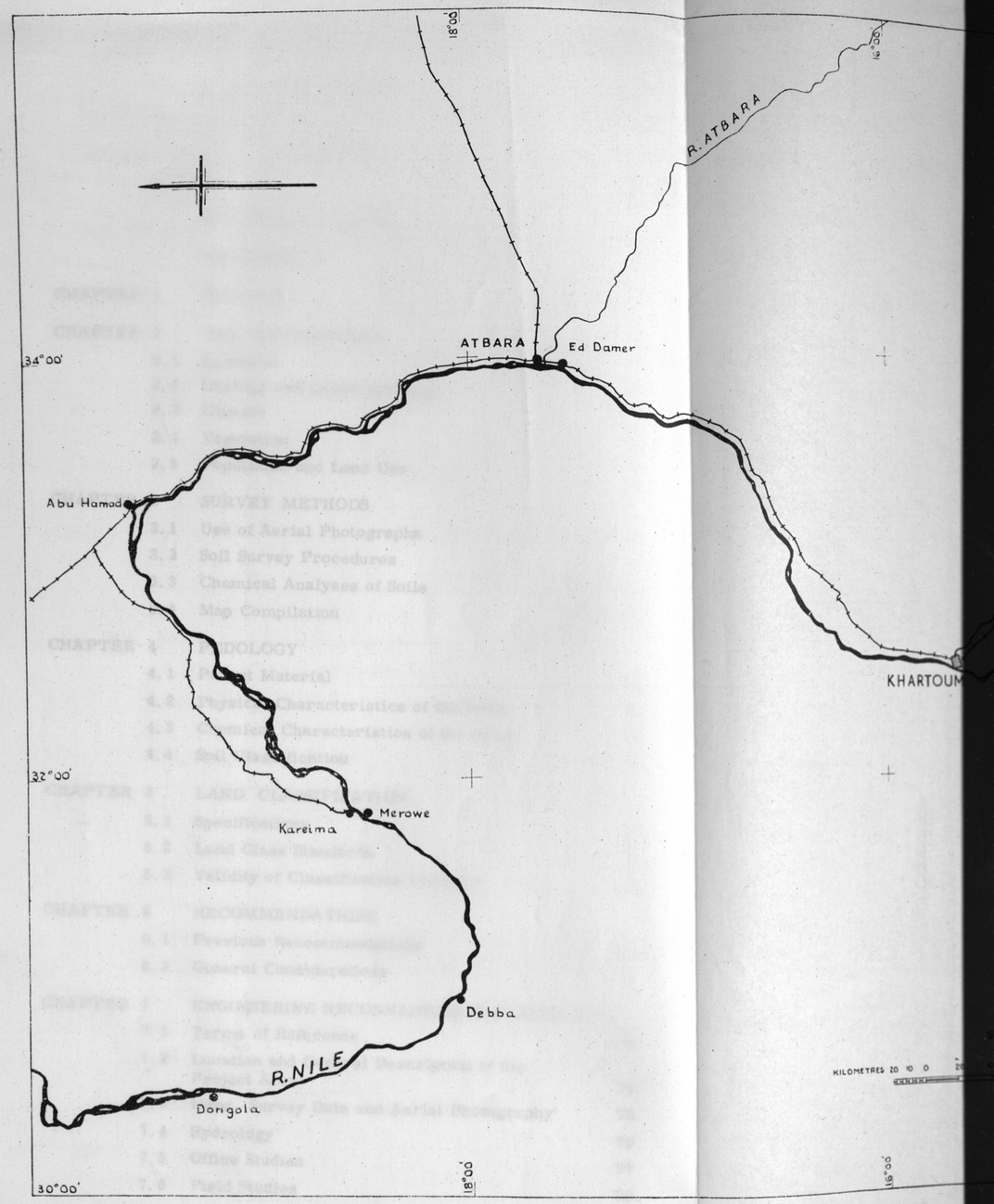
We should like to record our appreciation for the assistance received during the course of our survey from the officials of many Ministries of the Sudan Government, with special reference to the Ministry of Agriculture, the Ministry of Irrigation and Hydro-Electric Power and the Sudan Survey Department.

We are, Excellency,

Your obedient servants,

I.S. Gilmathews

SIR M. MACDONALD & PARTNERS.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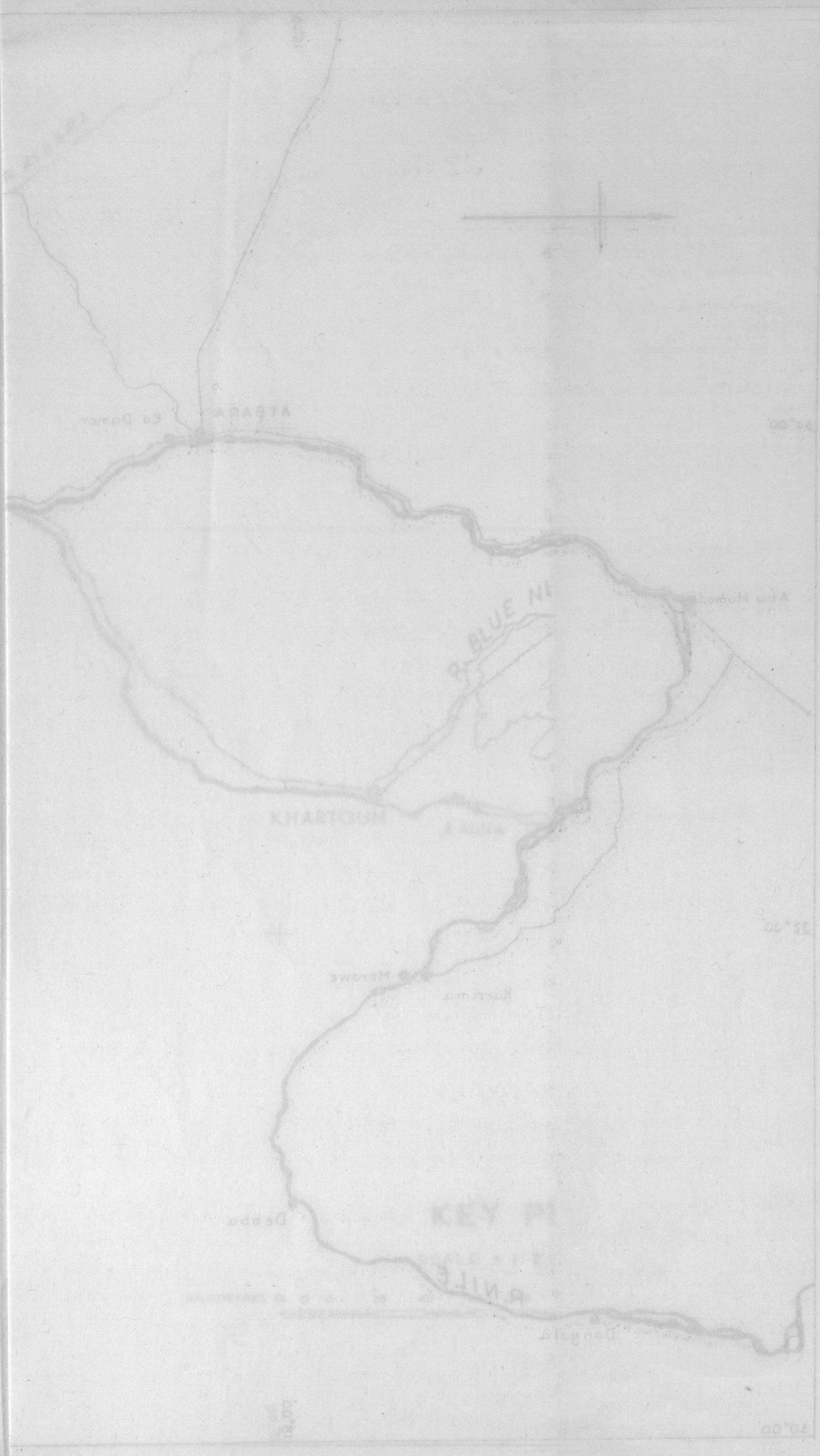
BLUE NILE
KHARTOUM

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Sudan Government:

The many members of both administrative and technical staff in the Ministry of Agriculture, including the Director of Agriculture and his staff in Khartoum, Singa and Wad Medani. Also the members of the Ministry of Animal Resources in Singa and 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.

University of Khartoum:

Professor Whiteman, Head of the Department of Geology and Mr. L. Berry of the Geography Department for their help. Miss E.A. Bari, Department of Agriculture, for helping to identify our plant specimens.

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Chapter 2.5 Population and Land Use

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ROSEIRES SOIL SURVEY

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Report No. 3 — The Nile from Kareima to the Third Cataract (Area 4A). Soils and Engineering Reconnaissance.

Report No. 4 — Rahad and Dinder Area. (Areas 3B and 3C). Semi-Detailed Soil Survey and Land Classification.

1963/64 Period

Report No. 4A. — Rahad East Bank Extension (Area 3C Extension) Semi-Detailed Soil Survey and Land Classification.

Report No. 5 — The Nile from Khartoum to Kareima, (Area 4B). Soils and Engineering Reconnaissance.

Report No. 6 — The White Nile East Bank, Rabak to Khartoum (Area 5A) Soils and Engineering Reconnaissance.

Report No. 7 — Blue Nile East Bank, Guneid to Khartoum (Area 3D). Semi-Detailed Soil Survey and Land Classification of Selected Areas

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Report No. 8 — The Nile from Kareima to the Third Cataract (Area 4 North). Semi-detailed Soil Survey and Land Classification of Selected Areas.

Report No. 9 — Dinder - Blue Nile Gezira, Sennar to Confluence (Area 3A and Part Area 2A). Semi-Detailed Soil Survey and Land Classification.

1964-65 Period

Report No. 10 — Dinder to Rahad Exploratory Soil Traverses and Extensions to Rahad Project Exploratory Engineering Surveys.

Report No. 11 — The White Nile East Bank, Melut to Rabak (Area 5B). Exploratory Soils and Engineering Survey.

Report No. 8 The Nile from Kareima to the Third Cataract (Area 4 North). Semi-detailed Soil Survey and Land Classification of Selected Areas.

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Report No. 10 Dinder to Rahad Exploratory Soil Traverses and Extensions to Rahad Project Exploratory Engineering Surveys.

Report No. 11 The White Nile East Bank, Melut to Rabak (Area 5E). Exploratory Soils and Engineering Survey.

GLOSSARY

Ardeb - A volume measure for agricultural produce equalling 198 litres.

1 ardeb of dura weighs 336 rotls
1 " of dukhn " 360 "
1 " of simsim" 264 "

Bamia - Lady's fingers or okra, Hibiscus esculentus Linn.

Dukhn - The food grain, Pennisetum typhoideum (Burm.) Stapf. and Hubbard.

Dura - The great millet, Sorghum vulgare, Pers.

Feddan - An area of land approximately equal to one acre:

1 feddan = 1.038 acres = 0.420 hectares.

Haboob - A strong wind usually accompanied by thick dust.

Hafir - A pool usually made by man for the storage of water.

Heglig - A ubiquitous tree with straight green spines and edible fruit, Balanites aegyptiaca Del.

Kankar - Dark coloured, hard, rounded to semi-rounded calcium carbonate concretions.

Kantar - A unit of weight; normally 1 kantar = 100 rotls = 99.05 lb.
In the Gezira 1 kantar of cotton means 315 rotls or 312.01 lb. unginned cotton.

Kerrib - Gullied land resulting from steep run-off in deep homogeneous clay plains. It consists of eroded water channels cutting from the plain into the valley.

Kitr - A common shrub or small tree with well developed thorns and highly scented blossoms, Acacia mellifera Benth.

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Limoon	-	The lime, Citrus aurantifolia (Christm.) Swingle.
Lubia	-	The bean, Dolichos lablab Linn.
Marisa	-	Beer made from various grains but chiefly dura; a valuable protective food.
Qoz	-	A sand hill or sand dune.
Piastre	-	P.T. for short, a unit of money, 100 P.T. = £1,000 Sudanese.
Rotl	-	A measure of weight approximately one pound: 112 lb = 113 rotls. 100 rotls - 99.05 lb. = 44.94 kg.
Seluka	-	A digging stick with foot rest; also applied to the land cultivated by the seluka.
Simsim	-	The valuable oil seed crop, Sesamum orientale Linn.
Terus	-	A small earth bund built with hand tools for impounding rain water for watering rain grown dura. Commonly used in Blue Nile, Khartoum and Northern Provinces.

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CHAPTER 1

SUMMARY

1.1 The semi-detailed soil survey and land classification of Area 2B (Blue Nile West Bank) covers an area of some 60,000 feddans.

1.2 The project area is divided into nine separate sub-areas on the west bank of the Blue Nile between Sennar in the north and Abu Hugar in the south.

1.3 The climate is hot, tropical and semi-arid, with a rainy season from May to mid October followed by a hot dry winter with dominant north winds. The average annual rainfall is 588 mm at Singa in the middle of the area and 679 at Tozi in the south. Sennar with 460 mm is just beyond the northernmost point of the area.

1.4 The vegetation of the area is part of a transition zone between the Acacia mellifera thornland on cracking clays and the Acacia seyal - Balanites aegyptiaca savannah with grassland. The large population in the town of Singa has considerably modified the natural vegetation and much of the area is under cultivation or semi-permanent fallow.

In addition to this the movement of cattle to water at the Blue Nile has caused heavy overgrazing.

The meander channels have been least altered and carry a vegetation with a higher moisture requirement than the surrounding plains. Acacia nilotica often forms open stands in such areas.

1.5 The population of the overall project area has been estimated at 35,800 of which 11,300 is contributed by the town of Singa. Settlement has developed along the river and the Khor Umm Ish which runs parallel to it, but the availability of water from the pump schemes has facilitated development away from these two traditional settlement zones.

Apart from the pump schemes producing cotton and sorghum, the other main land uses of the area are rainfed cultivation and livestock grazing. The riverain cultivation strip producing vegetables, maize, lubia and fruit is only on the border of the area investigated.

CHAPTER 1

SUMMARY

1.1 The semi-detailed soil survey and land classification of Area 2B (Blue Nile West Bank) covers an area of some 69,000 feddans.

1.2 The project area is divided into nine separate sub-areas on the west bank of the Blue Nile between Sennar in the north and Abu Hugar in the south.

1.3 The climate is hot, tropical and semi-arid, with a rainy season from May to mid October followed by a hot dry winter with dominant north winds. The average annual rainfall is 538 mm at Singa in the middle of the area and 679 at Tosi in the south. Sennar with 460 mm is just beyond the northernmost point of the area.

1.4 The vegetation of the area is part of a transition zone between the Acacia mellifera thornland on cracking clays and the Acacia seyal - Balanites aegyptiaca savannah with grassland. The large population in the town of Singa has considerably modified the natural vegetation and much of the area is under cultivation or semi-permanent fallow.

In addition to this the movement of cattle to water at the Blue Nile has caused heavy overgrazing.

The meander channels have been least altered and carry a vegetation with a higher moisture requirement than the surrounding plains. Acacia nilotica often forms open stands in such areas.

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Apart from the pump schemes producing cotton and sorghum, the other main land uses of the area are rainfed cultivation and livestock grazing. The riverain cultivation strip producing vegetables, maize, lubia and fruit is only on the border of the area investigated.

Rainland cultivation is mainly confined to sorghum with some millet and sesame, but a few fields of groundnuts were also observed.

Grazing is not confined to the locally owned cattle as there is a considerable amount of nomadic movement through the area. Sections of both the Kenana and Rufa'a el Hoi tribes pass through on their annual migrations.

1.6 The survey was carried out according to the agreed specifications with a minimum density of one site per 250 feddans. The actual density achieved in the field was much closer than this as the survey beacons were used as intervening traverse lines thus giving an approximate grid of 0.9 km and not 1.0 km. Over five per cent of the sites were 2 metre pits with an additional bore down to 3 metres.

1.7 Soil classification is based on the U.S. Department of Agriculture System the Seventh Approximation (1960). Virtually all the soils in the area belong to the order of Vertisols roughly divided between the two soil orders of Usterts and Aquerts. These are composed of the four Grum' or Maz' great groups and the soils have been mapped at sub-group level, e.g. Orthic Grumustert.

Only one great group within the order of Entisols was represented; this was the Orthustent sub-group which was divided into four sub-groups and mapped as such.

1.8 The specifications used in the land classification are based on standards evolved by the U.S.D.I. Bureau of Reclamation with criteria modified for Sudan conditions. The most frequently limiting criteria was that of alkali level and most soils downgraded to Class 6 had high exchangeable sodium levels.

1.9 The project area was mapped into land classes as follows:-

Land Class	Area in feddans
2	12,660
3	12,380
4	6,530
6	26,200
2/3a	2,000
	59 770

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Land Class	Area in feddans
2	12,660
3	12,380
4	6,530
6	26,200
2\3s	2,000

1.10 Because the project area as defined lies wholly below the 20 metre isopotamon, the semi-detailed engineering survey was concerned with the demarcation of topographically suitable areas for soil survey. The 37 existing private pump schemes and the Government Dairy Scheme at Umm Benein together occupy about half the total land between the river and the western boundary of the project area so that the lands selected for semi-detailed soil survey are mostly in separate blocks at some distance from the river. The engineering survey located six possible pump sites on the river bank and surveyed short lengths of pump canal headreach to serve each of eight possible irrigated blocks of land totalling altogether about 60,000 feddans. Of this total 46,500 feddans were considered for new pump schemes, 1,300 feddans as extensions to existing schemes and a further 12,900 feddans could be developed in either manner. These surveys, together with the locations of existing irrigation projects, were tied in with the grid of survey beacons which give the geographical co-ordinates at one minute intervals.

1.11 The possible new pump scheme projects are as follows :-

The Tabit site near Abu Hugar, which requires a static lift of 19.5 metres to command a gross area of 7,000 feddans in the project area, also commands an additional 30,000 feddans in the adjoining Kenana area. Because of a severe alkalinity problem about 75% of the area surveyed is non-arable and the remaining small areas of arable land, totalling about 1,500 feddans, can best be developed as extensions to the existing Sieru and Layouna pump schemes.

The El Tewfigia site requires a static lift of 19.0 metres to command a block of 2,300 feddans of mostly arable land. These lands could be developed either as a new pump scheme or as extensions to the existing pump schemes of El Tewfigia and Sieru using secondary

1.10 Because the project area as defined lies wholly below the 20 metre isopotamon, the semi-detailed engineering survey was concerned with the demarcation of topographically suitable areas for soil survey. The 37 existing private pump schemes and the Government Dairy Scheme at Umm Benein together occupy about half the total land between the river and the western boundary of the project area so that the lands selected for semi-detailed soil survey are mostly in separate blocks at some distance from the river. The engineering survey located six possible pump sites on the river bank and surveyed short lengths of pump canal headreach to serve each of eight possible irrigated blocks of land totalling altogether about 80,000 feddans. Of this total 46,500 feddans were considered for new pump schemes, 1,390 feddans as extensions to existing schemes and a further 18,900 feddans could be developed in either manner. These surveys, together with the locations of existing irrigation projects, were tied in with the grid of survey beacons which give the geographical co-ordinates at one minute intervals.

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The Tabit site near Abu Hugar, which requires a static lift of 19.5 metres to command a gross area of 7,000 feddans in the project area, also commands an additional 30,000 feddans in the adjoining Kenana area. Because of a severe alkalinity problem about 75% of the area surveyed is non-arable and the remaining small areas of arable land, totalling about 1,500 feddans, can best be developed as extensions to the existing Siera and Layouna pump schemes.

The El Tewfigia site requires a static lift of 19.0 metres to command a block of 2,300 feddans of mostly arable land. These lands could be developed either as a new pump scheme or as extensions to the existing pump schemes of El Tewfigia and Siera using secondary

low-lift pump stations.

The Umm Marih site with a static lift of 19.0 metres could command a gross area of 4,000 feddans of mostly arable land. Because of difficulties at this site, however, it is recommended that the arable lands be developed from the secondary pump station of the existing Umm Marih scheme by low-lift pump.

The Singa site with a static lift of 16.5 metres commands a gross area of 37,000 feddans. There is here considerable variation in soil quality and a large area suffers from severe alkalinity particularly a block north east of the railway line, together with a strip west of the railway line between Kewkab and Umm Benein. There area, however, about 15,000 feddans of arable land forming a fairly compact block adjacent to the Khor Umm Ish which can be developed from the Singa pump site.

The Wad Rabaa and Wad Abati Extensions, totalling 1,300 feddans of arable lands can be developed as extensions to the existing Wad Rabaa and Wad Abati pump schemes.

The Abidin site with a static lift of 11.3 metres commands a gross area of 2,500 feddans of which about 1,500 feddans are arable.

The Maiurno West site with a static lift of 13.3 metres commands 3,800 feddans of arable land at Maiurno West and a further 2,800 feddans of arable land west of Sennar town. These lands are of uniformly high quality containing 66 per cent of Class 2 land. In addition this site commands an additional area of 40,000 feddans to the north of Sennar and, if shown to be arable after soil survey, the development of this area would reduce the overall cost of development of the project area lands at Maiurno West and Sennar.

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The Singa site with a static lift of 18.5 metres commands a gross area of 37,000 feddans. There is here considerable variation in soil quality and a large area suffers from severe alkalinity particularly a block north east of the railway line, together with a strip west of the railway line between Kewkab and Umm Benein. There are, however, about 15,000 feddans of arable land forming a fairly compact block adjacent to the Khor Umm lah which can be developed from the Singa pump site.

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CHAPTER 2

THE ENVIRONMENT

2.1 Location

Project area 2B, some 60,000 feddans in extent, is located along the west bank of the Blue Nile, in nine separate small areas extending from near Sennar in the north to Abu Hugar in the south.

2.2 Geology and Geomorphology

2.2.1 Solid Geology

Since virtually the whole of Area 2B is covered to a considerable depth by superficial alluvial deposits, the underlying rock plays little part as a soil parent material.

The deposits are underlain mainly by rock of the Umm Ruwaba series deposited in a small depression east and south of Sennar. Outside the limits of this depression, the Umm Ruwaba series is missing and the underlying rock is Basement Complex. There are no outcrops of the underlying rock within the area.

2.2.2 Geomorphology

Since deposition of the Nubian series, considered to have occurred mainly during the Mezosoic period, there has been gentle warping and uplift of Eastern Sudan. This uplift gave rise to the Red Sea Hills and the Abyssinian Plateau, the height of the latter being further increased by extensive volcanicity, producing a thick mantle of lava. This lava is the source material of much of the clay plains of central Sudan.

Associated downwarping of the original erosion plain occurred in Mid-Tertiary times and continued into the Pleistocene, giving rise to a north-south orientated hollow along which the Nile systems now run. At an early stage, depressions forming in this north-south hollow may have acted as local checks to the free flow of the Blue Nile until these had been infilled by deposition. It is not thought that the free flow of the Blue Nile to the north was ever completely interrupted.

CHAPTER 2

THE ENVIRONMENT

2.1 Location

Project area ZB, some 60,000 feddans in extent, is located along the west bank of the Blue Nile, in nine separate small areas extending from near Sennar in the north to Abu Hugar in the south.

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The deposits are underlain mainly by rock of the Umm Ruwaba series deposited in a small depression east and south of Sennar. Outside the limits of this depression, the Umm Ruwaba series is missing and the underlying rock is Basement Complex. There are no outcrops of the underlying rock within the area.

2.2.2 Geomorphology

Since deposition of the Nubian series, considered to have occurred mainly during the Mesozoic period, there has been gentle warping and uplift of Eastern Sudan. This uplift gave rise to the Red Sea Hills and the Abyssinian Plateau, the height of the latter being further increased by extensive volcanicity, producing a thick mantle of lava. This lava is the source material of much of the clay plains of central Sudan.

Associated downwarping of the original erosion plain occurred in Mid-Tertiary times and continued into the Pleistocene, giving rise to a north-south orientated hollow along which the Nile systems now run. At an early stage, depressions forming in this north-south hollow may have acted as local checks to the free flow of the Blue Nile until these had been infilled by deposition. It is not thought that the free flow of the Blue Nile to the north was ever completely interrupted.

With the cessation, or, at least, the slowing of the downwarping, aggradation of the river valley began, with possibly intervening periods of degradation.

The actual manner in which the superficial clay deposits were laid down has been a matter for considerable discussion. The prevailing idea is that, at least in the area under consideration, the clays are an alluvial deposit of the Blue Nile. It is considered that this deposition took place during annual flooding which may have lasted for around five months of every year in a humid and marshy environment. One of the reasons for holding the view that the flood receded annually, is the fact that large numbers of immature Cleopatra sub-fossil shells have been found, especially in the Gezira. This would tend to disprove the hypothesis that the clays were laid down in a permanent lake, at least as far as the surface three metres are concerned, this being the maximum depth examined in this survey.

The permanent lake theory (Ball 1939) postulates a large lake dammed up behind the Sabaloka Gorge and rising to the 400 metre contour. The lake is considered to have drained via the Sabaloka Gorge when aggradation of the valley floor had reached a possible outlet level over the gorge. This is considered to have occurred during Lower Sebilian times. However, the discovery of Chellean and Achenlean implements only a few metres above present Nile level at sites between Omdurman and Sabaloka would indicate that the gorge must have been cut earlier than this period and very much earlier than the proposed Lower Sebilian age (Arkell, 1948).

The clay deposit seems to consist of a succession of depositional layers or horizons. Within three metres of the surface (the maximum depth within which the soil survey examinations were carried out) it is possible that there are at least three, possibly four depositional layers. It has been fairly well established that water percolation seldom exceeds a depth of 90 cm and is often considerably less than this, and that there is very little active leaching, especially of clay. Therefore, under present conditions, it would seem that normal pedological processes proceed only very slowly and would, in any case, be confined to a shallow depth in the observed profile. This,

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coupled with the fact that the surface depositions are likely to be comparatively recent, would tend to indicate that the characteristics of the observed horizons within a depth of three metres are depositional rather than pedological. It has also been found that, in many of the sites examined, the clay percentage figures of the 0-45 cm and 45-90 cm depths show very marked differences, in many cases the figure for the 0-45 cm depth being considerably higher than that for the 45-90 cm depth. Since very marked structural differences also occur approximately at these depths, it is possible that even within the 0-90 cm depth, two depositional horizons occur.

Below the three metre depth, horizons are found which differ from each other in colour, degree of mottling, nature and amount of concretionary content etc. as shown by exposures along the banks of the Blue Nile, especially well seen near Singa.

The actual age of the deposition, especially as regards the topmost part of the deposition, is only vaguely known. Fossil remains have been found in a layer of calcareous gravel underlying the main clay deposits at Singa and Abu Hugar on the Blue Nile. Some of these fossil remains have been dated by the C14 method, at around 30,000 B.P. The main clay depositional phase is, therefore, later than this date.

C14 dating of shell-beds in silt terraces between the first and third cataracts by Fairbridge (1962), indicate that the aggradation stage reached a peak in this part of the main Nile around 10,000 B.P. At Senna, on the main Nile, silt retaining dykes have been found at a level 8 metres above present water level. These belong to Dynasties XII-XIII, and are dated at around 3700 B.P. Progressive downcutting has gone on since then, although only slowly since 500 A.D. (Arkell 1948). It is, therefore, possible that extensive flooding of the Blue Nile basin may have been going on as late as 3000-4000 B.P., and that the surface clay deposits in the area under consideration are comparatively very recent, especially since it is believed that the period 3000-4000 B.P. was somewhat wetter and more humid than now, a fact borne out by molluscan remains found near Khartoum (Tothill 1948), and by the finding of archeological sites of a sedentary population in the southern Libyan desert, an area now too dry for permanent settlement (Arkell 1948).

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On the west bank of the Blue Nile, a series of wide, deep meander depressions are found which probably indicate a former course or courses of the Blue Nile. It has been suggested that these depend on the former existence of a cataract at Sennar, on which the dam is founded.

These relic meanders show decided evidence of their later movement in a series of slight, concentric ridges within the concave side of the meander. There is no true clay deposition along the edge of these channels, the superficial deposits being mainly sandy, and containing a very high amount of hard, sub-angular calcium carbonate concretions. It may be that any surface clay has been removed by erosion into the channels, or, more likely, that there never was a clay capping. This may indicate that these meanders are comparatively very recent, certainly more recent than small relic meanders found on the east side of the Nile, which are covered by an overlying clay deposit.

Objections to a purely alluvial derivation of the clays have been raised on the grounds that there is no stratification (Worrall 1957). However, in the majority of the pits examined, a fair degree of platy structure was found, and this may have resulted from slight depositional planes of weakness. The point is also made that although the main constituents of the clay agree with the suggestion of Abyssinian derivation, some of the heavy mineral suite, especially horneblende and epidote, indicate a more local derivation (Worrall 1957).

2.2.3 Topography

Most of Area 2B is gently undulating due to the fact that it is everywhere dominated by the large relic meanders running through it. Only sub-area 6, the largest of the nine sub-areas surveyed, shows any extent of comparatively flat land. Most of the rest of the area is affected to some degree by the slight progression ridges left by the laterally migrating meanders.

Also, many of the meanders are edged by a slight but definite sandy level usually associated with slightly depressional areas along the inner side of these levels.

The smaller sub-areas are mainly rather sandy meander coves, and are generally well drained.

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2.3 Climate

2.3.1 General

This description of the climate is inevitably biased, since records cover only a very limited period as compared with the age of the environment. Although the present climate of Central Sudan is hot, tropical and semi-arid, evidence suggests that much wetter conditions prevailed during the pluvial phases of the Pleistocene (Zeuner, 1959).

Under present-day conditions the year is divided into two distinct climatic periods. During the dry, hot winter and spring (November to April) the north winds are dominant, bringing hot air heated during its passage over the northern deserts: towards the end of this period the Inter Tropical Front moves north, accompanied by moisture derived from the Congo and South Atlantic systems. The ensuing rainy season, or "harif", continues until mid-October, during which the south to south-western winds predominate. Following the harif there is a transitional hot, humid period during which the Inter Tropical Front retreats southward, but before the drying northern winds commence.

Climatological data for this report have been taken from two stations:

First Class Sta. Tozi 12°27'N 34°00'E (9 year record)

Second Class Sta. Singa 13°09'N 33°57'E (30 year record, 1931/60).

2.3.2 Temperature

The mean monthly maximum and minimum temperatures for the two stations are presented graphically in figure 2.1 . The annual means are:-

Station	Maximum	Minimum
Singa	36.6°C	20.7°C
Tozi	35.9	19.5

The highest temperatures have been recorded in April, with a secondary peak in November. The mid-summer minimum is attributable to the decreased solar radiation and the latent heat lost through increased evaporation during the harif. The lowest night temperatures, however, are experienced in January and February.

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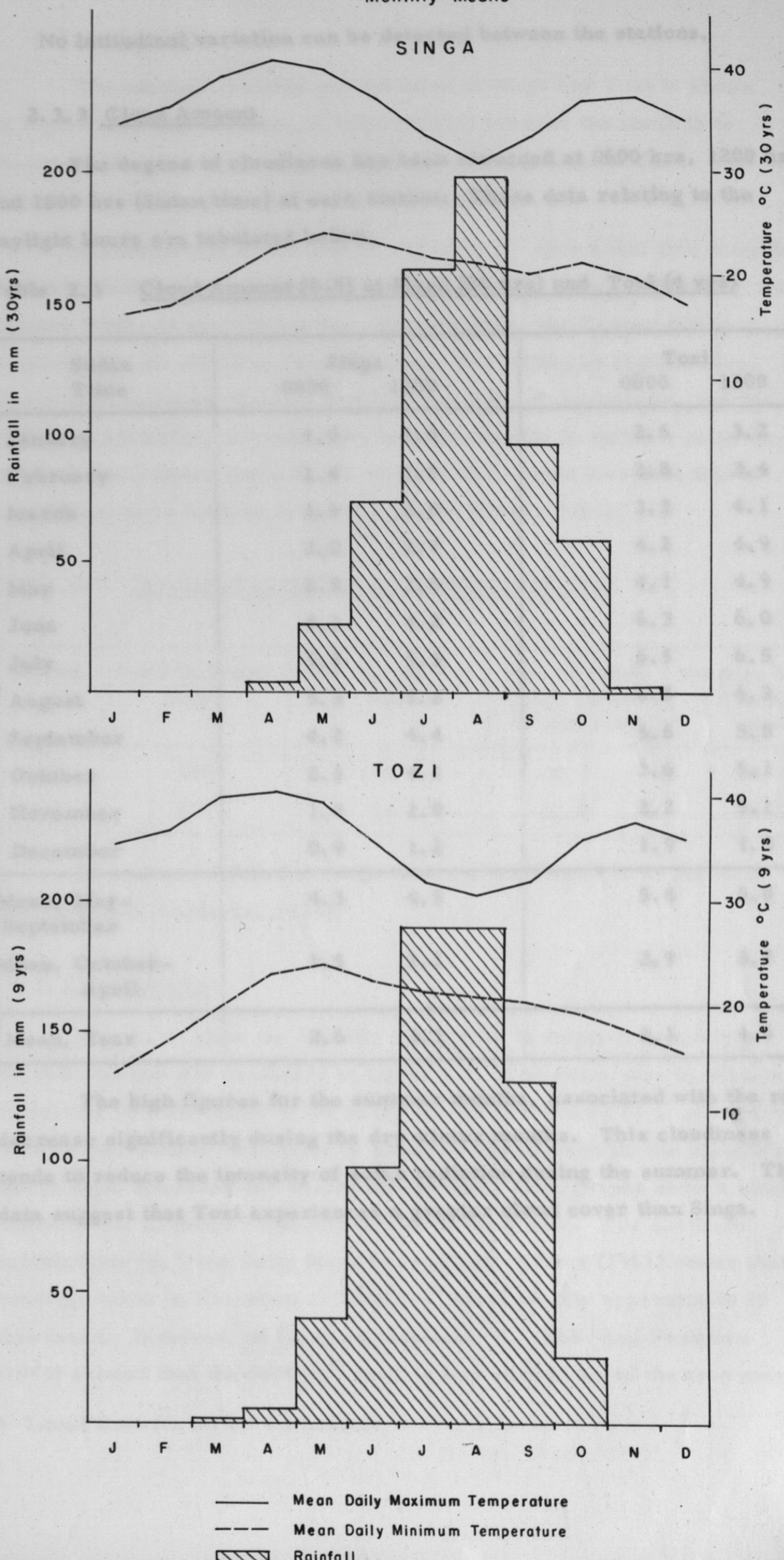
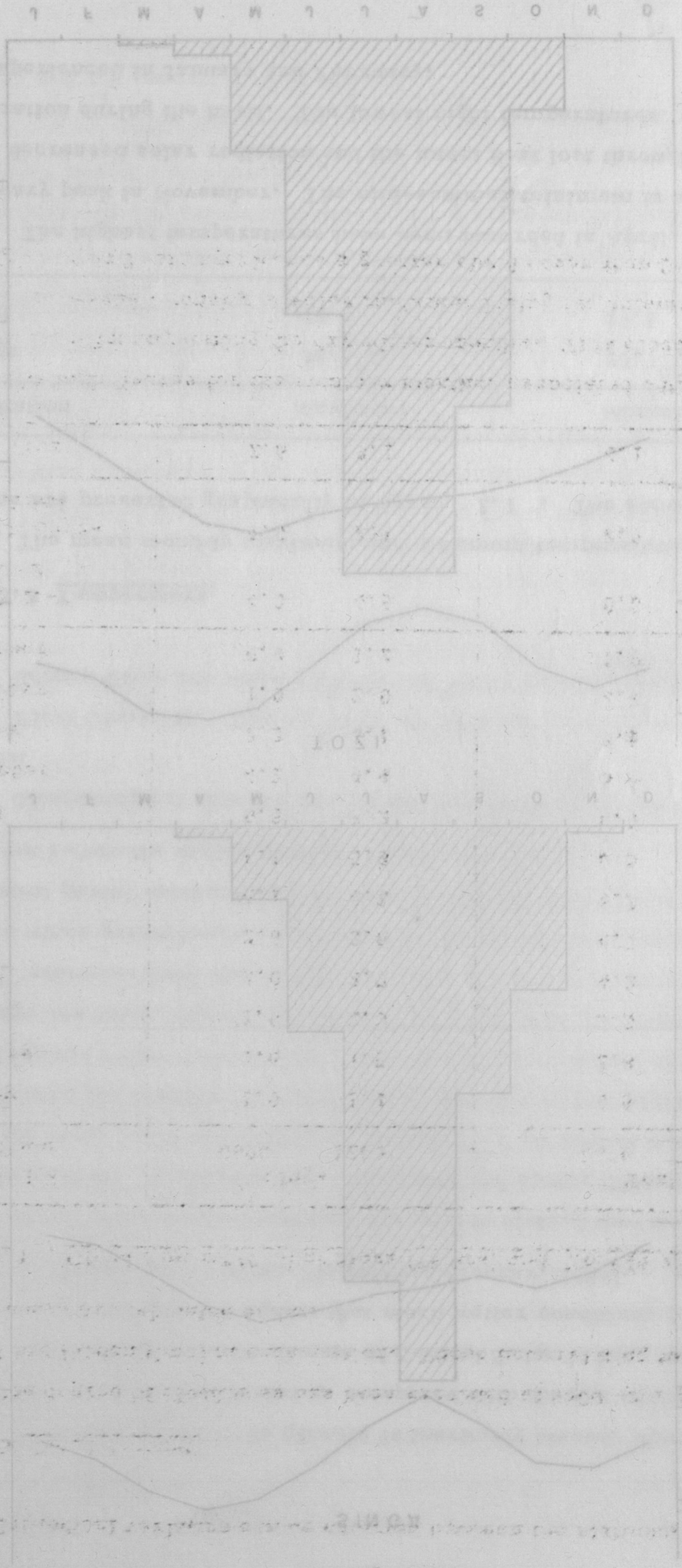
RAINFALL; MAXIMUM AND MINIMUM TEMPERATURE

Monthly Means




J F M A M J J A S O N D
Rainfall
Mean Daily Minimum Temperature
Mean Daily Maximum Temperature

No latitudinal variation can be detected between the stations.

2.3.3 Cloud Amount

The degree of cloudiness has been recorded at 0600 hrs, 1200 hrs. and 1800 hrs (Sudan time) at each station. Those data relating to the daylight hours are tabulated below.

Table 2.1 Cloud Amount (0-8) at Singa (28 yrs) and Tozi (4 yrs)

Sudan Time	Singa 0800	Singa 1200	Tozi 0800	Tozi 1200
January	1.0	1.4	2.5	3.2
February	1.4	1.5	2.8	3.4
March	1.6	2.0	3.3	4.1
April	2.0	2.7	4.2	4.9
May	2.8	3.6	4.1	4.9
June	4.1	4.2	6.3	6.0
July	5.1	5.3	6.5	6.5
August	5.3	5.2	6.5	6.3
September	4.2	4.4	5.6	5.5
October	2.3	4.1	3.6	5.1
November	1.0	2.0	2.2	3.1
December	0.9	1.2	1.9	1.8
Mean, May-September	4.3	4.5	5.8	5.8
Mean, October-April	1.5	2.1	2.9	3.7
Mean, Year	2.6	3.1	4.1	4.6

The high figures for the summer months, associated with the rains, decrease significantly during the dry winter months. This cloudiness tends to reduce the intensity of solar radiation during the summer. The data suggest that Tozi experiences a greater cloud cover than Singa.

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2.3.4 Rainfall

The average monthly precipitation at Singa and Tozi is shown in figure 2.1. The decrease in total rainfall towards the north is to be expected, yet the actual peak figure for Singa exceeds Tozi. The duration of the harif is similar at each station.

A comparison of the data in Table 2.2 shows that this variation in total rainfall is related to the number of rainy days, rather than the amount falling in any one storm. Nevertheless, the figures fail to demonstrate the effective rainfall, since that falling by night is less liable to evaporation than the daylight rainfall. Furthermore, had the data been available, it would have been preferable to define a rainy day as that experiencing more than 5 mm rainfall, since less than this is considered to be useless in an arid region (Oliver 1961).

Table 2.2 Averaged Rainfall Data: Period 1931-1960

Station	Total Rainfall mm	Max. in one day mm	No. of rainy days (over 1 mm rain)	Average rainfall per rainy day mm
Singa	588	100	49.9	11.8
Tozi	679	94	62.0	11.0

The annual rainfall at Singa shows a variability of 13 per cent (A. Gibb and Partners, 1954).

2.3.5 Humidity

Graphs to show the monthly variability in relative humidity at the two stations are presented in figure 2.2. The sharp rise in humidity coinciding with the onset of the rainy season is followed by a secondary peak in mid-winter: the latter is probably associated with the significant fall in night temperatures during this period. Both graphs show a similar distribution, although Singa appears to be most arid. For accurate calculations the True Daily Mean is required: Oliver (1961) states that readings taken in Khartoum at 1026 hrs* most closely approximate to this mean. However, at Kosti and Malakal, A. Gibb and Partners (1954) showed that the 0800 hr* reading was very close to the true mean,

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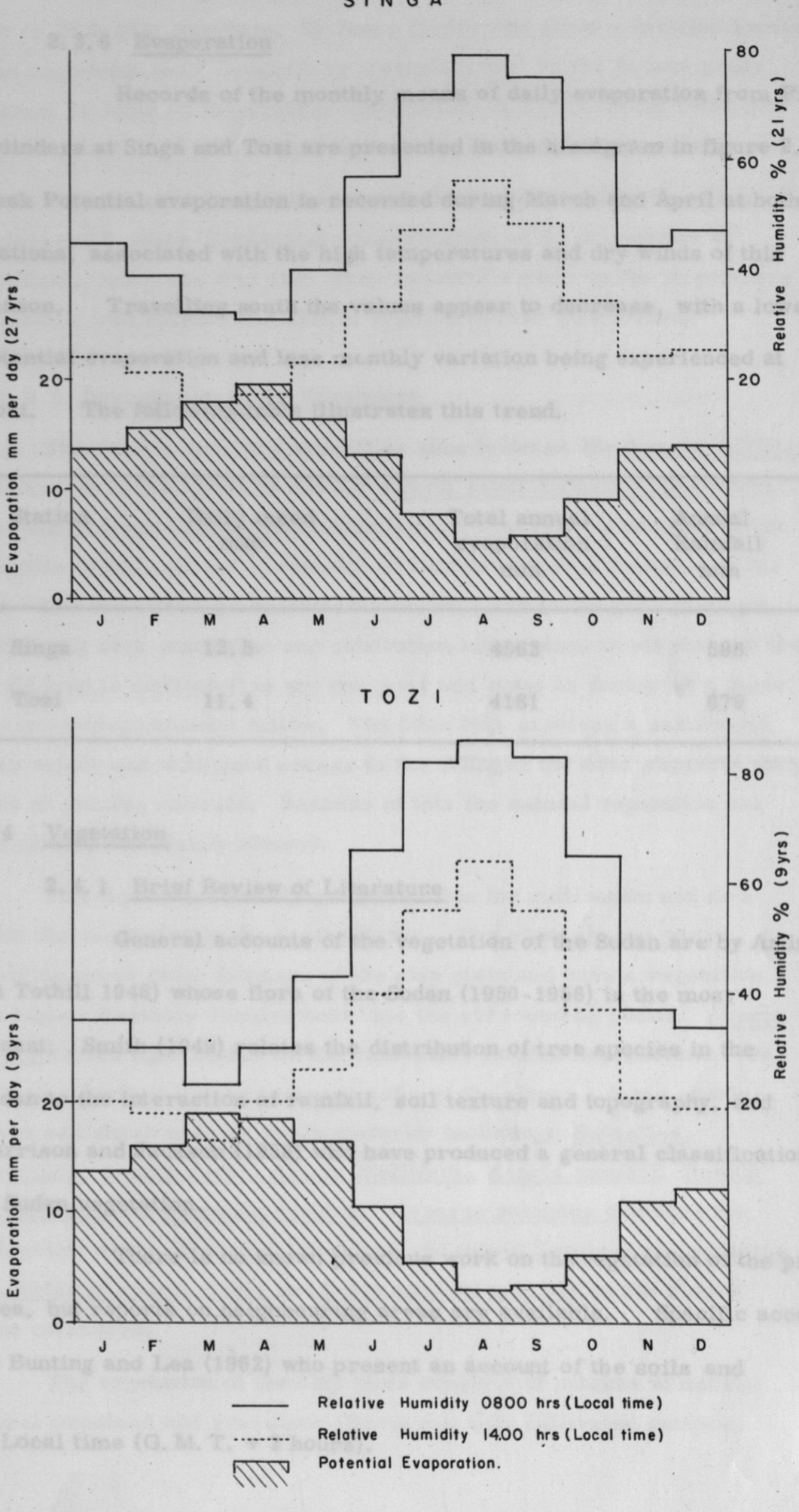
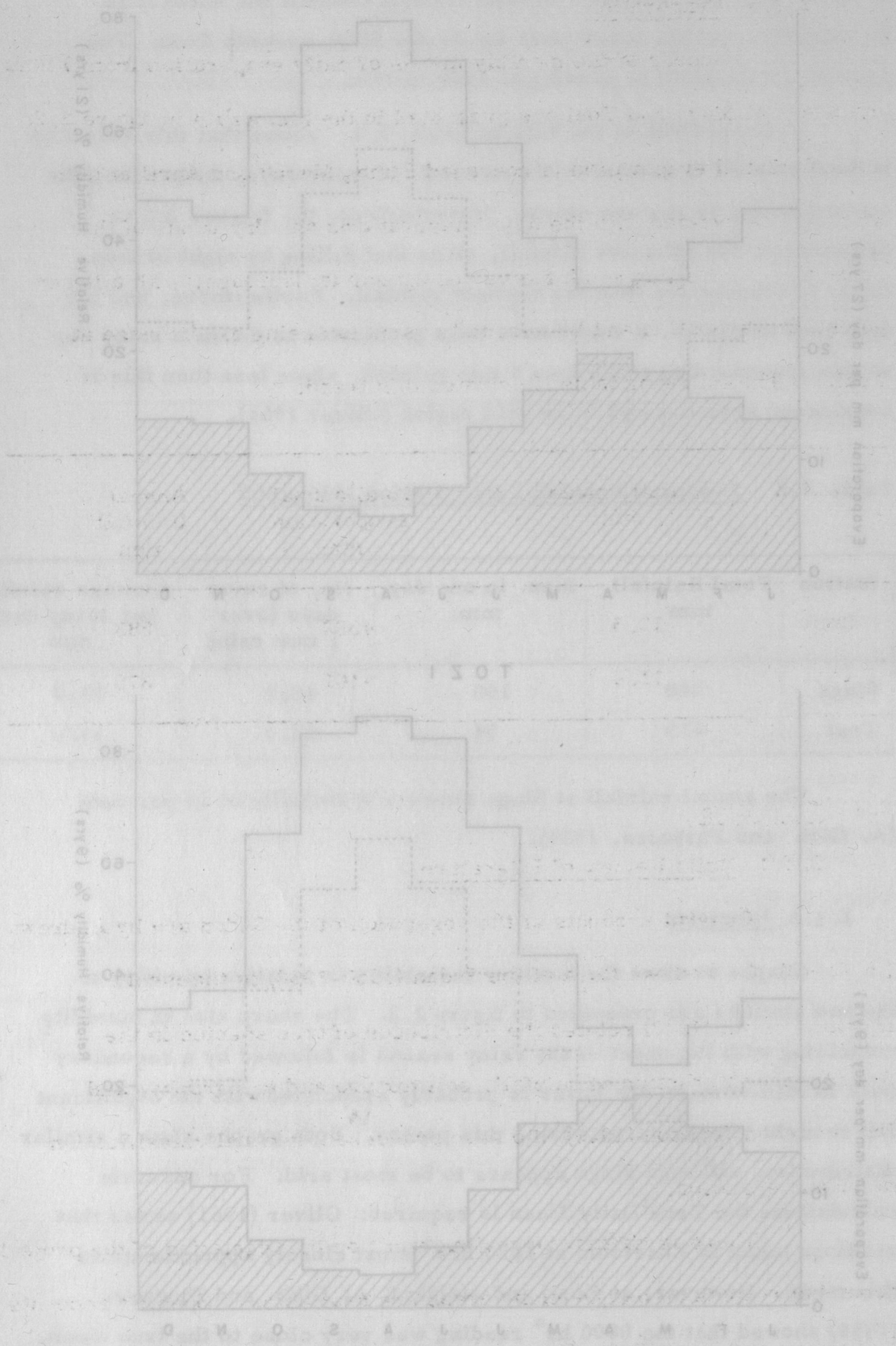
Fig. 2·2

RELATIVE HUMIDITY AND POTENTIAL EVAPORATION (Piche)

Monthly Means





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Records of the monthly means of daily evaporation from Piche cylinders at Singa and Tozi are presented in the histogram in figure 2.2. Peak Potential evaporation is recorded during March and April at both stations, associated with the high temperatures and dry winds of this season. Travelling south the values appear to decrease, with a lower potential evaporation and less monthly variation being experienced at Tozi. The following table illustrates this trend.

Station	Daily mean mm	Total annual evaporation mm	Annual Rainfall mm
Singa	12.5	4562	588
Tozi	11.4	4161	679

2.4 Vegetation

2.4.1 Brief Review of Literature

General accounts of the vegetation of the Sudan are by Andrews (in Tothill 1948) whose flora of the Sudan (1950-1956) is the most recent; Smith (1949) relates the distribution of tree species in the Sudan to the interaction of rainfall, soil texture and topography, and Harrison and Jackson (1958) who have produced a general classification of Sudan vegetation.

There is no known previous work on the vegetation of the project area, but reports on neighbouring areas are available. Specific accounts by Bunting and Lea (1962) who present an account of the soils and

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The classification used is basically that outlined by Harrison and Jackson in their 'Ecological Classification of the Vegetation of the Sudan', reference was also made to Smith's work on the importance of rainfall, soil texture and site in relation to tree distribution.

2.4.2 Description of the Vegetation

The area is part of a transition zone between the Acacia mellifera thornland on cracking clays and the Acacia seyal-Balanites aegyptiaca savannah with grassland, vegetation types. The area is bounded by the Blue Nile in the east and a complex of ancient meander channels in the west. The town of Singa is immediately adjacent to the area giving it a relatively high population and cultivation takes place in all parts of the area. Not all land is cultivated in any one year and some is rested as a more or less semi-permanent fallow. The Blue Nile provides a permanent water supply and with good access to the villages the area supports many herds of grazing animals. Because of this the natural vegetation has been almost completely altered.

The meander channels are unsuitable for cultivation and as a result the vegetation is the least altered. The channels are water receiving areas from drainage of the clay plain and have a vegetation with higher moisture requirement than the surrounding plains. Acacia nilotica forms open stands on the seasonally flooded depressions. On the better drained lighter textured soils of the slopes a large number of tree and shrub species attain maturity including: Balanites aegyptiaca, Acacia seyal, Acacia mellifera, Acacia senegal, Boscia senegalensis and Capparis decidua. Cyperus rotundus provides the herb cover on the flooded depressions and mixed Cymbopogon nervatus with Aristida adscensionis and Schoenefeldia gracilis on the slopes of the meanders.

The vegetation of the clay plain consists of patches of semi-natural woodland and grassland alternating with cultivated patches.

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The meander channels are unsuitable for cultivation and as a result the vegetation is the least altered. The channels are water receiving areas from drainage of the clay plain and have a vegetation with higher moisture requirement than the surrounding plains. Acacia nilotica forms open stands on the seasonally flooded depressions. On the better drained lighter textured soils of the slopes a large number of tree and shrub species attain maturity including: Balanites aegyptiaca, Acacia seyal, Acacia mellifera, Acacia senegal, Boscia senegalensis and Capparis decidua. Cyperus rotundus provides the herb cover on the flooded depressions and mixed Cymbopogon nervatus with Aristida adscensionis and Schoenefeldia gracilis on the slopes of the meanders.

The vegetation of the clay plain consists of patches of semi-natural woodland and grassland alternating with cultivated patches.

Being a transition zone both type species, Acacia mellifera and Acacia seyal are found throughout the area. Remnants of natural Acacia mellifera thickets occur along the railway line and regenerate on the semi-permanent fallow patches. Mature Acacia seyal trees are scarce on the plain but dense thickets of saplings are frequent on undisturbed areas. Acacia nubica is a common species forming impenetrable patches close to villages. Scattered throughout the plain are occasional Balanites aegyptiaca saplings and Cadaba rotundifolia bushes. The grass flora is dominated by Cymbopogon nervatus and Sehima ischaemoides with Sorghum purpureo-sericeum on sites of moisture accumulation.

The cultivated areas generally have some of the naturally occurring species, particularly acacia seedlings as weeds. Certain species are restricted to the cultivated patches such as: Ischaemum afrum, Pennisetum ramosum, Dinebra retroflexa, Gynandropsis gynandra, Hibiscus cannabinus, Ocimum basilicum.

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2.4.3 Check list of the species identified in Area 2B

TREES AND SHRUBS

Acacia nilotica (L.) Willd. ex Del. var. nilotica (A. arabica (Lam) Willd.)

Acacia seyal Del. fistula (Schweinf.) Oliv. (A. fistula Schweinf.)

Acacia mellifera (Vahl) Benth. subsp. mellifera

Acacia nubica Benth.

Acacia senegal (L.) Willd.

Acacia seyal Del. var. seyal

Balanites aegyptiaca (L.) Del.

Boscia senegalensis (Pers.) Lam. ex Poir.

Cadaba glandulosa Forsk.

Cadaba rotundifolia Forsk.

Capparis decidua (Forsk.) Edgew.

Dichrostachys cinerea (L.) Wight and Arn. subsp. cinerea (D. glomerata (Forsk.) Chiov.)

Ziziphus spina-christi (L.) Willd.

HERBS

1) Dicotyledons.

Celosia argentes L.

Cissus quadrangularis L.

Cynandropsis gynandra (L.) Briq.

Hibiscus cannabinus L.

Leonotis nepetifolia (L.) Ait. F. var africana (P. Beauv.) J.K. Morton (L. africana (Beauv.) Briq.)

Ocimum basilicum L.

Sesbania microphylla Harms ex Phillips and Hutch.

Sesbania macroptera Hochst. ex Bak.

1) Monocotyledons.

Andropogon gayanus Kunth.

Aristida adscensionis L.

Brachiara brizantha (Hochst.) Stapf

Cymbopogon nervatus (Hochst.) Chiov.

Cyperus rotundus L.

Dinebra retroflexa (Vahl) Panz.

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Pennisetum ramosum (Hochst.) Aschers. and Schweinf

Schoenefeldia gracilis Kunth

Sehima ischaemoides Forsk.

Setaria pallide-fusca Stapf et Hubbard

Sorghum purpureo-sericeum (Hochst.) Aschers. and Schweinf.

Sorghum sp. S. sudanense (Piper) Stapf

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2.5 Population and Land Use

2.5.1 Population

(i) Settled

Although this area was originally the centre of the Fung Kingdom, the former Arab population has been diluted by immigrants from Western Sudan. Despite this immigration the Arabs still maintain authority within the Omodias. Several villages to the east of Singa (e.g. Silk, Umm Benain, Suntat, Saqr) are populated by settled elements of the nomadic Kenana tribe; some (e.g. El Hariri, Arbat Ushar, Gemmeiza) have been founded by army pensioners of mixed tribes, whilst others are populated by diverse Western tribes. An estimate of the population within the project area has been compiled from the 1955/56 Census data, Areas271 and 272.

Omodia	Approx. Population
Dar Oqeil	9,035
Abu Gandoul	3,918
El Suntat	6,786
Singa villages	984
Singa town	9,436
	30,159

Taking 2 per cent as a reasonable figure for net annual increase, the present rural population would be approximately 24,500, with Singa town having risen to 11,300.

Settlement has developed in two regions, related to the water supplies which are derived from either the Blue Nile or drawn from shallow wells in the Khor Umm 'Ish which runs parallel to, and 15-20 km west of the river. The availability of water from the pump schemes has facilitated development away from the crowded riverain zone.

(ii) Nomadic

Both the Kenana and Rufa'a el Hoi tribes pass through the area during their annual migrations. In December the Kenana people move with their livestock to their winter grazing on the east bank,

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Both the Kenana and Rufa'a el Hoi tribes pass through the area during their annual migrations. In December the Kenana people move with their livestock to their winter grazing on the east bank,

returning to the dry and fly-free Kenana grasslands during the rains. Similarly, a section of the Rufa'a el Hoi moves to winter grazing areas further south.

The only available estimate of the nomadic population was compiled from the 1955/56 Census which gives the following figures for the Fung Nazirates (271) Nomadic population.

Rufa'a el Hoi	26,890
Kenana	5,708
	32,598

However, the proportion of these people living within the project area at any one time is impossible to estimate.

2.5.2 Land Use

Four distinct land use categories occur within the region:

a) Private Pump schemes, producing cotton and dura.
b) Riverain cultivation of the silt terraces, yielding maize, lubia, and a variety of fruit and vegetables, for which Singa provides a convenient market.
c) Rainland cultivation of the hinterland.
d) Livestock grazing.

Since it is only the last two categories which fall within the area surveyed, these will be discussed in more detail.

(i) Rainland Cultivation

Falling between the 500 and 600 mm isohyets, the area is able to produce reasonable crops of dura, dukhn and simsim; occasional fields of groundnuts were also observed.

The majority of rainland cultivators, inhabit the non-riverain villages and depend upon their rainfed crops for subsistence, although the development of pump schemes and the higher yields obtainable within them has increased their prosperity and provided alternative employment. It can be seen from aerial photographs that most of the area has been cultivated at some time, but a preference exists for soils of high clay content. The growth of 'nahl' grass (Cymbopogon

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nervatus) on former cultivated areas provides a valuable source of thatching material.

Dura (Sorghum vulgare)

This constitutes the staple diet of the local population. Any surplus is sold in Singa, although the quantity is insignificant when compared with sales of grain from the Mechanised Crop Production Schemes at Jebel Dali, which enter the same market.

Feterita is the most favoured variety, yielding up to 2.8 ardebs/feddan, although experience at Jebel Dali indicates that by the introduction of Tozi varieties this could be raised to 4.0 ardebs. Weeding is generally efficient, but 'buda' (Striga hermonthica) has reduced yields in some instances. All field operations are done by hand. The harvested straw is sometimes stacked for cattle feed during the dry season.

Simsim (Sesamum orientale)

Simsim provides a valuable oil seed crop, being grown most frequently in the south, where up to 3.0 ardebs/feddan may be obtained. Where rotations are practiced this crop provides a break from dura. On newly cleared land simsim is always the first crop to be sown.

Dukhn (Pennisetum typhoideum)

As a grain, this is particularly favoured amongst the Western population. Being a deep rooted plant, dukhn is often planted on the frequent lighter textured sites in the area, and is second only to dura in importance as a grain crop. Cultivation is similar to that of dura, but dukhn is more susceptible to bird damage and generally provides lower yields.

Ful Sudani (Arachis hypogea)

Isolated fields of ful sudani were observed in the northern areas, especially upon loamy soil. This crop has been recommended as an alternative to dura where 'buda' infestation becomes excessive, but necessitates greater effort to harvest. Yields of up to 7 ardebs/feddan are obtained.

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(ii) Livestock

Most of the villagers own small numbers of cattle, sheep and goats. The animals are watered at inland wells, pump scheme canals or at the Blue Nile. Rough grazing and browsing which is plentiful during the rains but sparse during the dry season, together with some dura and dukhn straw, make up the main elements in the diet. It has been estimated that despite this poor feeding, cows may commonly be giving 350 gallons per lactation. At the nearby Umm Benain Cattle Breeding Station similar cows on irrigated pasture have yielded up to 750 gallons per lactation.

A large proportion of the animal products are consumed locally but during the period of surplus milk from July to October, some clarified butter and, near Singa, some fresh milk may be sold. The retail price of milk is about 2-4 P.T./rotl. A dairy has now been started by the Department of Animal Resources in Singa, they have also set up pilot schemes to the north of the area for the development of grazing in Khors seasonally flooded from the Blue Nile. This latter scheme is designed to be used by the local sedentary population.

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CHAPTER 3

SURVEY METHODS

3.1 Use of Aerial Photographs

The value of aerial photo-interpretation as an aid to soil survey depends to a large extent on topographical features and on vegetational patterns, which can be related to the overall soil complex. These features and patterns may be recognised by means of a stereoscope. The procedures followed during the survey were:-

Study of the mosaics in conjunction with aerial photographs in order to gain an idea of the area and to eliminate areas which were topographically unsuitable for irrigation, and rock outcrops.

A full photo-interpretation was carried out when the Survey Party was more familiar with different features and patterns in the field. A sample area was also selected at this time.

After the completion of the field work, a final photo-interpretation was carried out. During the field work a preliminary field legend was made and written out as a formula. After the site had been investigated in the field, this formula was placed behind the site number on the photographs. In addition, the final soil class was marked on the photographs. Both were of great help in the final soil mapping.

3.1.2 Elements

The following elements have been distinguished during the photo-interpretation.

Relief

In the clay plains of the Sudan the value of photo-interpretation is limited by several factors. The main limiting factor is, in general, the low relief. However, the surface is by no means level. The variations are mostly so slight that they cannot easily be delineated by stereoscopic examination. It was not always possible in the field to map these differences in micro-topography at this scale of survey, although there were differences at very short distances. These differences

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were mainly in colour associated with mounds and depressions. Therefore, even where the field data show sites to be in slight depressions, it may be impossible to see under the stereoscope the extent or shape of such an area.

Vegetation

The use of vegetation as an interpretative factor is limited by the fact that many of the species which do give identifiable patterns on the photographs, grow with equal success on a large number of different soil types. Vegetation is also affected by areas which are flooded for a certain period giving rise to species common to higher rainfall areas. In addition human interference and cattle has a great influence on the vegetation and has greatly limited the value of vegetation in interpretation in area 2B.

Different colour tones of grey on the photographs are related to vegetation covers, mainly grasses. But colour tone may be different from one photo to the other due to bad printing and also due to cloud shadows. Throughout area 2B, it is possible to identify the light grey colour tone of Cymbopogon nervatus, usually confined to drier sites. Darker colour tones usually indicate a more mixed vegetation with mixtures of C. nervatus and Cyperus rotundus in wetter, receiving sites.

Entisols can often be delineated by relief, but where no relief can be identified, it can be delineated by the very light grey colour of Aristida and Schoenefeldia, which often colonise such a soil type.

Soils.

Several factors have been used in delineation of the soil boundaries. Straight correlation between soil types and topography has been possible at rather low level of relief. Where the relief itself could not be identified, the secondary factors in relief variations, e.g. vegetation, could be seen on the photographs. Receiving sites quite often show up darker compared with datum or shedding sites, irrespective of the colour tone due to the vegetation cover.

In general, the cultivator tends to avoid soils of the Mazustert and Mazaquert Great Groups, due to their hard massive surfaces. In some places it has been noted that the cultivation of wetter Aquerts has been avoided, in favour of drier Usterts. This is further emphasised by the

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fact that these wetter areas remain uncleared and carry varying densities of scrub A. mellifera, A. seyal and A. nubica. It will be obvious, from what has been said, that the main value of photo-interpretation lies in delineating Aquerts from Usterts and Natrargidic from non-natrargidic soils. It was extremely difficult to find photo-interpretation evidence to help separate Orthic and Entic subgroups wihtin any one Great Group and in many cases to separate Orthic Grumusterts and Orthic Grumaquerts. The Usterts and Aquerts have just one main difference i.e. colour, and as the survey is carried out by several individuals, who interpret colours in slightly different ways, there may well be slight colour differences and thus a difference at suborder level, due to individual estimations of colour and not to any real difference.

The most important factor in separating soil types is relief. As already mentioned under vegetation many vegetational patterns are reflections of relief, because this decides the amount and duration of easily available water.

Thus the correlation exists between soils and vegetation not so much because they are mutually interacting, but because both are affected by the same basic factor: relief.

This is not the case with the Entisols, where there is a direct correlation between vegetation and soil type. But this refers to the Orthic and Natrargidic Orthustents and not to the Vertic Orthustents which usually show vegetation similar to that carried by Vertisols.

Land Use

Three main Land Use types have been recognised during the Survey and have been mapped (see Land Use Map, fig. 3.1).

1) Pump schemes by their regular patterns and shapes.
2) Rain Cultivation. This gives an irregular pattern of small fields on the photographs. The sesame and sorghum fields show similar patterns, but one could say that the dark coloured fields were under sorghum cultivation while the slightly lighter ones indicated sesame cultivation. The lightest in colour were fallow or abandoned fields.

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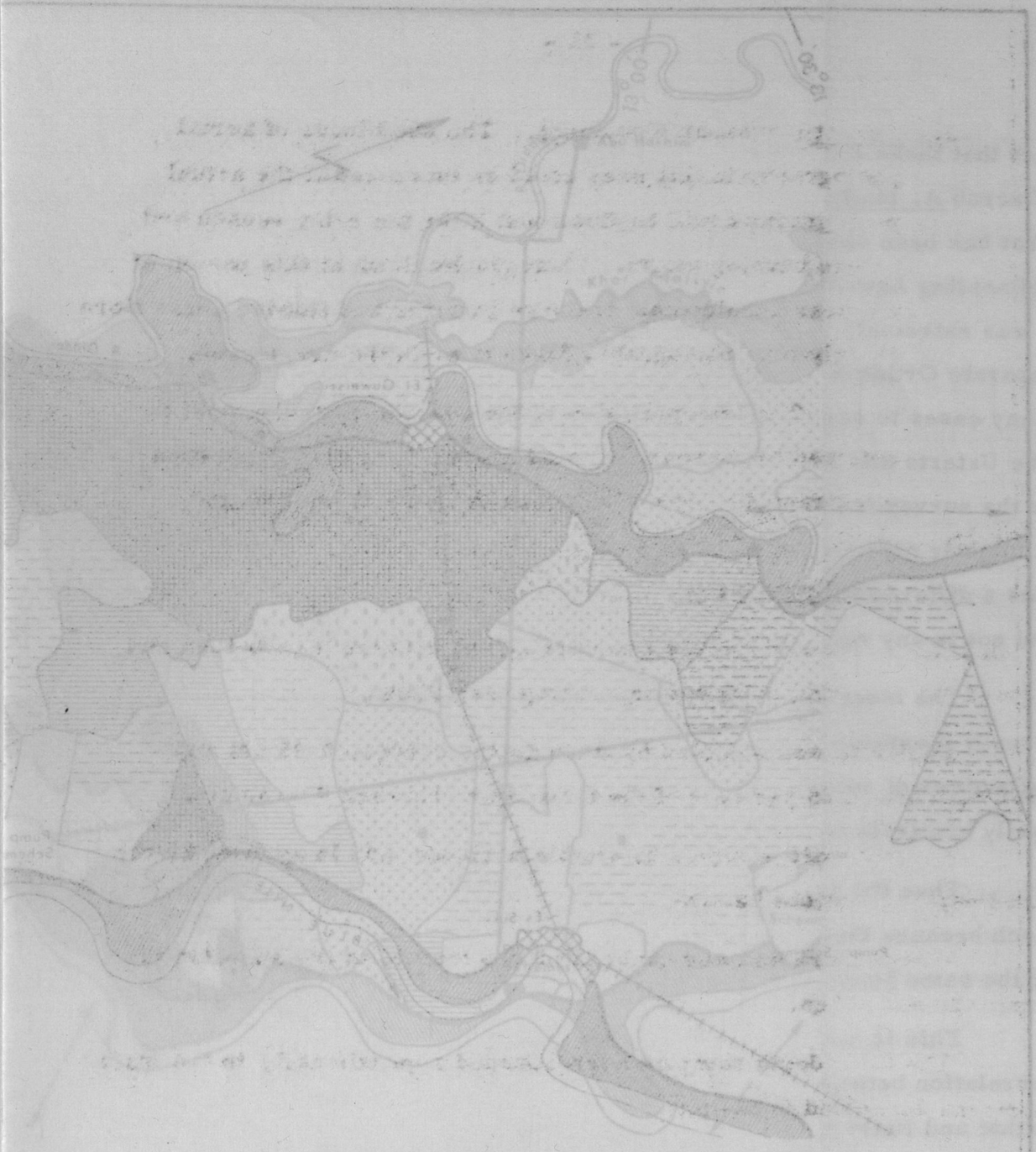

3) Forest (Savannah Woodland). The usefulness of aerial photography in this area could be increased if the actual photography could be flown just after the rainy season and before burning starts. Photography flown at this period of the year should show drainage patterns and flooded areas more clearly than photography flown later in the dry season.

The interpretation of the specific patterns must be confined to reasonably small areas: it is very dangerous to extrapolate over wide areas from local information.

3.2 Soil Survey Procedures

3.2.1 The soil survey was carried out between March 1965 and April 1965, working from one base camp near Singa.

Each site was sampled by fixed depths between 0-45 cm and 45-90 cm and in 23 per cent of the total sites, between 90-150 cm.

All pits were sampled by visible horizons and in addition by the fixed depths mentioned above.

Where there was any doubt about the texture of the sub-stratum a sample was taken.

The fixed depth samples corresponded approximately to the major horizons described in the pits.

The sampling density required was at least one site for every 250 feddans. For convenience, Sudan Survey beacons occurring at 1.8 km intervals were used as grid intersections and bores sited near each beacon. Intervening bore sites were plotted where a change in soil characteristics was expected, either from field observation, or from patterns on aerial photographs. Where no such differences were apparent or expected, the intervening sites were plotted at 0.9 km intervals, mid-way between the beacons. Pits were plotted as representative of all special ground features observed by field inspection or photo-interpretation. One site in twenty was a pit, in the bottom of which a one metre bore was augered, and a full field description up to 3 metres was made.

The pits were described and sampled both by fixed depth and by horizons, but the bores by fixed depths only.

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All pits were sampled by visible horizons and in addition by the fixed depths mentioned above.

Where there was any doubt about the texture of the sub-stratum a sample was taken.

The fixed depth samples corresponded approximately to the major horizons described in the pits.

The sampling density required was at least one site for every 250 feddans. For convenience, Sudan Survey beacons occurring at 1.8 km intervals were used as grid intersections and bores sited near each beacon. Intervening bore sites were plotted where a change in soil characteristics was expected, either from field observation, or from patterns on aerial photographs. Where no such differences were apparent or expected, the intervening sites were plotted at 0.9 km intervals, mid-way between the beacons. Pits were plotted as representative of all special ground features observed by field inspection or photo-interpretation. One site in twenty was a pit, in the bottom of which a one metre bore was augered, and a full field description up to 3 metres was made.

The pits were described and sampled both by fixed depth and by horizons, but the bores by fixed depths only.

A method of recording vegetation was introduced to standardise the observations made by a number of surveyors and to make the best use of the space provided on the proforma sheets. The method was to make three separate observations and record them in three sections A, B and C. Section A is an estimate of the numbers of all tree and bush species occurring in one feddan around the sampled site. Section B is an eye estimate of the bare ground in a representative square metre close to the bore site. Section C is the two most common herbs found close to bore site with an estimate of their average height.

Example.

A. Acacia seyal 25
Balanites aegyptiaca 9

B. 40 per cent

C. Hyparrhenia pseudocymbaria 275 cm
Cymbopogon nervatus 90 cm

3.2.2 Sample Area

A sample area was chosen in conjunction with aerial photo-interpretation after the soil surveyors were more familiar with the soils in the area. This was approximately 10 sq. km in extent, located 4 km west of Singa. A full description of the sample area is given in Appendix 1.

3.2.3 Chemical Analyses

(i) Routine sites

The following analyses were carried out on the samples from the top two layers - 0-45 cm and 45-90 cm:-

a) Mechanical analysis.
b) Moisture saturation percentage of soil paste.
c) Electrical Conductivity of the saturation extract in mmhos/cm.
d) Soluble sodium in mg-equivalent/100 gm soil.
e) Total extractable sodium in mg-equivalent/100 gm soil.

Third layer - 90-150 cm:- (25 per cent of total sites)

E.C. and Saturation percentage only.

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Third layer - 90-150 cm:- (25 per cent of total sites)

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(ii) Pits

Samples from all major horizons.

All analyses as for routine sites together with

(a) pH of soil paste and 1:5 dilution,

(b) Mechanical analysis to International Standards.

(c) Cation exchange capacity in mg equivalent/100 gm soil.

(iii) Soil series profiles

Samples from all major visible horizons of selected profiles representing the soil series mapped.

All analyses as for horizon sample plus the following:-

(a) Total nitrogen per cent.

(b) Total organic carbon per cent.

(c) Available phosphorus and potassium in mg/100 gm soil.

(d) Soluble anions in saturation extract in mg equivalent/litre i.e. Carbonate, Bicarbonate, Sulphate and Chloride.

(e) Soluble cations in saturation extract in mg equivalent/litre i.e. Sodium, Potassium, Calcium, Magnesium.

The exchangeable sodium percentage at routine sites is calculated as follows:-

$$E.S.P. = \frac{\text{exchangeable Na in mg - equivalent/100 gm soil}}{\text{clay percentage}} \times 100.$$

For soil series the E.S.P. is calculated as follows:-

$$E.S.P. = \frac{\text{exchangeable Na (m.e.)}}{\text{C.E.C. (m.e.)}} \times 100$$

3.3 Chemical Analyses of soils

The following methods were used by Agricultural Services (Sudan) Ltd. in making the determinations.

(i) Mechanical Analysis: Bouyoucos Hydrometer Method

40 grams soil were soaked with 250 m water and 11 ml of 10 per cent sodium hexametaphosphate solution overnight, and dispersed the next morning in an electric stirrer for 10 minutes, transferred to a 1 litre measuring cylinder, shaken and readings taken after 4 minutes, 2 hours and 7 hours in order to estimate percentages of sand, silt and

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clay, respectively. With every reading the temperature is recorded and corrections made for temperatures and dispersing agent content. The readings are also corrected for soil moisture content, when required, by performing separate moisture determinations.

(ii) pH

Potentiometric determinations using a glass electrode on the soil paste or 1:5 suspension, were carried out.

(iii) Electrical Conductivity

Calculated by using a Solubridge on the saturation extract.

(iv) Total Nitrogen

Estimation of organic plus ammonia nitrogen, by Kjeldahl digestion, followed by distillation of freed ammonia into a boric acid solution, and titration with 0.05 N. HCl.

(v) Organic Carbon

Wet oxidation of the organic matter by the Walkley-Black rapid method (Piper, 1942, page 223).

(vi) Total Extractable Phosphorus

Extracted using constant boiling hydrochloric acid on a sand bath for a few hours (Piper, 1942). Estimated by reduction of an aliquot portion, with ascorbic acid in sodium, hexametasulphite, to molybdo-phosphoric blue, and comparison with standards on the absorption spectrophotometer.

(vii) Total Extractable Potassium

Extracted during the above process. An aliquot is taken, treated with ammonia to precipitate the sesquioxides, reacidified, and compared with standards flamephotometrically.

(viii) Carbonate as Incorporated Calcium Carbonate

Gasiometrical determination in Collins calcimeter (Collins 1906). The volume of CO_2 generated from a known weight of the soil is reduced to standard conditions, and calculated as if the total volume were derived from calcium carbonate only.

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(ix) Carbonate and Bicarbonate in Saturation Extract

A suitable aliquot of saturation extract is pipetted and titrated first against phenolphthalein indicator (it is essential to add always the same amount of indicator to the same volume) followed by titration against methyl-orange.

(x) Chloride in Saturation Extract

A suitable aliquot is pipetted into a porcelain evaporation dish, and the chloride content determined by Mohrs method (ref. Vogel, Quantitative Analyses) using 5 per cent potassium chromate as indicator, and titrated with 0.02 N silver nitrate solution.

(xi) Sulphate in Saturation Extract

1 ml of suitably diluted saturation extract is added to a medium of glycerol and glucose solution. Barium sulphate is generated and determined turbidimetrically in the electric photometer. (ref. Current Science Vol. 31, No. 10, October 1962, page 419).

(xii) Soluble Calcium and Magnesium in Saturation Extract

A suitable aliquot of saturation extract is titrated with 0.01 N sodium versenate solution first against the Eriochrome Black T indicator, and a second aliquot against the Purpurate (Murexide) indicator. It is essential in this second titration to work to as much as possible with equal volumes as the end point of titration against purpurate varies with the dilution. (Ref. Agric. Handbook No. 60, U.S. Dept. of Agriculture).

(xiii) Soluble Sodium and Potassium in Saturation Extract

Appropriately diluted saturation extract is analysed on flame-photometer for Na viz K.

(xiv) Exchangeable Sodium and Potassium

12.5 g of soil are soaked in 50 ml of normal ammonium chloride, left for one hour then leached a few times (about four times) by decantation. Then the soil is transferred into the filter and leached with successive portions of normal ammonium chloride when drained. Leaching is continued until 250 ml of filtrate are collected. The filtrate (5 ml) is diluted 20 times and sodium read off on the flamephotometer against 10 ppm sodium standard containing the same amount of ammonium

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chloride. Zero is set with 0.05 N. ammonium chloride. In another portion of suitably diluted filtrate, potassium is determined flamephotometrically against standards containing the same amount of ammonium chloride. From these readings the sum of soluble plus exchangeable sodium viz. potassium are calculated. By subtracting the soluble sodium and potassium from saturation extract data the net figures for exchangeable sodium and potassium are obtained.

(xv) Exchangeable Calcium and Magnesium

The method is essentially that described in C.S. Piper, Soil and Plant Analysis, page 170, the difference being only in the amount taken and leached twice with 250 ml of normal sodium chloride. Ca viz. calcium plus magnesium are determined by versenate titration (ref. Agric. Handbook No.60, U.S. Dept. of Agriculture, page 94).

(xvi) Cation Exchange Capacity

The clay is converted into a sodium clay using sodium acetate. Soluble salts are washed out with 96 per cent alcohol, and sodium is released by ammonium acetate. It is estimated flamephotometrically (ref. U.S.D.A. Handbook No.60).

3.4 Map Compilation

3.4.1 The Base Maps

The maps are based on the Sudan Survey maps, Nos. 55K 5-1, 55K 5-2, 55K 5-4, 55-0 2-2, at scale 1:50,000, on which the Blue Nile river and the pump schemes have been adjusted according to information gained from aerial photographs, detailed pump scheme maps and field surveys.

Pit,auger-hole and field permeability sites are indicated on the soil and land class map by the following numbered symbols:-

○ ..... 2 metre auger hole

△ ..... 2 metre pit, with 1 metre auger hole in the bottom of the pit

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The soil boundaires were first determined on the mosaics using photo-interpretation where possible, and where the boundaries could not be delineated by the above-mentioned method, they were interpolated between the sites.

Overlays were made and then traced on to the base maps. Each soil series has a certain colour and the striped areas indicate complexes in accordance with the legend colours.

3.4.3 Land Class Maps

The boundaries were determined using the same system as for the soil class boundaries but using the soil boundaries where possible. There is a good correlation between the soil and the land class maps. The anomalous sites in a particular land class are marked at each site on the map.

The land classes downgraded from 2, 3l and 4a to class 6a due to lower horizons deficiencies are shown with a circle and the same colour as the original land class. This is explained in Chapter 6.

These are only shown in class 6a, whereas in the other land classes they are shown as an impurity.

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CHAPTER 4

PEDOLOGY

4.1 Parent Material

The mode of occurrence and nature of the soil parent material has already been discussed in some detail in the section on Geomorphology, Chapter 2.

As already stated, it is strongly suspected that the horizons observed within the examined maximum depth of 3 metres are depositional and not pedogenic, giving a recurring AC horizon type of profile in which the A characteristics are probably only very weakly developed.

The main parent material is an alluvial montmorillonitic clay with locally more sandy areas of variable clay percentage usually associated with relic stream channels. The clay is considered to be an alluvial deposit of the Blue Nile, and the relic channels are probably former courses of the river.

4.2 Physical Characteristics of the Soils

4.2.1 Since the physical characteristics of the soils were recorded by six different surveyors, standardisation of field estimates of the soil characteristics was somewhat difficult. Texture, consistency and visible salts gave no great discrepancies, but it is almost impossible to completely standardise estimates of colour. Slight difficulty in this way was also experienced in the case of estimation of structure.

It was impossible to describe accurately rooting depth and structure from bore sites, so that estimations were used only from pits. Consistency was noted for bore sites, but could only be done rather generally, and more accurate estimates could be made in pits.

4.2.2 Texture

The assessment of texture in the field gave, in general, no difficulty. Some difficulties did arise in estimating textures of Entisols and the very fine sandy clays often found in the substrata of the Vertisols. When there was any doubt about the texture of these substrata, samples

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were taken for mechanical analysis. In pits, all visible horizons were sampled.

The soils are generally fine textured, except in the case of the Entisols, which often show a coarse sandy clay or light clay with much coarse sand.

Table 4.1 shows the distribution of clay percentages for all routine sites in the area for the fixed depths 0-45 cm and 45-90 cm.

Table 4.1 Percentage of total sites within each clay per cent range

Depth	0-35%	35-50%	50-60%	60-70%	>70%
0-45 cm	1	8	21	50	20
45-90 cm	1	9	23	50	17

The average clay percentage is therefore around 65 and the upper horizon is frequently of a higher percentage than the lower horizon which gives the impression that it may be a different depositional layer.

It is very doubtful if there is any leaching of clay, because no clay coatings have been found, although clay may have been washed into cracks.

The low percentage ranges 0-35 and 35-50 occur in the point-bars of the old meander channels. These soils were classified as Entisols, both Vertic and non Vertic Orthustents, although they are a small percentage of the total area. The clay percentage in area 2B is in general higher than in 2A.

A one metre bore for examination was made in the bottom of all pits. The texture was found to be clay, except in the area between the old meander gullies.

4.2.3 Colour

It appears that there is an increase of Aquerts towards the south while in the north (areas 1 and 2) the Usterts dominate.

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The second horizon has a slightly darker colour than the top and the third horizon is darker still, in the range very dark grey (10YR 3/1) to dark grey (10YR 4/1).

The substratum if present (in Aquerts in pronounced depressions it is often absent) has colours varying between dark grey brown (10YR 4/2) and grey brown (10YR 5/2).

The colours with hue 10YR are often intergrading to the hue 2.5Y with the same values and chromas.

Mottling is found mainly in the substratum and in the lower part of the third horizon and is in the colour range yellowish brown (10YR 5/4-5/6) to brown (7.5YR 4/3-4/4).

Attempts to correlate soil colour and alkalinity have met with only limited success, mainly in areas where there are obvious depressions. In these cases, the alkaline soils usually show top horizon colours in the very dark grey (10YR 3/1) to dark grey (10YR 4/1) range, i.e. within the Aquerts. The strongly shedding sites along the edges of depressions are nearly always non-alkaline and belong to the subgroup of the Usterts.

4.2.4 Structure

The high degree of swelling and shrinking of these montmorillonitic clay soils is the main factor controlling structure. The more obvious structural elements are confined to, on the average, the top 60 cm of the profile which Bunting and Lea (1962) suggest is the average maximum depth of soil circulation in the Fung. In the wetter, more poorly drained areas in the south, this depth is often less.

In the dry season, the soil contracts, giving vertical cracks which may reach a depth of 120-150 cm, but, in the majority of cases,

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In the dry season, the soil contracts, giving vertical cracks which may reach a depth of 120-150 cm, but, in the majority of cases,

do not extend beyond 70 cm, with a maximum intensity in the top 40-50 cm. The cracking depth is likely to be controlled by depth of water percolation.

These cracks define a coarse prismatic structure which is further broken down to a coarse sub-angular or angular blocky structure by a series of fairly fine horizontal cracks and fissures. This is mainly confined to the top 40-50 cm. At the bottom of the horizon a platy structure may occur. Pit 1533 showed an extremely high cracking capacity up to 80-90 cm deep. The reason is not known. The site is situated in a depression, has a high clay percentage and an E.S.P. of 17 in 0-45 cm and 45-90 cm; but other sites in relatively the same situations did not show these very large cracks.

Structure is weakly developed. The top 80 cm is very coarse prismatic with a secondary platy and angular to sub-angular blocky structure.

The second horizon shows a weak coarse angular blocky structure with few wedges. The slickensides are very well developed.

The third horizon shows no structure.

The top 40 cm is very hard and dry, then moist and firm. 150-300 cm is wet and non plastic. A second structural horizon occurs to a depth of between 70-90 cm, in which the vertical cracking is much less intense than in the top 40-50 cm. A very coarse prismatic structure is still apparent with weak development of very coarse angular blocky structure. A further structural element is a medium to coarse platy structure, very variable in intensity and degree of development. When well developed, this platiness shows cleavage planes with slightly polished slickenside faces, usually discontinuous, and at an angle from the horizontal. When less well developed, the actual structural elements are very difficult to separate and show little or no cleavage surface polishing, although the grain of the platy structure is still very obvious on the profile face. Slickensides may occur in this horizon.

In the horizon immediately overlying the substratum, obvious cracking is absent. Structure is only very weakly developed, but slickensides occur in most of the profiles, usually fairly well developed. Structure of the substratum is depending on the texture, which is in general clay. When composed of clay, this horizon may show the same

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The top 40 cm is very hard and dry, then moist and firm. 150-300 cm is wet and non plastic. A second structural horizon occurs to a depth of between 70-90 cm, in which the vertical cracking is much less intense than in the top 40-50 cm. A very coarse prismatic structure is still apparent with weak development of very coarse angular blocky structure. A further structural element is a medium to coarse platy structure, very variable in intensity and degree of development. When well developed, this platiness shows cleavage planes with slightly polished slickensided faces, usually discontinuous, and at an angle from the horizontal. When less well developed, the actual structural elements are very difficult to separate and show little or no cleavage surface polishing, although the grain of the platy structure is still very obvious on the profile face. Slickensides may occur in this horizon.

In the horizon immediately overlying the substratum, obvious cracking is absent. Structure is only very weakly developed, but slickensides occur in most of the profiles, usually fairly well developed. Structure of the substratum is depending on the texture, which is in general clay. When composed of clay, this horizon may show the same

structure as the overlying horizon, especially in the top but in most cases structure is only weak angular blocky.

Where the texture is coarser, the structure shows a very weak fine blocky structure development. Vertic Orthustents show similar structural trends to those described for the Vertisols order, but are less well developed and have a lower clay content.

Structure has been used as a factor in the soil classification only in the separation of the Entisol and Vertisol Orders. In the classification at Great Group and Sub-groups levels, structure has been found to be less definitive than other factors, although some general trends are apparent. The drier Usterts normally show a somewhat better development of structure than the wetter Aquerts, especially the Mazaquerts which normally show a very corase, weakly developed structure. Differences in structure, apart from variations in clay content are probably due to differences in moisture regimes and alkalinity levels.

4.2.5 Soil Consistence

Consistence in this area falls mainly within two standard moisture contents, dry and moist. It was found convenient to sub-divide the second of these into moist and slightly moist, since, in many profiles, it was found that there is a slight moisture gradient within the top 60-70 cm, the top 30 cm being air dry and the next 30-40 cm being slightly moister than this, but still exhibiting characteristics of consistence similar to those for the dry soil. In fairly pronounced depressional sites, the middle horizon(s) of the profile are often in the wet moisture content range, but these constitute a small minority. The vast majority of horizons below the depth 0-60 or 70 cm are moist.

The consistence is related to structure and in the better structured, dry surface horizons the consistence is, at worst, classed as hard. Where structure is weaker, the consistence is normally very hard. The slightly moist soils are generally slightly less hard than the true dry ones.

Within the moist range, the soils become firmer with depth with maximum degree of consistence occurring within the average depth 90-150 cm. At this depth the soils are generally very firm, and, in many

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cases, extremely firm. There seems to be less correlation between the wedge structure and consistence of this horizon than in the case of the more obvious structures of the top horizon.

In the substratum, the degree of consistence is generally less and has usually been classed as firm.

Many of the more sandy entisols show varying degrees of cementation in the sub-surface horizons, some of which have been classed as indurated.

It is uncertain to what extent consistence and clay percentage can be correlated apart from the fact that soils with more than 45 per cent clay have never shown any signs of cementation.

4.2.6 Visible Salt Accumulations

The salts visible in field inspection of the profiles are calcium carbonate and gypsum.

Gypsum is virtually absent from the profiles in Area 2B; only rarely has it been seen in the substratum and even more rarely in the middle horizons. In the substratum, when it occurs, the gypsum is in the form of fairly large, platy or lenticular crystals with dull faces. On the few occasions gypsum has been noted in other parts of the profile it occurs in the depth 100-150 cm and forms small, rather acicular crystals with shiny crystal faces.

Calcium Carbonate is present in six different forms.

(i) Very hard grey sub-angular aggregates usually 1 cm in diameter but occasionally reaching 3 cm.

(ii) Small, very hard, very rounded, whitish aggregates up to 1 cm, but usually less than 0.5 cm.

(iii) Hard, sub-angular whitish aggregates up to 3 cm in diameter.

(iv) Easily fragmented light coloured aggregates up to 3 cm in diameter.

(v) Small, hard, very rounded dark brown to black aggregates.

(vi) Very small crystals occurring as streaks or distributed diffusely through the soil matrix.

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(vi) Very small crystals occurring as streaks or distributed diffusely through the soil matrix.

(i) The dark grey, sub-angular aggregates are found on the surface of the soil and in the top part of the profile. This concentration in the top part of the profile suggests that they have been so concentrated as a result of the self-mulching circulation within the top 60 cm of the profile, allowing the coarse aggregates to remain near the surface while the finer material is washed down by rain-water or removed by wind action. These aggregates are found in the profiles only in the north of the area. It has been suggested that the dark colour of these aggregates is due to a very thin skin of manganese, perhaps formed around the calcium carbonate during deposition of the carbonate in the soil matrix. Another theory is that the skin is formed by small quantities of manganese in the aggregate migrating outwards towards the surface.

(ii) Over most of the area, the main calcium carbonate aggregates in the upper part of the profile are small, hard, very rounded whitish concretions. They occur mainly in the upper 70-90 cm and are found only occasionally below that depth. These may be a secondary carbonate deposition. They seem to replace the large manganese stains aggregates in higher rainfall areas.

(iii) and (iv) These large white aggregates are found nearly always in a fairly narrow band in the profile, near the bottom of the third horizon and in the top of the substratum between 150 and 180 cm. They do occur occasionally scattered through the profile below this depth, but very seldom above it. They have, generally, a very irregular shape and show no evidence of manganese or other dark coloured skin. The two types of aggregates which occur at this depth, often together, seem to differ in their internal structure, the easily fragmented ones having a system of near radial cracks. They occasionally possess a small hard core. The concentration of these aggregates may indicate a lengthy period of swamp conditions during a stage in the deposition of the clays. In areas of strong gilgai formation, these large irregular aggregates have been found on the surface. This, as in the case of (i), may indicate some sort of soil circulation, although it is difficult to imagine movement from the depths that these aggregates are usually found under present day conditions. High concentrations of these aggregates are also found in the light textured soils of the "kerrib" lands.

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(vi) In certain clay profiles and fairly frequently in sandy textures soils, the calcium carbonate occurs in a fairly fine crystalline form disseminated through the soil matrix, or concentrated into vertical streaks. This is not a common occurrence. In the browner colour of the substratum, diffuse dark stains are found which may also be due to manganese deposition. These may occur elsewhere in the profile, but their presence may be masked by the soil colour.

4.2.7 Hydraulic Conductivity

The variation of the hydraulic conductivity for various clay percentages for 39 pits in Area 2B is given in Table 4.2 below:-

Table 4.2 Hydraulic Conductivity Variation with Clay Percentage

Pit No.	Clay Percentage	Hydraulic Conductivity m/day/unit hydraulic gradient	
4216	45	0.020	45-90% clay
4438	47	0.010	average 0.0130
2381	49	0.0089	
2535	51	0.0074	
2541	54	0.015	
2519	56	0.015	
5657	56	0.00084	51-57% clay
4506	57	0.0062	average 0.0125
3517	57	0.016	
3536	57	0.0080	
2621	57	0.032	

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2519	55	0.015
5657	56	0.0084
4506	57	0.0062
3517	57	0.018
3536	57	0.0080
2621	57	0.032

Pit No.	Clay Percentage	Hydraulic Conductivity m/day/unit hydraulic gradient	
5234	60	0.00036	
2364	60	0.021	
5634	61	0.010	
6256	61	0.058	
2537	61	0.022	
6147	61	0.032	
5194	62	0.0022	
3233	62	0.0093	60-69% clay
4269	62	0.012	average 0.0170
3557	62	0.24	
5295	63	0.0055	
2323	63	0.0044	
5334	63	0.00042	
5606	63	0.020	
5542	64	0.020	
2279	65	0.0015	
1399	65	0.050	
6230	66	0.030	
1415	67	0.012	
2568	69	0.0064	
5535	69	0.031	
1193	70	0.0069	
4171	70	0.013	
3202	70	0.026	70-77% clay
5597	71	0.0090	average 0.0156
1395	75	0.0012	
2220	77	0.013	
6201	77	0.040	

In view of the scattered location of land surveyed in area 2B, it is considered inadvisable to draw conclusions from the Hydraulic Conductivity determinations. It is therefore recommended that the data contained in report No. 12 Area 2A be applied to Area 2B.

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In view of the scattered location of land surveyed in area 2B, it is considered inadvisable to draw conclusions from the Hydraulic Conductivity determinations. It is therefore recommended that the data contained in report No. 12 Area 2A be applied to Area 2B.

4.3 Chemical Characteristics of the Soils

4.3.1 Salinity

All soil samples were tested for salinity, using the saturation extract, the results being expressed as electrical conductivities in millimhos/cm at 25°C. However, only rarely was the E. C. critical for the classification of the soils. Table 4.3 summarises the distribution of salinity within the profile. This table indicates the predominantly low E. C. values, especially in the upper horizon. The increase in salinity between 45 and 90 cm infers either a leaching of salts down the profile or the existence of a different depositional layer. Earlier reports favour the former explanation.

Table 4.3 Salinity, as expressed by Electrical Conductivity in mmhos/cm in the 0-45 cm and 45-90 cm layers

E. C. in mmhos/cm	Frequency percentage (total sites)	
	0-45 cm	45-90 cm
0-< 1.0	78	37
1-< 1.5	9	20
1.5-< 2.0	7	17
2.0-< 2.5	2	14
2.5-< 3.0	2	35
3.0-< 3.5	1	1
3.5-< 4.0	-	25
> 4.0-	1	5

The relationship between salinity and total soluble cations is illustrated in Figure 4.1. The straight line shows a 1:16 relationship between E. C. and total soluble cations. A similar graph compiled by

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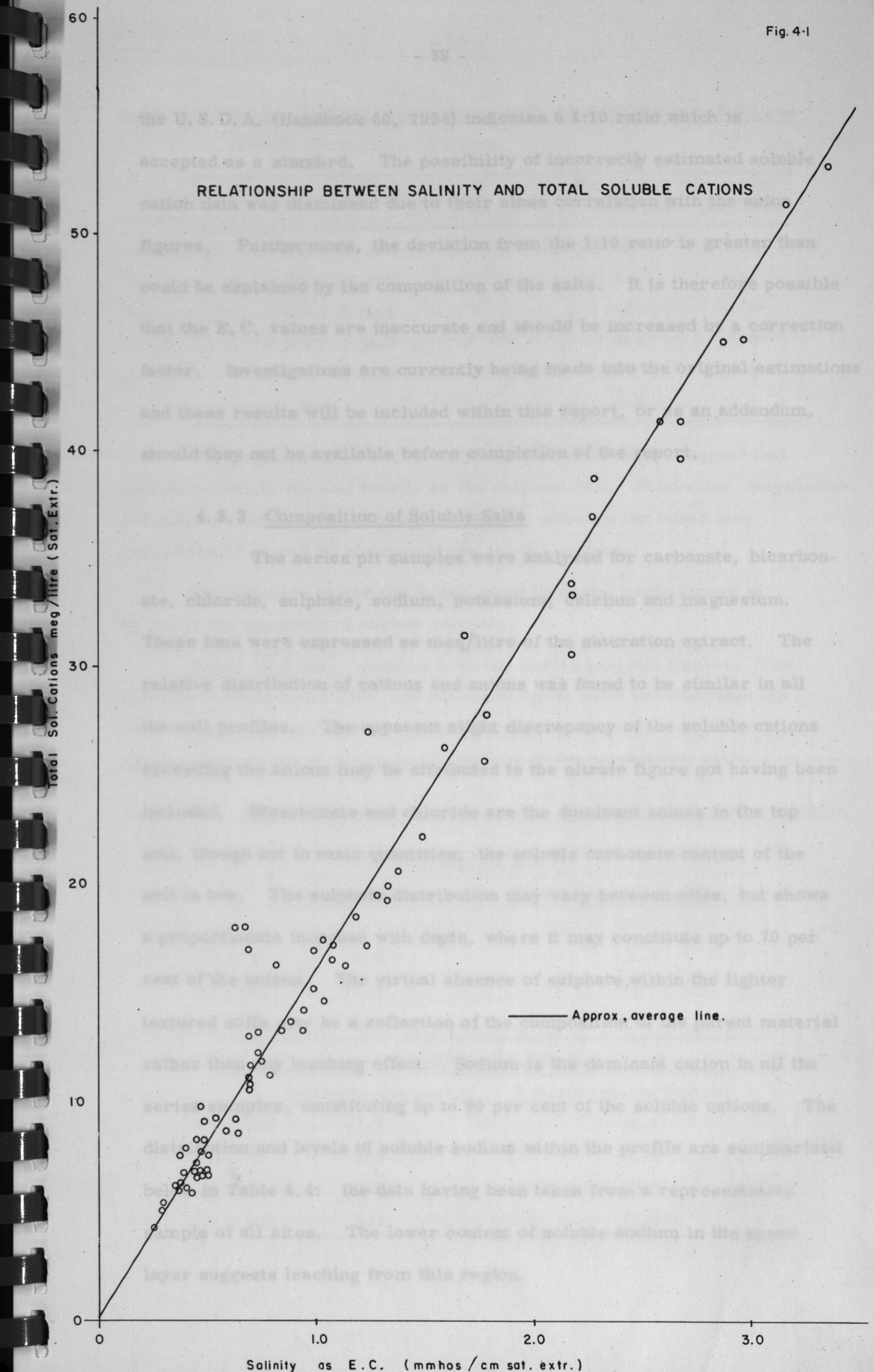
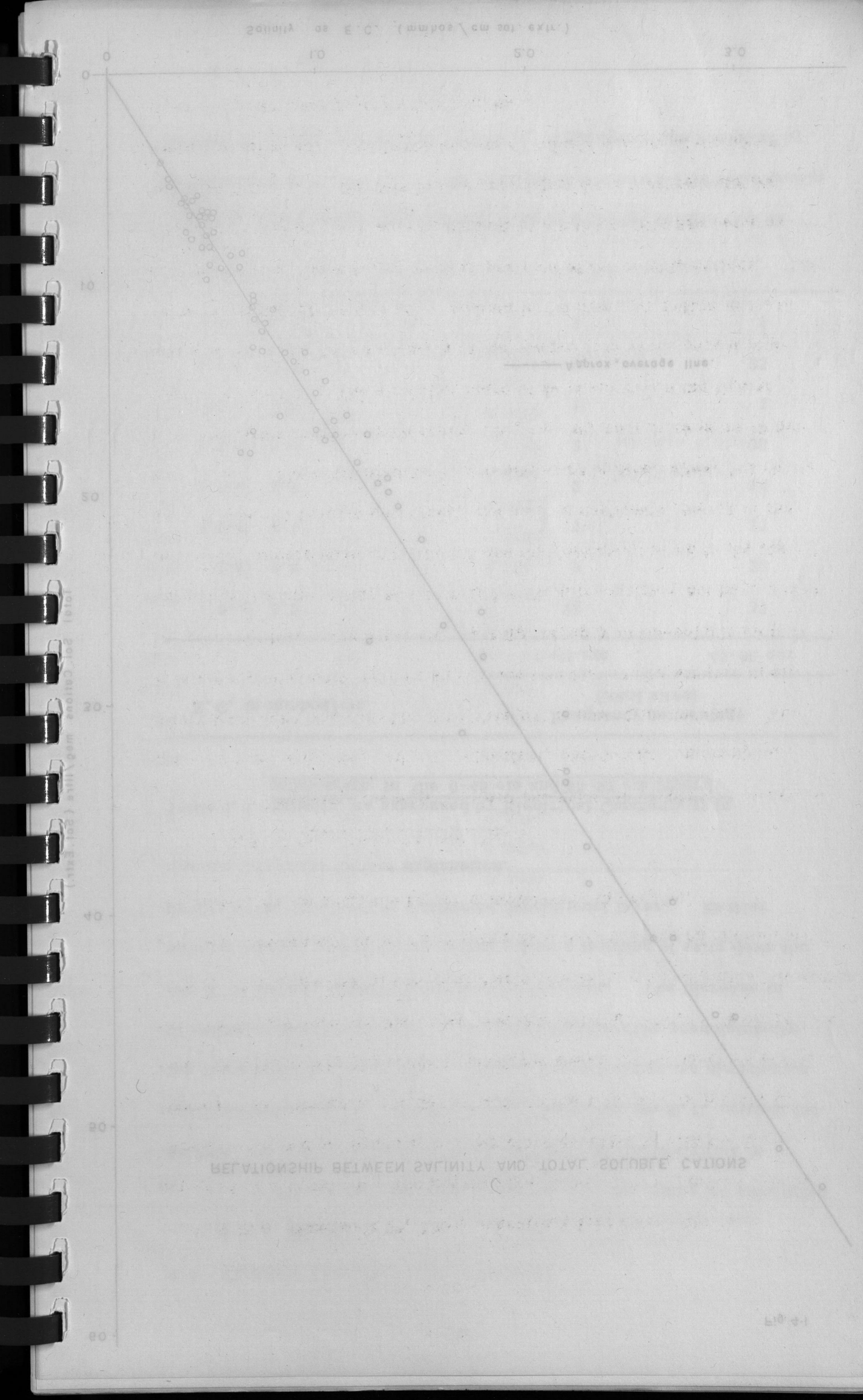
Fig. 4·1


RELATIONSHIP BETWEEN SALINITY AND TOTAL SOLUBLE CATIONS
Total Sol. Cations meg/litre (Sat. Extr.)
60
50
40
30
20
10
0
0
1.0
2.0
3.0
Salinity as E.C. (mmhos / cm sat. extr.)
Approx. average line.



the U. S. D. A. (Handbook 60, 1954) indicates a 1:10 ratio which is accepted as s standard. The possibility of incorrectly estimated soluble cation data was dismissed due to their close correlation with the anion figures. Furthermore, the deviation from the 1:10 ratio is greater than could be explained by the composition of the salts. It is therefore possible that the E. C. values are inaccurate and should be increased by a correction factor. Investigations are currently being made into the original estimations and these results will be included within this report, or as an addendum, should they not be available before completion of the report.

4. 3. 2 Composition of Soluble Salts

The series pit samples were analysed for carbonate, bicarbonate, chloride, sulphate, sodium, potassium, calcium and magnesium. These ions were expressed as meq/litre of the saturation extract. The relative distribution of cations and anions was found to be similar in all the soil profiles. The apparent slight discrepancy of the soluble cations exceeding the anions may be attributed to the nitrate figure not having been included. Bicarbonate and chloride are the dominant anions in the top soil, though not in toxic quantities; the soluble carbonate content of the soil is low. The sulphate distribution may vary between sites, but shows a proportionate increase with depth, where it may constitute up to 70 per cent of the anions. The virtual absence of sulphate within the lighter textured soils may be a reflection of the composition of the parent material rather than any leaching effect. Sodium is the dominant cation in all the series samples, constituting up to 80 per cent of the soluble cations. The distribution and levels of soluble sodium within the profile are summarised below in Table 4. 4: the data having been taken from a representative sample of all sites. The lower content of soluble sodium in the upper layer suggests leaching from this region.

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Table 4.4 Soluble Sodium Distribution within the 0-45 cm and 45-90 cm layers

Sol. Na Ranges meq/100 gm soil	Frequency percentage 0-45 cm	45-90 cm
0 - < 1.0	82	50
1.0 - < 2.0	14	34
2.0 - < 3.0	2	9
3.0 - < 4.0	0.5	4
4.0 - < 5.0	1	2
> 5.0	0.5	1

The preponderance of this cation and sulphate would suggest that sodium occurs in the soil mostly as the sulphate salt. Potassium, magnesium and calcium are present in small quantities, although the latter may exceptionally exceed 10 per cent of the soluble cations.

The increase in salinity in the lower horizons would appear to be due to the presence of sodium sulphate.

Table 4.5 was compiled from the series analysis figures. The division between natrargidic and non-natrargidic soils demonstrates the near identical proportions of the soluble cations, but emphasises the greater importance of exchangeable sodium in the natrargidic soils.

Table 4.5 Soluble and exchangeable cations. Average of all series samples

Natrargidic Soils		
	% Soluble Cations	% Exchangeable Cations
Na	79.9	26.4
K	1.6	2.6
Ca	11.4	47.1
Mg	5.6	24.6

Non-natrargidic Soils		
	% Soluble Cations	% Exchangeable Cations
Na	81.0	18.6
K	1.5	3.2
Ca	12.5	50.8
Mg	5.1	27.6

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4.3.3 Exchangeable Cations and Exchange Capacity

4.3.3.1 Exchangeable Cations

Sodium is the most important exchangeable cation in these soils. To correlate soluble with exchangeable sodium, the presence of other ions must be taken into consideration. The sodium-absorption-ratio (S.A.R.) has been suggested to give the relationship of soluble sodium to other soluble ions, which can inhibit the effect of Na^+ on the soil exchange complex. These are ions with valencies greater than 1, predominantly Ca^{++} and Mg^{++}; Schofield's Law describes the relationship between ions of different valencies, in solution, and their effects on the exchange complex.

It has been suggested (USDA, 1954) that a linear relation exists between the monovalent-divalent cation ratio of the exchange complex, and the soluble salts when the concentration of soluble monovalent cations is divided by the square root of the concentration of the divalent ions.

viz: Exchangeable Sodium Ratio

$$\text{S.A.R.} = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} \propto \text{E.S.R.} = \frac{\text{Exch. Na}}{\text{C.E.C. - Exch. Na}}$$

A linear relationship obtained from this expression has been used by the U.S.D.A. to construct a nomogram for the direct estimation of soil E.S.P. values from the soluble Na, Ca and Mg data of the soil solution. Figure 4.2 demonstrates that although a linear relationship exists for the present data, the regression slopes are dissimilar to those prepared by the U.S.D.A. for the compilation of the nomogram. The non-natrargidic values showed less scatter (r=0.88) than those for the natrargidic soils (r=0.69).

In order to clarify this point, a comparison was made between the calculated E.S.P.'s and those measured from the clay percentage and exchangeable sodium data. Although this showed a broad correlation between the two, the mean calculated values were 57 per cent below the mean measured values. Reviewing the figures relating to horizons of exceptionally high sodium content did not improve the relationship. Thus a fundamental difference appears to exist between the soils of the Sudan clay plains and those from which the nomogram was compiled. It is

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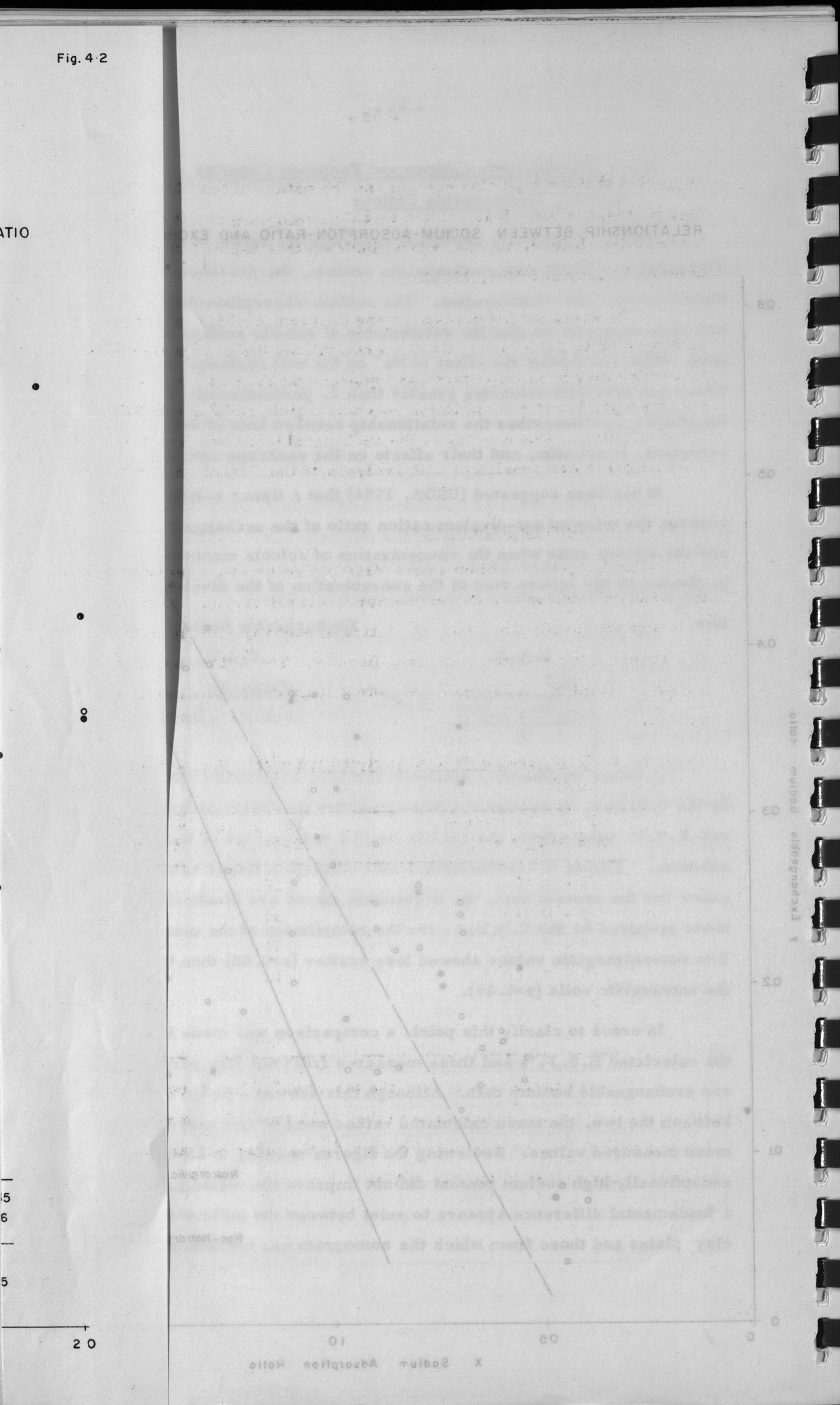
$$\frac{E.S.R.}{\text{Excp. } Na} \propto \frac{S.A.R.}{\sqrt{\frac{Na^{+}}{\frac{Ca^{++} + Mg^{++}}{2}}}}$$

A linear relationship obtained from this expression has been used by the U.S.D.A. to construct a nomogram for the direct estimation of soil E.S.P. values from the soluble Na, Ca and Mg data in the soil solution. Figure 4.5 demonstrates that although a linear relationship exists for the present data, the regression slopes are significant to those prepared by the U.S.D.A. for the completion of the nomogram. The non-saturation values showed less scatter (88.0=r) than those for

Fig.4.2

Fig. 4·2



suggested that the high clay content and the nature of the clay minerals may be responsible. It is evident that the nomogram is not applicable to these soils. Indeed, recent reports indicate that relationship is not universal (Levy and Mor, 1965).

The averaged proportions of the different exchangeable cations are summarised in Table 4.5. Calcium constitutes the dominant cation, a fact which may have important consequences on the soil structure. The lower proportion of sodium in the non-natrargidic soils is compatible with their definition. One quarter of the exchangeable cations are magnesium. These figures are consistent with analyses of the Gezira soils (Jewitt, 1955).

4.3.3.2 Exchangeable Sodium

Exchangeable sodium as meq/100 gm soil was determined for the top standard horizons of all routine bores and all horizons of pit sites. This was necessary since the calculation of exchangeable sodium percentage was required for soil and land classification. The following table (4.6a) shows the level of exchangeable sodium and its distribution down the profile.

Table 4.6a Exchangeable Sodium Distribution within the 0-45 and 45-90 cm layers

Exch. Na Ranges meq/100gm soil	Percentage frequency 0-45 cm	45-90 cm
0 - < 5	18	5
5 - < 10	33	22
10 - < 15	31	41
15 - < 20	13	21
20 - < 25	5	9
> 25	0.5	3

Whereas in the upper layer the modal value lies between 5 and 10 meq/100 gm soil, it increases to the 10-15 meq/100 gm range lower in the profile. The proportion of sodium to the other exchangeable cations is illustrated in the next table.

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Table 4.6a Exchangeable Sodium Distribution within the 0-45 and 45-90 cm layers

Exch. Na Ranges meq\100gm soil	Percentage frequency 0-45 cm	45-90 cm
0 - < 5	18	5
5 - < 10	33	22
10 - < 15	31	41
15 - < 20	13	21
20 - < 25	5	9
> 25	0.5	3

Whereas in the upper layer the modal value lies between 5 and 10 meq\100 gm soil, it increases to the 10-15 meq\100 gm range lower in the profile. The proportion of sodium to the other exchangeable cations is illustrated in the next table.

Table 4.6b Exchangeable sodium percentage in the 0-45cm and 45-90cm layers

E.S.P. Range	Percentage frequency (total sites)	
	0-45 cm	45-90 cm
0 -< 5	8.7	2.8
5 -< 10	15.3	3.8
10 -< 15	23.0	16.8
15 -< 20	23.3	28.0
20 -< 25	13.9	20.6
25 -< 30	7.5	12.6
30 -< 35	5.9	7.4
> 35	2.4	8.0

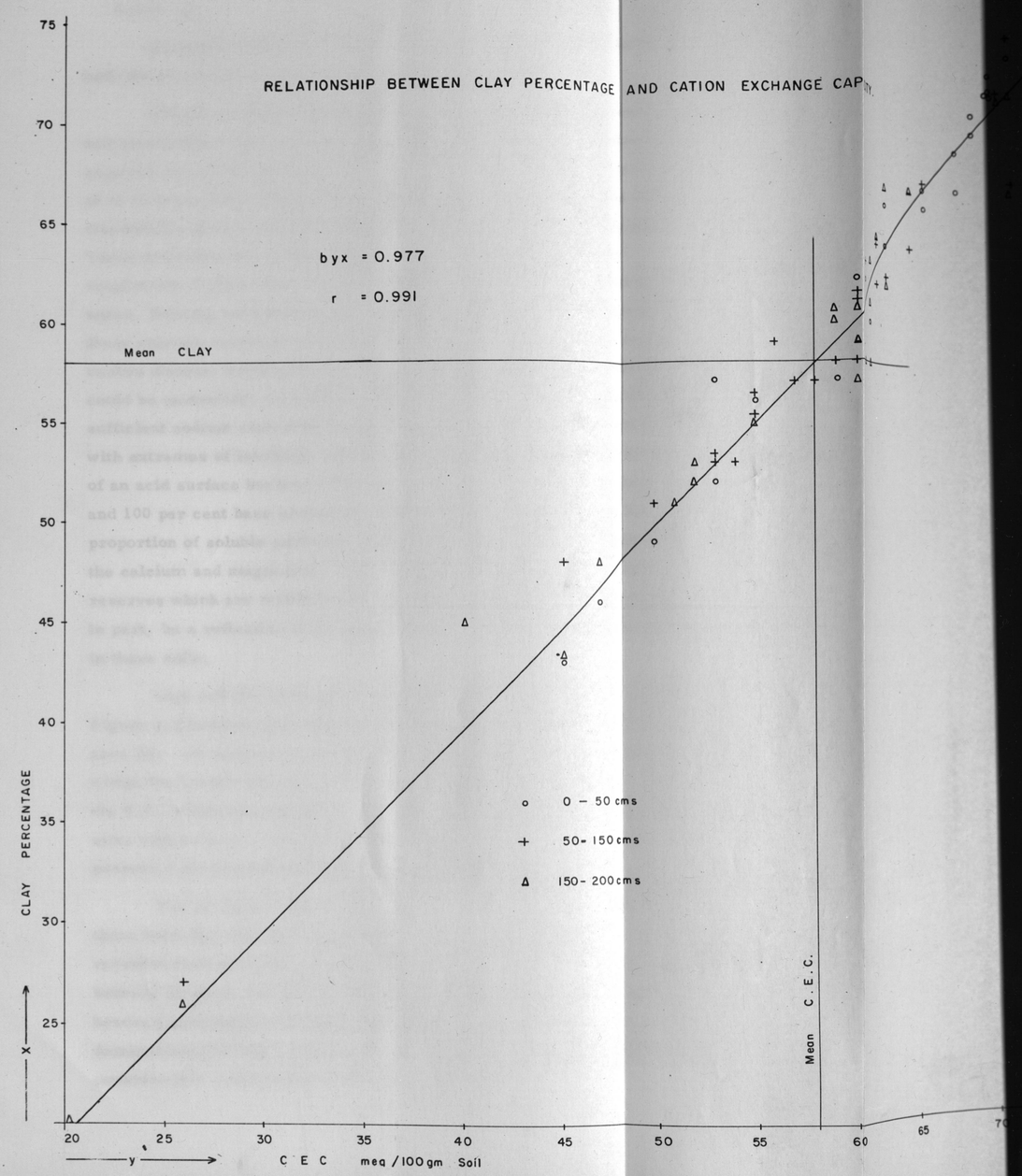
The above tables show both relative and absolute increases in exchangeable sodium with depth as compared with other exchangeable cations. This may indicate that sodium is being more readily translocated from the clay complex than other cations, which would concur with standard theory.

4.3.3.3 Exchange capacity

The cation exchange capacities were measured on all pit samples. The graph (figure 4.3) demonstrates the strong correlation (r=0.99) between C.E.C. and the clay content throughout three arbitrarily chosen horizons. Allowing for the slight margin of error to be expected from C.E.C. estimations, the series analyses is not a feature of these soils since sodium is replaced on the exchange complex by other cations and not hydrogen.

In a few cases, it has been found that the use of clay percentage rather than C.E.C. has caused slight discrepancies in the soil classification between natrargidic and non-natrargidic sites: e.g. In one pit, an exch. Na. value of 7.4 meq/100 gm and a C.E.C. of 46 gives an E.S.P. of 16, while the E.S.P. calculated from the clay percentages of 51 for the same horizon gave an E.S.P. of less than 15. In the first case the soil would be natrargidic and, in the second, non-natrargidic. This applies only to a few cases where the E.S.P. is near 15.

Fig. 4.3


RELATIONSHIP BETWEEN CLAY PERCENTAGE AND CATION EXCHANGE CAPACITY.
byx = 0.977
r = 0.991
Mean CLAY
Mean C.E.C.
o 0 – 50 cms
+ 50- 150 cms
Δ 150- 200 cms
CLAY PERCENTAGE
x
y
C E C meq / 100 gm Soil
75
70
65
60
55
50
45
40
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20
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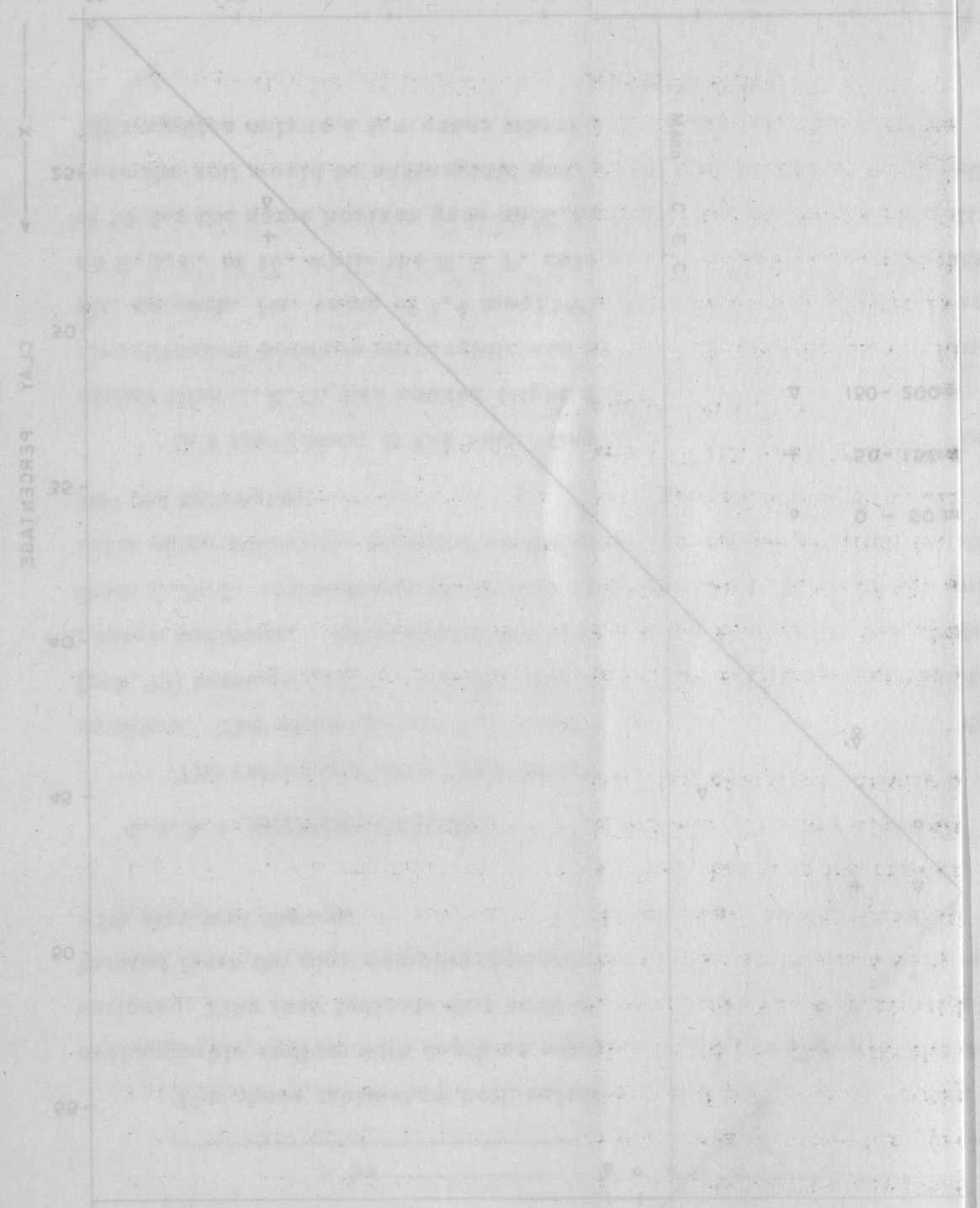
70



4.3.4 pH

pH determinations were performed on all pit samples, using both the soil paste and the 1:5 suspension in each case.

The pH readings for the saturated soil paste rarely exceed 8.4 and rarely fall below 7.4. This range is lower than would normally be expected for alkali soils (U.S.D.A., 1954), where an E.S.P. in excess of 15 is associated with a pH of at least 8.5. The lower figures may be attributable to the relatively large free calcium reserves in the soil. These neutralise the carbon dioxide, which originates from the respiration of plant roots and soil organisms and from percolating rain-water, forming relatively inert calcium carbonate. In the absence of these calcium reserves one of two processes may occur. The dissolved carbon dioxide, existing in the soil as carbonate and bicarbonate anions could be neutralised by sodium from the exchange complex, producing sufficient sodium carbonate to raise the soil pH above 9. Alternatively, with extremes of leaching, solodisation could proceed with the formation of an acid surface horizon. However, since there is a minimal leaching and 100 per cent base saturation in these clay soils and a very low proportion of soluble carbonate and bicarbonate anions in relation to the calcium and magnesium, it is assumed that it is the free calcium reserves which are modifying the pH values. The low alkalinity may, in part, be a reflection of the generally low chemical activity occurring in these soils.

High salinity is known to depress pH readings, yet the graph in Figure 4.4 demonstrates that this is not the reason for low alkalinity in area 2B. No value exceeds pH 8.5 even at an E.S.P. of 40, although within the scatter high E.C. values do reduce the pH slightly. If it was the E.C. which was responsible for the generally low pH values, then sites with an E.S.P. exceeding 20 and an E.C. less than 1.0 should possess a pH greater than 8.5: this does not occur.

The pH figures obtained from the 1.5 suspension are higher than those from the soil paste, due to the dilution effect. There is very little variation between sites. A comparison between E.S.P. and the difference between pH paste and pH 1:5 suspension failed to show a correlation between natrargidic soils and a difference in excess of 1, as has been demonstrated by the U.S.D.A. (1954). However, these workers did not consider this relationship to be universally valid.

pH determinations were performed on all pit samples, using a 1:1 soil paste and the supernatant liquid.

The pH readings for the saturated soil paste rarely exceed 8.3 but are usually above 7.4. This range is lower than known criteria for alkali soils (U.S.D.A., 1951), where an E.S.P. of 10 is expected for alkali soils (U.S.D.A., 1954), although the E.S.P. may be responsible for the generally low pH values, when within the sensitive high E.C. values do reduce the pH slightly. It is also associated with a pH of at least 8.2. The lower figures may be attributable to the relatively large free calcium reserves in the soil. These neutralise the carbon dioxide, which originates from the respiration of plant roots and micro organisms and from percolating rain-water, forming relatively inert calcium carbonate. In the absence of these calcium reserves one of two processes may occur. The dissolved carbon dioxide, existing in the soil as carbonate and bicarbonate anions could be neutralised by cations from the exchange complex, producing sufficient caustic to raise the soil pH above 9. Alternatively, with extremes of leaching, solonisation could proceed with the formation of an acid surface horizon. However, since there is a minimal leaching and very low exchangeable sodium percentage in these clay soils a pH of 10 or more would be necessary to solonise carbonate and bicarbonate anions in relation to the calcium and magnesium. It is assumed that it is the free calcium reserves which are mobilising the pH values. The low alkalinity may in part, be a reflection of the generally low chemical activity occurring in these soils.

High salinity is known to depress pH readings, yet the range in salinity is demonstrated that this is not the reason for low alkalinity although the E.S.P. of 10 is as high as 25. No value exceeds pH 8.2 even at an E.S.P. of 40. The total salt content is also relatively low, rarely exceeding 0.5 and an E.C. less than 1.0 mmho/cm at 25°C. exceeding pH 8.3: this does not occur.

The pH figures obtained from the 1:2 suspension are higher than those from the 1:1 paste, due to the dilution effect. There is very little variation between sites. A comparison between E.S.P. and the difference between pH paste and pH 1:2 suspension plotted to show a correlation between sites but a difference in excess of 1. as has been demonstrated by the U.S.D.A. (1951). However, these workers did not consider this relationship to be particularly valid.

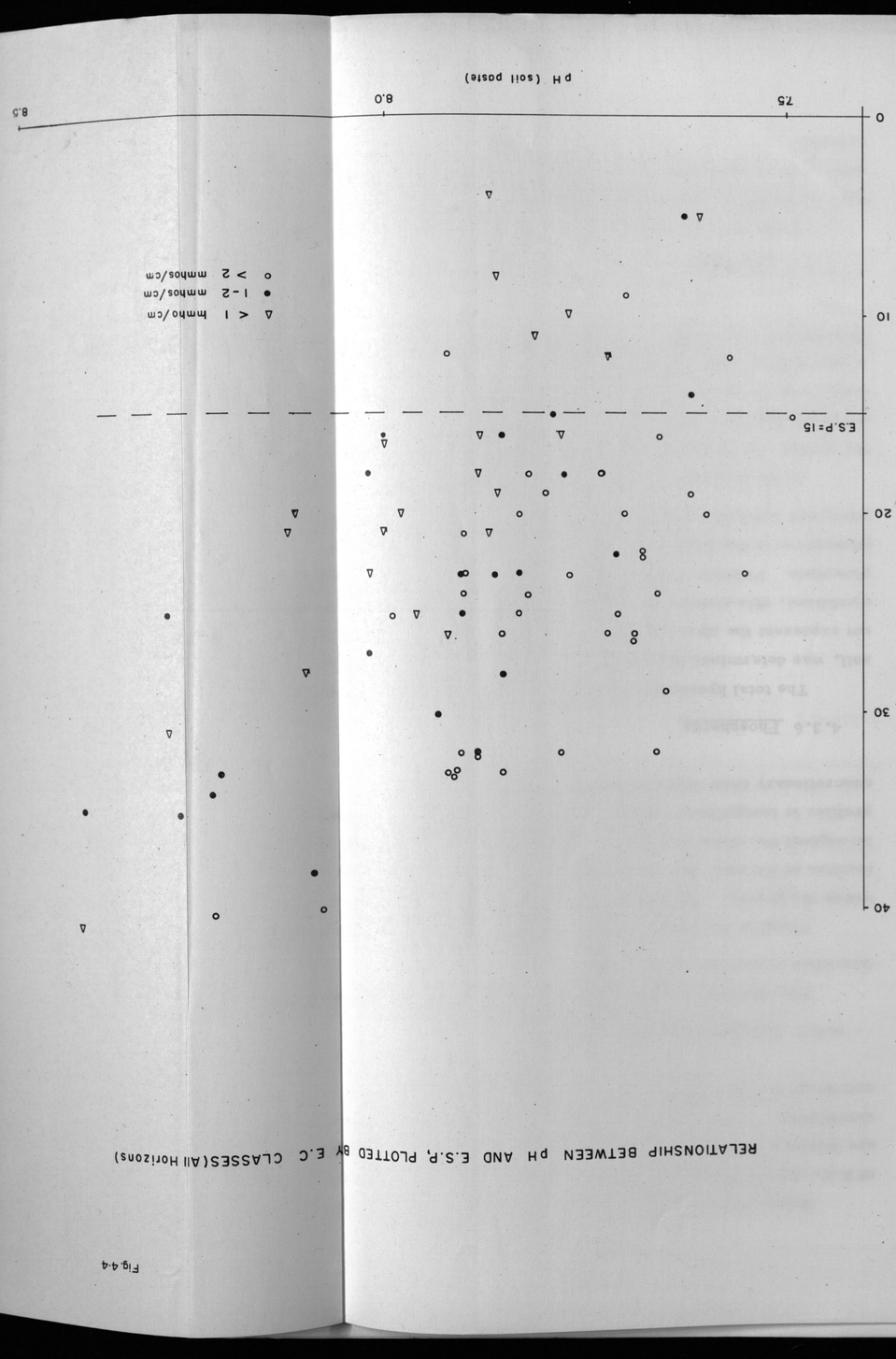


Fig.4.4

It has been suggested that E.S.P. can be measured on the basis of E.C. and pH (Dieleman, 1963). However, although higher E.S.P.'s are inferred by high pH, in this case, no definite relationship could be established. For example, by reference to figure 4.4 it can be seen that around pH 8.0 the soil E.S.P. may vary between 6 and 33.

4.3.5 Calcium carbonate and Gypsum

The distribution of visible calcium carbonate and gypsum has been described in section 4.2.6 of this report.

There is no chemical data concerning the distribution of gypsum within the profile. The amount of carbonate in the fine earth (<2 mm) fraction of the soil, the "incorporated carbonate", is generally constant throughout the series analyses. The slight increase with depth in some profiles is insignificant owing to the variable quantities of carbonate in concretionary form discarded during the dry sieving.

4.3.6 Phosphorus

The total hydrochloric acid extractable phosphorus, in mg/100 gm soil, was determined for all horizons of the series sites. This value does not represent the plant available phosphorus since, under such alkaline conditions, this element is probably combined as the di-or-tri-calcium phosphate. Previous work has shown that there is adequate available phosphorus in the Gezira soils and that there is no necessity for phosphate fertiliser on these soils, (Tothill, 1948; Peters, 1964).

At the majority of series sites phosphorus tends to increase down the profile, but frequently decreases within the lowest horizon. The averaged figures in Table 4.7 show a steady rise in phosphorus with depth from 35 mg/100 gm soil to 43 mg/100 gm. Evidence of leaching of phosphorus under similar conditions has been reported at Tozi (Bunting and Lea, 1962).

4.3.7 Potassium

Using the same extract as for the phosphorus determination, the total hydrochloric acid extractable potassium was estimated, in mg/100 gm soil. The amount extracted is dependent upon the duration of the extraction process.

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Although montmorillonite predominates in these soils, illite is also thought to occur. In the degraded form illite can "fix" potassium ions, especially when subjected to a wetting and drying cycle (Russel 1961). Fixation may also occur in montmorillonite under these conditions (Handbook 60, 1954). However, although much of the potassium extracted may have been in a "fixed" state in the soil, there is no evidence that it is limiting to plant growth in the Gezira (Tothill, 1952).

The extractable potassium values range from 200 to 600 mg/100 gm soil, rarely exceeding 700 mg/100 gm. The averaged data are shown in Table 4.7 below. Relative changes down the profiles in the exchangeable potassium are occasionally reflected in the extractable values, especially within the Entisol group. The exchangeable form, which is the primary source of potassium for plants, exhibits a variable distribution, averaging 2-3 per cent of the exchangeable cations: this is slightly higher than the 2 per cent average recorded in the Gezira (Jewitt, 1955), but the present figures include lower horizons.

Table 4.7 Averaged Extractable Phosphorus and Potassium values, by depth, of series samples

Approx. Depth cm	HCl extractable P in mg/100g	K mg/100g
0-50	35	386
50-150	39	424
150-200	43	410

4.3.8 Nitrogen

All series samples were analysed for nitrogen and the results represent the organic plus ammonium nitrogen in the soil.

Although nitrogen is fairly evenly distributed through the profiles, Table 4.8 indicates an average decline from 0.046 per cent at the surface to 0.035 per cent in the lowest horizon. The corresponding figure for surface horizons in the Gezira is 0.030 per cent (Jewitt, 1955). Such low values explain the great response to nitrogenous fertilisers by these soils.

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This nitrogen deficiency is emphasised by the C/N ratio, averaged figures for which appear in Table 4.8. Actual values vary between 15 and 33. The lower ratio in the upper horizon is probably as a result of decomposing organic matter in this zone. Sloughing and cracking may assist the distribution of decomposed material throughout the profile.

4.3.9 Organic Carbon

The organic carbon percentage was determined on all series samples. The small amounts of organic carbon (see Table 4.8) suggest that very little organic material is currently being added to the soil. The average quantity of organic matter, as calculated by multiplying the organic carbon by 1.72, remains fairly constant down the profile.

Table 4.8 Averaged values of Organic Nitrogen, Total organic carbon, C/N Ratio and Organic Matter

Approx. Depth cm.	Percentage, dry matter Org. Nitrogen	Total Org. Carbon	Organic Matter	C/N Ratio
0-50	0.046	0.83	1.43	18.0
50-150	0.039	0.76	1.30	19.4
150-200	0.035	0.70	1.20	20.0

4.4 Soil Classification

4.4.1 Definitions

The classification of the soils within the project area is based on the Seventh Approximation, U.S. Department of Agriculture. The definitions of the Orders, sub-orders, groups and sub-groups are as laid down in the Seventh Approximation, with the exception that the critical depth of 30 cm used in the Seventh Approximation has been extended to 45 cm in this survey following the use of 0-45 cm as the initial fixed depth sample in bore sites. Nine new sub-groups have been erected to accommodate soils not covered by the existing sub-groups described in the Seventh Approximation. These are in the case of soils which, although similar in all other respects to soils in the existing sub-groups, differ in having an E.S.P. of 15 or more in the upper 45 cm. These are indicated by the insertion of the word Natrargidic in the nomenclature.

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One further sub-group has been erected to include those Mazusterts which have a colour value of more than 3.5 in the upper 45 cm, Entic Mazusterts.

All classification units are shown in table 4.11.

4.4.2 Discussion of Soil Map Legend

In the compilation of the soil map, sub-groups have been set at series level, and where possible, have been mapped out as separate units.

However, because of the very complex pattern which arises even at sub-group level, it has been found necessary to erect two soil complexes. These complex units combine sub-groups which occur either with too high a degree of variability within a particular area to be mapped separately or have too high a percentage of the minor component to allow this to be regarded as an impurity within the unit. The degree of impurity allowed within a unit has been limited to 15%. This can be accepted in a semi-detailed survey with 1 observation per 250 feddans.

A further factor which has necessitated the use of soil complex units is the critical part soil colour plays in differentiating between the Ustert and Aquert sub-orders and the Entic and Orthic sub-groups. It has been found impossible to fully standardise the colour estimations of different surveyors and although colour differences due to this are very slight, they may be critical. Where the colour descriptions obviously vary slightly due to individual estimates and have given rise to different soil classes, these have been combined in one or more soil complexes.

Some difficulty was experienced in the project area in deciding what should constitute a mulch. Throughout most of the area, the soft surface layer does not fit the definition of a mulch as stated in the Seventh Approximation. This layer is composed of medium to fine sub-angular blocky structures with considerable pore space, often with a well formed thin rain-crust. For the purposes of classifying the soils, this has been considered as a mulch. Only soils with a definite hard, massive surface have been classed as Mazusterts or Mazaquerts. The Seventh Approximation admits the difficulty in defining easily determined limits to separate the self-mulching clays from the crusty clays since these obviously grade one to the other.

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Also the estimation of the mulch is done by different surveyors which could give some discrepancies.

A total of 19 sub-groups have been recognised and mapped as separate units along with 2 separate soil complex units. This comparatively high number of mapping units has made it necessary to limit the series at sub-group level.

The Sub-group Entic is introduced regarding the soil colour lighter than 3.5 and the relatively more weakly developed structure of these immature soils.

E.S.P. phases for the top 45 cm have not been mapped but are marked in the lists.

The frequency distribution of classified sites is shown below in Table 4.9.

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E.S.P. phases for the top 45 cm have not been mapped but are marked in the lists.

The frequency distribution of classified sites is shown below in Table 4.9.

Table 4.9 Frequency Distribution of Classified Sites in the Project Area

Site Classification	Number of Sites	Percentage of Total
A11	21	6.9
A12	11	3.6
A13	31	10.1
A14	26	8.5
A21	2	0.7
A22	1	0.3
+ A23	3	0.9
A24	6	2.0
B11	22	7.2
B12	13	4.2
B13	38	12.4
B14	74	24.3
B21	8	2.6
* B22	3	0.9
B23	10	3.3
B24	20	6.5
C21	2	0.7
* C22	5	1.6
C23	4	1.3
C24	6	2.0
Total	306	100.0

* Sub-group B22 has been mapped only as a complex or shown as an impurity and as sub-group C22 occurs only as a very small percentage of total sites. Therefore no series type analysis was undertaken.
+ Sub-group A23 has been regarded as intergrading towards A13 and A21 and therefore no complete analysis has been undertaken.

Pit and routine analysis for all sites can of course be found in appendices 1-3.

Table 4.2 Frequency Distribution of Classified Sites in the Project Area

Site Classification	Number of Sites	Percentage of Total
A11	21	6.9
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+ A23	3	0.9
A24	6	2.0
B11	22	7.2
B12	13	4.2
B13	38	12.4
B14	74	24.3
B21	8	2.6
* B22	3	0.9
B23	10	3.3
B24	20	6.5
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Table 4.10 Soil Complexes in Area 2B

Complex of A11 + A13

Complex of B11 + B13

4.4.3 Sub-Group Examples

Examples of the mapped sub-groups as written profile descriptions with series type chemical analysis are included in the Appendix 2. Where particularly appropriate examples were not available from the limited number of sites investigated in Area 2B then those from Area 2A have been drawn upon.

Table 4.10 : Soil Complexes in Area 2B

Complex of A11 + A13

Complex of B11 + B13

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Examples of the mapped sub-groups as written profile descriptions with series type chemical analysis are included in the Appendix 2. Where particularly appropriate examples were not available from the limited number of sites investigated in Area 2B then those from Area 2A have been drawn upon.

TABLE 4.11 CLASSIFICATION UNITS — ORDER - VERTISOLS

SUB ORDER	GREAT GROUP	SUB GROUP		MAPPING SYMBOL
A USTERTS (Drier climatic range) (Chroma more than 1.5 in top 30 cm)	A1 GRUMUSTERTS (self mulching surface)	ORTHIC GRUMUSTERTS	Non-alkali - E.S.P. below 15. Dark upper horizons, moist value less than 3.5	A11
		NATRARGIDIC GRUMUSTERTS	Alkali - E.S.P. exceeds 15.	A12
		ENTIC GRUMUSTERTS	Non-alkali. Pale upper horizon, moist value exceeds 3.5	A13
		ENTIC NATRARGIDIC GRUMUSTERTS	Alkali. Pale upper horizon, moist value exceeds 3.5	A14
	A2 MAZUSTERTS (crusty surface)	ORTHIC MAZUSTERTS	Non-alkali - E.S.P. below 15.	A21
		NATRARGIDIC MAZUSTERTS	Alkali- E.S.P. exceeds 15.	A22
		ENTIC MAZUSTERTS	Non-alkali. Pale upper horizons, moist value exceeds 3.5	A23
		ENTIC NATRARGIDIC MAZUSTERTS	Alkali. Pale upper horizon.	A24
B AQUERTS (subject to seasonal flooding) (Chroma less than 1.5 in top 30 cm)	B1 GRUMAQUERTS (self-mulching surface)	ORTHIC GRUMAQUERTS	Non-alkali - E.S.P. below 15. Dark upper horizon exceeds 30 cm	B11
		NATRARGIDIC GRUMAQUERTS	Alkali - E.S.P. exceeds 15	B12
		ENTIC GRUMAQUERTS	Non-alkali. Dark upper horizon less than 30 cm	B13
		ENTIC NATRARGIDIC GRUMAQUERTS	Alkali - Dark upper horizon less than 30 cm	B14
	B2 MAZAQUERTS (crusty surface)	ORTHIC MAZAQUERTS	Non-alkali - E.S.P. below 15. Moist value less than 3.5	B21
		NATRARGIDIC MAZAQUERTS	Alkali - E.S.P. exceeds 15	B22
		ENTIC MAZAQUERTS	Non-alkali. Pale upper horizons moist value exceeds 3.5	B23
		ENTIC NATRARGIDIC MAZAQUERTS	Alkali. Pale upper horizon.	B24

TABLE 4.11 CLASSIFICATION UNITS

ORDER - VERTISOLS

SUB ORDER	GREAT GROUP	SUB GROUP		MAPPING SYMBOL
	A1 GRUMUSTERTS (self mulching surface)	ORTHIC GRUMUSTERTS	Non-alkali - E.S.P. below 15. Dark upper horizons, moist value less than 3.5	A11
		NATRARGIDIC GRUMUSTERTS	Alkali - E.S.P. exceeds 15.	A12
		ENTIC GRUMUSTERTS	Non-alkali. Pale upper horizon; moist value exceeds 3.5	A13
		ENTIC NATRARGIDIC GRUMUSTERTS	Alkali. Pale upper horizon, moist value exceeds 3.5	A14
A USTERTS (Drier climatic range) (Chroma more than 1.5 in top 30 cm)	A2 MAZUSTERTS (crusty surface)	ORTHIC MAZUSTERTS	Non-alkali - E.S.P. below 15.	A21
		NATRARGIDIC MAZUSTERTS	Alkali - E.S.P. exceeds 15.	A22
		ENTIC MAZUSTERTS	Non-alkali. Pale upper horizons, moist value exceeds 3.5	A23
		ENTIC NATRARGIDIC MAZUSTERTS	Alkali. Pale upper horizon.	A24
	B1 GRUMAQUERTS (self-mulching surface)	ORTHIC GRUMAQUERTS	Non-alkali - E.S.P. below 15. Dark upper horizon exceeds 30 cm	B11
		NATRARGIDIC GRUMAQUERTS	Alkali - E.S.P. exceeds 15	B12
		ENTIC GRUMAQUERTS	Non-alkali. Dark upper horizon less than 30 cm	B13
		ENTIC NATRARGIDIC GRUMAQUERTS	Alkali - Dark upper horizon less than 30 cm	B14
B AQUERTS (subject to seasonal flooding) (Chroma less than 1.5 in top 30 cm)	B2 MAZAQUERTS (crusty surface)	ORTHIC MAZAQUERTS	Non-alkali - E.S.P. below 15. Moist value less than 3.5	B21
		NATRARGIDIC MAZAQUERTS	Alkali - E.S.P. exceeds 15	B22
		ENTIC MAZAQUERTS	Non-alkali. Pale upper horizons moist value exceeds 3.5	B23
		ENTIC NATRARGIDIC MAZAQUERTS	Alkali. Pale upper horizon.	B24

TABLE 4.11 (continued)

ORDER - ENTISOLS

SUB-ORDER	GREAT GROUP	SUB GROUP		MAPPING SYMBOL
C USTENTS (dry range)	C2 ORTHUSTENT (Pale surface horizon. coarse texture)	ORTHIC ORTHUSTENT	Less than 40% expanding lattice clay. Non-alkali	C21
		NATRARGIDIC ORTHUSTENT	Less than 40% expanding lattice clay. Alkali	C22
		VERTIC ORTHUSTENT	More than 40% expanding lattice clay. Non-alkali.	C23
		VERTIC NATRARGIDIC ORTHUSTENT	More than 40% expanding lattice clay. Alkali.	C24

TABLE 4.11 (continued)

ORDER - ENTISOLS

SUB-ORDER	GREAT GROUP	SUB GROUP		MAPPING SYMBOL
C USTENTS (dry range)	C2 ORTHUSTENT (Pale surface horizon. oarse texture)	ORTHIC ORTHUSTENT	Less than 40% expanding lattice clay. Non-alkali	C21
		NATRARGIDIC ORTHUSTENT	Less than 40% expanding lattice clay. Alkali	C22
		VERTIC ORTHUSTENT	More than 40% expanding lattice clay. Non-alkali.	C23
		VERTIC NATRARGIDIC ORTHUSTENT	More than 40% expanding lattice clay. Alkali.	C24

CHAPTER 5

LAND CLASSIFICATION

5.1 Specifications

The objective of the survey carried out was not only to produce a soil classification map but also a land suitability classification map for the purpose of 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.

If the specifications given in the U.S.B.R. Manual for a sample area in Colorado, quoted as an example, had been uncompromisingly adhered to without taking into account local conditions then virtually all the land surveyed would have been classified as 4, 5 and 6. This would have been due to the high exchangeable sodium levels prevalent in Sudan clay plains soils. On the other hand in the example given in the U.S.B.R. Manual an electrical conductivity of 8.0 mmhos was permissable in class 3 which under local conditions would be considered dangerously saline. In devising the classification for Sudan clay plains soils U.S.B.R. principles of land classification have been followed but the physical criteria for the limitations to each class have been arrived at from the international and local knowledge of the behaviour of the soils under irrigation.

The main difficulty has been the lack of adequate knowledge of actual local crop yields at specific levels of the three basic criteria i.e. clay percentage, salt content and exchangeable sodium percentage. This necessary research work is now being undertaken by the Soils Institute at Medani and the results will no doubt show that present criteria are rather harsh and economic crop growth is possible on some of the land presently downgraded to class 6. In the absence of detailed research findings it has been considered wiser to err on this side than risk the development of land which could turn out to be uneconomic.

5.2 Land Class Standards

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

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5.2 Land Class Standards

The following pages give 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 and the range of climatically adapted crops is probably somewhat limited. In addition the soils are low in nitrogen and organic matter.

Class 2

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" ---------" 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.

(i) Clay percentage

It has been suggested by Finck and Ochtman (1961) that there is a correlation between cotton yields 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 at 58 per cent clay. Therefore the position in regard to "heaviness" of soil is different in the clay plains to that appertaining to soils in many other areas where a very high clay percentage soil would be considered difficult to work and probably down-graded in relation to the lower clay percentage soils.

The explanation is that the "cracking" capacity of these montmorillonitic clays affects the depth and extent to which water can penetrate and therefore the more clay there is present the greater the cracking capacity. A lower limit of 50 per cent clay has therefore been used for the 0-45 cm zone of Class 2 soils.

In area 2B 90 per cent of sites show a favourable clay percentage; indeed, more than two thirds of these have a clay percentage greater than 60.

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Class 2

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" ---------- 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.

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In area 2B 90 per cent of sites show a favourable clay percentage; indeed, more than two thirds of these have a clay percentage greater than 60.

The validity of using Gezira results in this area is probably more questionable in regard to clay percentage than other criteria.

No correlation between clay percentage and structure was noted in the field and depth and extent of cracking were no greater at sites with 70 per cent clay than those with 50 per cent.

It could be, that under irrigation such correlations would begin to appear. However area 2B receives higher rainfall than the Gezira and so presumably the higher clay areas should already have exhibited their differences.

(ii) Salinity

Research work at G.A.R.S. Medani has shown that in the Gezira there has not been a build up of soluble salts in the rooting zone which was at one time considered a possibility. If anything, there may be a slight leaching of salts to a zone below rooting depth but Gezira soils originally were not intrinsically saline in general. That is to say that the electrical conductivity of the saturation extract was well below the internationally accepted limit of 4.0 millimhos. This level of 4.0 mmhos has been fairly well established in research findings in many parts of the world and it can safely be said that saline intolerant plants grown in a soil with an E.C. greater than this would begin to exhibit signs of toxicity.

Due to the impermeability of the soil, movement of salts either up or down is considerably restricted and therefore the upper limits for E.C. in Class 2 have been set at 4 mmhos in the 0-45 cm zone and 5.3 mmhos in the 45-90 cm zone.

In area 2B only one per cent ot total sites were recorded with an E.C. greater than 4 mmhos in the upper zone.

(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 percentage levels of well above 40 and even up to 60, when presumably the sodium begins to exert a toxic effect. However, in most soils a deleterious physical effect is found at E.S.P.'s of over 15, they become deflocculated, compact and extremely impermeable and plant

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growth is inhibited by this poor structure due to lack of air and moisture. Therefore an E.S.P. of 15 has been generally accepted as the upper limit for good class soils.

Above this level soil ameliorants or expensive irrigation techniques are required e.g. the use of gypsum or sulphuric acid to cause replacement of sodium by calcium on the exchange complex, or saline irrigation water to inhibit deflocculation.

Due perhaps to a type of colloidal bonding preventing clay dispersion the montmorillonitic clays of the Sudan appear to be able to resist structural breakdown until levels of E.S.P. well above 15 are reached. Evidence for this has always been from cotton yields and in the absence of conclusive experimental results it would be dangerous to suggest that other crops may not be affected by E.S.P.'s in excess of 15 or even to state categorically that cotton yields are not reduced to some extent.

Therefore this internationally accepted limit has been taken as the upper limit for Class 2 soils and any sites with E.S.P.'s greater than 15 in the 0-90 cm zone have been downgraded.

In the project area 53 per cent of total sites exceeded this limit in the 0-45 cm but 77 per cent exceeded it in the 45-90 cm zone.

(iv) Extent and Location

Class 2 land is found only in two small patches in the southern part of the area and a larger piece west of Singa. Almost all of sub area 2 between Maiurno and the railway line is Class 2. The total area mapped as solely in this class is 12,660 feddans.

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."

"They may have uneven topography, moderate to high concentration of salines or restricted drainage, susceptible to correction but only at relatively high costs."

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"They 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."

The moderately good blocks in the Gezira could be described in this fashion and a land classification survey of the Gezira would probably show a large part of the area as Class 3 land.

(i) Clay Percentage

The letter 1 in this class signifies that the clay percentage lies between 35 and 50 and therefore according to Finck and Ochtman would produce lower yields of cotton than the higher clay percentage soils.

The reduction in yield would be between 20 to 50 per cent below average if one assumes that results appertaining to the Gezira can be directly applied to all the clay plains. Several sites in Blue Nile pump schemes showed clay percentages of between 40 and 50 and these schemes regularly produce yields higher than the Gezira. This does not preclude the fact that such low clay areas may be producing yields which are relatively lower than the area average and in the absence of statistical evidence it is safe to assume that soils with a clay percentage of between 35 to 50 should be downgraded due to reduced production potential.

They may well be more suited to crops such as groundnuts and although they are suspect in regard to high cotton yields they are still economically feasible in regard to irrigation development.

Only 5 sites (1.5 per cent of total) fell into this 31 category in area 2B.

(ii) Soil Salinity

The levels acceptable in the Class 3 s limitation are 4.0 - 5.3 mmhos in the 0-45 cm zone and 5.3 - 8.0 mmhos in the 45-90 cm zone.

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 would however be some inhibition to the proper growth of normal plants probably in the early stages and at germination. Therefore these soils have a reduced yield potential. No sites fell into this category in the area.

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(iii) Alkali Levels

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

From the following table it can be seen that 49 per cent of the sites investigated in the area have an E.S.P. between 15 and 25 in the 45-90 cm zone.

Table 5.1 E.S.P. Frequency Occurrence (% of total sites)

E.S.P.	0-45 cm	45-90 cm
0-5	8.7	2.8
5-10	15.3	3.8
10-15	23.0	16.8
15-20	23.3	28.0
20-25	13.9	20.6
25-30	7.5	12.6
30-35	5.9	7.4
> 35	2.4	8.0

This means that a large part of the area has been downgraded from Class 2 to 3a due to high E.S.P. in the subsoil. As there is little cracking in this area much below 50 cm the physical effect of high E.S.P.'s in the subsoil would not appear to have the relevance that it might have elsewhere. Also it has already been stated that the montmorillonitic clays do not exhibit deleterious physical effect until considerably higher E.S.P.'s than is normally required are reached. A comparison of Class 3a sites with Class 2 sites shows that depth and extent of cracking are much the same.

There is no difference in structure and as this is mainly confined to the top horizon this is to be expected as both classes have E.S.P.'s below 15 in the 0-45 cm zone. Admittedly the chances of 3a soils having higher topsoil E.S.P.'s must be greater as due to their higher subsoil E.S.P. their topsoil would tend to be nearer the limit of 15 E.S.P. but they are still below this limit.

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It was also found that there is no correlation between pH and E.S.P. and therefore Class 3a soils would not be any worse than Class 2 soils in this respect.

Therefore if the only 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 then it would be said that 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. From Table 5.1 it can be seen that their range of Sodium Values was between 10 and 24 with a modal value of 17 and an average of 15.3.

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 this would no doubt exhibit itself by inhibiting root growth thus reducing yields.

(iv) Extent and Location

The total area mapped as Class 3 is 12,380 feddans made up as follows:-

Class 3a	11,250 feddans
3al	270 feddans
31	860 feddans

Most of this is in scattered patches in the Singa area with one small piece S.W. of Umm Marih pump scheme.

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 ....."

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Class 3s	11,250 feddans
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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 ....."

Although this class is essentially limited arable or special use land the alkali limitation actually puts a considerable amount of land into it 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.

However the 4a classification includes soils which have only slightly higher E.S.P.'s than class 2 in the topsoil and similar to class 3a in the subsoil. Therefore they have been recommended for development and it is only the 4l category with low percentages that are "the special use" lands and are not recommended for initial inclusion in irrigation schemes.

(i) Clay Percentage

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

The 4l lands would be suitable for a number of specialised crops, particularly as their alkali limits are so strict, but they would need different management and water requirements than the main scheme crops and have therefore not been recommended for inclusion, In fact only one site was in this category, but as its boundary would be defined by photo-interpretation it has been mapped as a discrete unit.

(ii) Salinity

The permitted upper levels of salinity are 5.3 mmhos in the 0-45 cm zone and 8.0 mmhos in the 45-90 cm zone which are the same as those for Class 3s.

When combined with low clay soils these levels would be of low significance as leaching would soon reduce them but in the alkaline 4a lands where leaching is not possible they could be an additional factor in reducing crop yield potential of the more sensitive crops.

Although this class is essentially limited arable or special use land the alkali limitation actually puts a considerable amount of land into it that would be fully acceptable on Sodium Value standards. On the other hand if the U.S.D.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.

However the 4a classification includes soils which have only slightly higher E.S.P.'s than class 2 in the topsoil and similar to class 3a in the subsoil. Therefore they have been recommended for development and it is only the 4i category with low percentages that are "the special use" lands and are not recommended for initial inclusion in irrigation schemes.

(i) Clay Percentage

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

The 4i lands would be suitable for a number of specialised crops, particularly as their alkali limits are so strict, but they would need different management and water requirements than the main scheme crops and have therefore not been recommended for inclusion. In fact only one site was in this category, but as its boundary would be defined by photo-interpretation it has been mapped as a discrete unit.

(ii) Salinity

The permitted upper levels of salinity are 5.3 mmhos in the 0-45 cm zone and 8.0 mmhos in the 45-90 cm zone which are the same as those for Class 3a.

When combined with low clay soils these levels would be of low significance as leaching would soon reduce them but in the alkaline 4a 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 from class 3a is that in class 4a the topsoil 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 anomalies of subsoils with low E.S.P's underlying more alkali topsoils, the classification states "below 25" whereas the 3a classification reads, "15-25". Therefore in a very few cases the average E.S.P. of the overall 0-90 cm zone could be less than that of a 3a site. The number is negligible and the fact remains that the more important topsoil definitely has a greater alkali content.

As in general the E.S.P. increase with depth, 4a lands have subsoils that mostly lie nearer to the 25 E.S.P. limit than the 3a lands so combining this with their more alkali topsoil they would therefore reach danger limits sooner if an alkali build-up under irrigation was a possibility.

In regard to Sodium Value levels they are very definitely within the accepted limits for arable land. Some 46 sites are classed as 4a and 94 per cent of them had a Sodium Value of below 25. The overall average was 20.1 with a lowest recorded value of 16 and a highest value of 28. The modal value for all sites was 20.

The main reason for the favourable Sodium Values in relation to E.S.P. is that the amount of soluble sodium is less than in areas previously investigated, particularly in the 45-90 cm zone.

This makes the total extractable sodium, on which Sodium Values are based, much lower when averaged throughout the top 90 cm of soil. Also soluble sodium does not correlate with total extractable sodium but remains at a fairly low level therefore high exchangeable sodium does not necessarily show a corresponding increase in soluble sodium. 4a lands are recommended for inclusion in the irrigable area and 14.4 per cent of total sites are so classified.

Only 5 sites fell into the 4a1 category which has clay percentage limits of 35-50, but is otherwise similar to 4a and as these were scattered they have been mapped with 4a units where possible.

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Only 5 sites fell into the 4ai category which has clay percentage limits of 35-50, but is otherwise similar to 4a and as these were scattered they have been mapped with 4a units where possible.

(iv) Extent and Location

The total area mapped as class 4 land is 6,530 feddans made up as follows:-

4a	6,130 feddans
4al	240 feddans
41	160 feddans

It is in small scattered patches that these lands occur, there are no large units as with classes 2 and 6. The majority of these patches lie in the area investigated around Singa.

Class 5

This is a non-arable class but only under existing conditions, further investigation is required. It is therefore a tentative class and will eventually be placed in one of the other classes when conditions change or more detailed work is undertaken. It has not been found necessary to use it in this report.

Class 6

In the U.S.B.R. Manual these lands are designated as, "non-arable under the existing project plan because of failure to meet the minimum requirements for the other classes of land. They can include class 4 and 5 land when the extent of such lands or the detail of the particular investigation does not warrant their segregation. 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".

The criteria to which the Class 6 lands in area 2B have failed to meet the minimum requirements are those of alkali levels, and, to a much lesser extent, topography. In regard to the latter all areas classed as 6t have been mapped by photo-interpretation and are either low lying seasonally flooded areas or gullies.

In area 2B the difference in alkali content between the 0-45 cm and 45-90 cm depths is much greater than in areas investigated previously. This was also the case in area 2A. The overall topsoil E.S.P.'s are not much lower whilst in area 2A they are considerably lower but the incidence of areas with highly alkali topsoil is more

(iv) Extent and Location

The total area mapped as class 4 land is 6,530 feddans made up as follows:-

4s	6,130 feddans
4s1	240 feddans
4l	160 feddans

It is in small scattered patches that these lands occur, there are no large units as with classes 2 and 6. The majority of these patches lie in the area investigated around Singa.

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In area 2B the difference in alkali content between the 0-45 cm and 45-90 cm depths is much greater than in areas investigated previously. This was also the case in area 2A. The overall topsoil E.S.P.'s are not much lower whilst in area 2A they are considerably lower but the incidence of areas with highly alkali topsoil is more

frequent. In the subsoil the diversity of alkali occurrence is even more marked. The following table illustrates this point of greater "spread".

Table 5.2 E.S.P. Occurrence as percentage of total sites

	0-45 cm				45-90 cm			
E.S.P.	Area 3A	Area 3C(e)	Area 2A	Area 2B	Area 3A	Area 3C(e)	Area 2A	Area 2B
0-5	4	2	24.5	8.7	-	--	3.5	2.8
5-10	18	30	26	15.3	2	2	9	3.8
10-15	28	41	19.5	23.0	17	15	22	16.8
15-20	27	16	14	23.3	28	45	21.5	28.0
20-25	17	6	8	13.9	29	24	20.5	20.6
25-30	5	3	4.5	7.5	17	9	12.5	12.6
30-35	1	1	2	5.9	6	4	7	7.4
35 and over	-	1	1	2.4	1	1	5	8.0

This increased spread in the occurrence of the higher and lower alkalinity ranges in both topsoil and subsoil has meant that the number of sites with non-alkali topsoils and alkali subsoils is much increased. This fact plus the low overall soluble sodium levels has given many cases where Sodium Values are low yet the sites are downgraded as non-arable due to high subsoil E.S.P. If the E.S.P. of the 0-45 cm zone is within acceptable topsoil limits then in these cases the 6a classification has the topsoil classification 2, 31, 4a and 4al added to it, e.g. 6a/2. This is explained in the following sections.

(i) Clay Percentage

In class 6 the postscript 1 indicates that the clay percentage is less than 5 per cent but no soils of this nature are found within the area. In the alkali subdivisions of class 6 the 6al limitation has only a lower limit of 5 per cent clay so that it is the alkali level which determines whether the clay percentage limits are 5-35 or 35-50, i.e. with low clay (5-35 per cent) would only need a topsoil E.S.P. >15, subsoil >20 to make it 6al. A medium soil, clay per cent 35-50 would need topsoil E.S.P. >15 but a subsoil E.S.P. >25.

A soil with high clay, greater than 50 per cent, would require topsoil E.S.P. > 20 subsoil E.S.P. >25 to cause it to be downgraded and would then become 6a. Despite the higher alkalinity content of the

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0-5	4	2	24.5	8.7	-	--	3.5	2.8
5-10	18	30	26	15.3	2	2	9	3.8
10-15	28	41	19.5	23.0	17	15	22	16.8
15-20	27	16	14	23.3	28	45	21.5	28.0
20-25	17	6	8	13.9	29	24	20.5	20.6
25-30	5	3	4.5	7.5	17	9	12.5	12.6
30-35	1	1	2	5.9	6	4	7	7.4
35 and over -		1	1	2.4	1	1	5	6.0

This increased spread in the occurrence of the higher and lower alkalinity ranges in both topsoil and subsoil has meant that the number of sites with non-alkali topsoils and alkali subsoils is much increased. This fact plus the low overall soluble sodium levels has given many cases where Sodium Values are low yet the sites are downgraded as non-arable due to high subsoil E.S.P. If the E.S.P. of the 0-45 cm zone is within acceptable topsoil limits then in these cases the 6a classification has the topsoil classification 2, 3l, 4a and 4al added to it, e.g. 6a/2. This is explained in the following sections.

(i) Clay Percentage

In class 6 the postscript indicates that the clay percentage is less than 5 per cent but no soils of this nature are found within the area. In the alkali subdivisions of class 6 the 6al limitation has only a lower limit of 5 per cent clay so that it is the alkali level which determines whether the clay percentage limits are 5-35 or 35-50; i.e. with low clay (5-35 per cent) would only need a topsoil E.S.P. > 15, subsoil > 20 to make it 6al. A medium soil, clay per cent 35-50 would need topsoil E.S.P. > 15 but a subsoil E.S.P. > 25.

A soil with high clay, greater than 50 per cent, would require topsoil E.S.P. > 20 subsoil E.S.P. > 25 to cause it to be downgraded and would then become 6a. Despite the higher alkalinity 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 in this area then soils with clay percentages greater than 50 would have a better yield potential.

The clay percentages of the class 6a, 6a/2 and 6a/4a sites were all well above 50. Only 1 site was classified as 6a/31 and 2 sites as 6a/4al.

(ii) Salinity

There were no sites downgraded to class 6s due to excessive salinity. The E.C. must exceed 5.3 mmhos in the 0-45 cm zone or 8.0 mmhos in the 45-90 cm. The salinity of the 90-150 zone, in previous areas 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 check that the salinity of this zone was still at the same reasonably low levels as previously encountered 25 per cent of the 90-150 cm bore samples were submitted for E.C. estimates. The majority of these did not even approach the 4 mmhos limit, 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 topsoil.

(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 percentage. This is because the lower the clay percentage the greater the potential danger of deleterious physical effect of a high alkali content. 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 less clay a high E.S.P. must exert a stronger adverse effect on the soil.

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However if Gezira results are applicable in this area then soils with clay percentages greater than 30 would have a better yield potential.

The clay percentages of the class 6a, 6a/2 and 6a/4a sites were all well above 30. Only 1 site was classified as 6a/3i and 2 sites as 6a/4al.

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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 topsoil 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 zone. Such sites have been designated as 6a/2, 6a/3l, 6a/4a or 6a/4al, the second classification symbol being the classification of the topsoil alone. They have all been marked on the land class map and mapped with class 6a but it can be seen that they frequently occur immediately adjacent to the better class land. The following table shows the Sodium Values of these controversial sites compared with Sodium Values of the other classes.

Table 5.3 Sodium Values in relation to Land Class

Na Values	Land Class					
	2	3a	4a	6a/2	6a/4a	6a
Average	10	15	20	22	25.2	29
Modal	11	17	20	23	23	30
Highest	14	24	28	27	30	47
Lowest	11	10	16	14	16	13
% Good (0-25)	100	100	94	78	54	33
% Medium(25-35)	0	0	6	22	36	47
% Bad (over 35)	0	0	0	0	10	19

It can be seen that even the 6a/4a sites would have been considered irrigable by previous standards as only 10 per cent have a Sodium Value greater than 35. However the overall poorer structure of the soils in this area as compared with the Gezira would make it safer to follow the present classification based on the three criteria of clay percentage, salinity and exchangeable sodium percentage even though the limits set may be rather strict.

Therefore although large areas downgraded to class 6 might, if irrigated, give reasonably initial yields of cotton, and high initial yields are often a feature of virgin alkali lands, their ability to give sustained economic yields of a range of crops is suspect.

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In the absence of sufficient evidence and with such large gaps in the knowledge of the behaviour of such soils it would be wiser to assume that if irrigated they would not produce such consistent yields as would provide an economic repayment capacity. Although they may turn out as good as the class of soil whose surface class they possess the safest policy is to provisionally exclude them from development until sufficient experimental data is obtained and their crop potential can be assessed. However where their inclusion would make the adjoining class 2, 3 or 4 boundary into a more rational one for development, it is suggested this would be preferable to drawing the development boundary well inside the acceptable class borders as the 0-45 cm zone of soil is the most important for plant growth.

The total number of sites in Class 6 is 146 which is 45 per cent of the total sites investigated. The number of sites in each sub-division is as follows:

Table 5.4 Number of sites in each sub-division of Class 6

Class	No. of sites	Percentage of total sites investigated
6a	84	26.0
6a/2	20	6.2
6a/4a	24	7.4
6al	12	3.7
6a/31	1	0.3
6a/4al	2	0.6
6as	3	0.9
	146	45.1

(iv) Extent and Location

The larger mapped units of class 6 land lie to the south of Jebel Gezira in the furthest south of the nine sub areas and in the northern section of the area south west of Singa. There are many other small units scattered throughout the area but only in small discrete units. The total areas mapped in this class is 26,200 feddans, and in the only mapped subdivision 6t 1,295 feddans.

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5.3 Validity of Classification Criteria

From the preceding sections it is evident that the criteria as defined in Table 5.5 are, to some extent, not completely satisfactory but it would be hard to find any system of land classification that was not subject to some criticism. The Sodium Value classification devised only for cotton development in a limited area of Sudan was coming under considerable criticism.

The present system is essentially a safe one and the main criticism is 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 percentage levels are based on research and practical knowledge obtained in the Gezira Scheme and the salinity levels on internationally accepted limits and local research experience. The high quality Blue Nile water is not conducive to a salinity build-up despite the impermeability of the soil.

The alkali limits are those which are most subject to controversy and these are based on internationally accepted limits i.e. an exchangeable sodium percentage of 15 in the case of class 2 land but relaxed for class 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 limit of 15 E.S.P. is that the clay plain soils are not undergoing deflocculation at this level of exchangeable sodium and thus causing crop yield reductions. The possible reasons for this favourable phenomena have already been discussed and it may be that the limits could be relaxed even further. There are two main considerations in support of this, one is that even the present expanded limits are still within 'Sodium Value' standards particularly in this area and the other is that the high E.S.P.'s do not necessarily result in a high pH.

Only one in twenty of sites at present is subjected to pH analysis and the following table shows the top horizon pH values of the above and below 8.0 are divided between sites with top horizon E.S.P's of above and below 15.

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Table 5.5 Criteria for Determining Land Classification

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
3l	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
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
3sl	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 10 or 25
6t	unsuitable due to adverse topography.			

NOTE - Not all these classes occur in the area investigated.

Table 5.5 Criteria for Determining Land Classification

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
3l	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
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
3sl	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
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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 10 or 25
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NOTE - Not all these classes occur in the area investigated.

Table 5.6 pH (paste) readings in relation to E.S.P.

E.S.P.	Number of sites	
	pH less than 8.0	pH greater than 8.0
0-15	5	1
15 and over	11	10

The selection of pH 8.0 as a limit for satisfactory plant growth on impermeable soils is reasonable and a critical pH above which plant growth would almost certainly be affected has been suggested as 8.5.

This is because a measured paste pH of 8.0 would give an effective pH of 7.0 - 7.5 around the plant roots, due to the carbon dioxide in the soil air forming carbonic acid.

No pH paste reading greater than the outside limit of 8.5 occurred in this area but one interesting point in the above table 5.6 is that almost as many sites with the unfavourable E.S.P. of above 15 fell below the pH limit of 8.0 as above it, i.e. 11 and 10 respectively. Yet it is generally accepted that above an E.S.P. of 15 the pH will exceed 8.0.

Therefore these alkali clays are not as alkaline as would be expected and the soil moisture around plant roots in some areas may even be non-alkaline.

To extend the E.S.P. limits further must await conclusive experiments on the specific degree of plant response and in the meantime the present criteria are the best to follow if disastrous mistakes are to be avoided.

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CHAPTER 6

RECOMMENDATIONS

6.1 Previous Recommendations

The Pre-Investment Reports of the Rahad and Roseires areas have dealt in detail with agricultural recommendations for areas which are virtually the same climatically and in other respects as Area 2B. The range of climatically adapted crops has been considered in Chapter 6 of Report Nos. 4 and 8. In addition the potential uses of non-arable lands was discussed in Chapter 6 of Report No. 12. Therefore to avoid unnecessary repetition this chapter will be used to consider general recommendations for lines of agricultural research which would attempt to solve some of the problems which will arise from development of the clay plains in these areas.

6.2 General Considerations

The problem which has occupied research workers almost since the beginning of such work in the Sudan is that of the life expectancy of irrigation schemes, bearing in mind that although the Blue Nile is of high quality by any standards all material in it remains in the soil. This is due to the impermeability of the profile which precludes virtually any net downward losses, so discounting lateral movement of a limited local nature, all loss is by evapotranspiration.

Work in the Gezira has shown that there is some indication of a salt build-up below the root zone but the soils of the Gezira, although similar, are not the same as those further south and detailed work on salt movement under intensive irrigation is required.

Another problem connected with the life of an irrigation scheme and also with the land classification of these montmorillonitic clay soils is the extent of crop tolerance to high levels of exchangeable sodium on the exchange complex.

The continued resistance of the soils to structural breakdown at E.S.P.'s elsewhere considered deleterious needs a full investigation.

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The continued resistance of the soils to structural breakdown at E.S.P.'s elsewhere considered deleterious needs a full investigation.

In addition to these two rather longer term lines of research, an investigation of more immediate benefit on the practical application of long furrow irrigation, and its effect on a range of crops, is required. In conjunction with this work, optimum crop water requirements should be assessed for all possible crops, as given this information it may be feasible to grow a much broader range of crops than at present.

All of these lines of research are intimately connected and any single experiment could be so designed as to yield results for the solution of several aspects of the problems discussed.

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CHAPTER 7

ENGINEERING RECONNAISSANCE IN AREA 2B

7.1 Terms of Reference

The terms of reference for the engineering survey carried out in Area 2B in conjunction with the semi-detailed soil survey were as follows:-

"An engineering survey to include areas up to the 20.0 metres isopotamon excepting those areas where a major topographical obstacle is encountered between the river and the isopotamon. The data on river levels to be provided by the Ministry of Irrigation and Hydro-Electric Power, Sudan Government".

"The areas to be studied for semi-detailed survey to be selected on the basis of data obtained from a reconnaissance survey carried out by Sir Alexander Gibb and Partners in 1951-53 (Sudan Government Report)".

Area 2B was designated as that area on the west bank of the Blue Nile between Sennar and Abu Hugar. The western boundary was taken as the Sennar-Singa railway as far as latitude 13°13' N. and then as the Khor Um Ish to latitude 12°58' where the Khor meets the railway, thence to Jebel Gereirisa and Abu Hugar.

The engineering studies began in Khartoum on 7th November, 1964, with the collection of existing maps and survey data. Field work began on 16th November and continued until 20th January, 1965.

7.2 Location and General Description of the Project Area

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7.2 Location and General Description of the Project Area

This area of the Blue Nile west bank lies along a

120 kilometre reach of the river between Abu Hugar and Sennar Dam. The railway line forms the area boundary for 46 kilometres on the western side but at latitude 13°13' N. the Khor Um Ish, which forms a major topographical feature, becomes the boundary until it recrosses the railway at latitude 12°58' N. From this point the boundary runs direct to Jebel Gereirisa and thence to Abu Hugar via the railway line.

Apart from one small area of qoz in the south of the project area and the rock outcrop (Jebel Gereirisa) near Abu Hugar, the area is a fairly level clay plain but with several small drainage channels dissecting it. There are two oxbows near the Blue Nile. The Khor Um Ish, which forms part of the western boundary, is a major drainage channel being an old course of the Blue Nile. The minor drainage channels are usually not more than 2 or 3 metres deep and can easily be crossed by a major canal; this has already been done by existing private pump schemes. However, minor canalization layouts will require careful planning.

There are 37 private pump schemes in the area and a Government Dairy Scheme at Umm Benein and altogether these have an approximate gross area of 80,000 feddans. In addition the Umm Benein Scheme has grazing lands of 3,000 feddans which could be developed and this area was recommended for soil survey.

The project area lies wholly in Blue Nile Province and is administered by three councils; Sennar Rural Council in the north, the Northern Fung Rural Council at Singa which covers the central and largest part of the area, and the Abu Hugar Rural Council in the extreme south.

Communications in the area are good during the dry season from mid-October to mid-June. The roads from Sennar to Singa and

Singa to Abu Hugar are regularly graded by the councils. There are also roads from Singa westwards to the Khor Um Ish and many tracks to the villages which lie away from the Blue Nile. The area is well served by rail, from Sennar Junction to Singa, Abu Hugar and finally to Roseires.

Because of its far greater slope the Blue Nile is not used by river traffic to the same extent as the White Nile. The only commercial traffic, apart from local sailing boats, is that provided by the Forest Department which ships logs by barge from the riverain forests to Es Suki saw mills. The area is not yet served directly by air but a new civil landing ground has been constructed near Sennar Dam. Crop spraying aircraft operate successfully from roughly prepared landing strips alongside the cotton fields.

The only road crossing of the Blue Nile is at Sennar Dam, but a ferry service for transport is also available at Singa.

7.3 Maps, Survey Data and Aerial Photography

7.31 Maps

The Sudan Government Survey Department produce three series of map sheets which are pertinent to the project area. The most generous series is the 1:250,000 scale topographical map series of which sheets 55-K and 55-O provide complete cover of the project area. South of latitude 13°30' N. the 1:100,000 scale Rainland Series provides good map cover, although some of the mapping detail is distorted in places. As the latest of the 1:250,000 series was last revised in 1943 and the 1:100,000 series were produced in 1952, neither series shows the location and extent of recent pump scheme development in the area. South of latitude 13°20' N. the area has been close contour surveyed and the Kenana contour survey maps at 1:20,000 give

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very good detail over the main part of the project area.

Additional information regarding the project area is shown on the 1:20,000 scale Sennar Dam Reservoir Cadastral Maps (published 1951) giving the precise location of the river, together with contouring between normal low water level and an assumed top water level of 422.5 metres A.S.L.

7.32 Survey Data

The most comprehensive series of levels in the project area is the grid formed by the minute beacons which incorporate bolt bench marks. However, there are no beacons in the northern part of the project area.

The other bench marks used during the fieldwork were the line of bench marks along the riverain road from Sennar to Abu Hugar, and the bench marks on the Sennar Reservoir Survey concrete poles.

7.33 Aerial Photography

For the Roseires Soil Survey new photography was carried out by the Sudan Survey Department of the Blue Nile river valley between Khartoum and Roseires during the period October to December 1962, with additional areas photographed in early 1963. Figure 7.1 shows the extent of photographic cover together with the sheet index of 1:50,000 scale base maps prepared by the Consultant.

The photography gives complete cover of the project area and most of it is covered by the 1:50,000 scale uncontrolled mosaics which were prepared by Hunting Surveys Limited.

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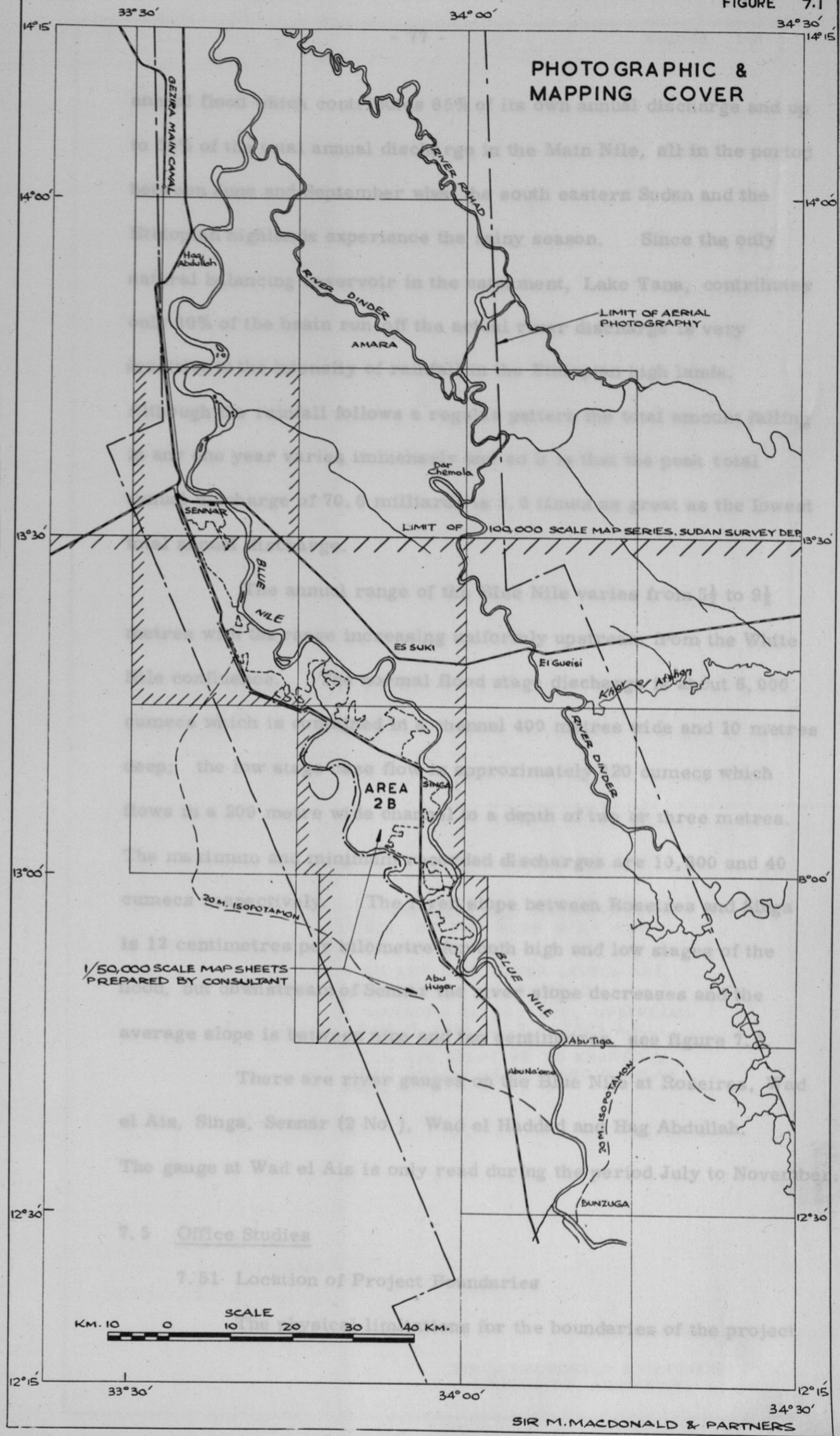


SIR M. MACDONALD & PARTNERS

FIGURE 7.1

PHOTOGRAPHIC & MAPPING COVER

annual flood which contributes 85% of its own annual discharge and up to 55% of the total annual discharge in the Main Nile, all in the period between June and September when the south eastern Sudan and the Ethiopian highlands experience the rainy season. Since the only natural balancing reservoir in the catchment, Lake Tana, contributes only 10% of the basin run-off the actual river discharge is very sensitive to the intensity of rainfall in the Ethiopian high lands. Although the rainfall follows a regular pattern the total amount falling in any one year varies immensely and so it is that the peak total annual discharge of 70.6 milliards is 3.5 times as great as the lowest total annual discharge.

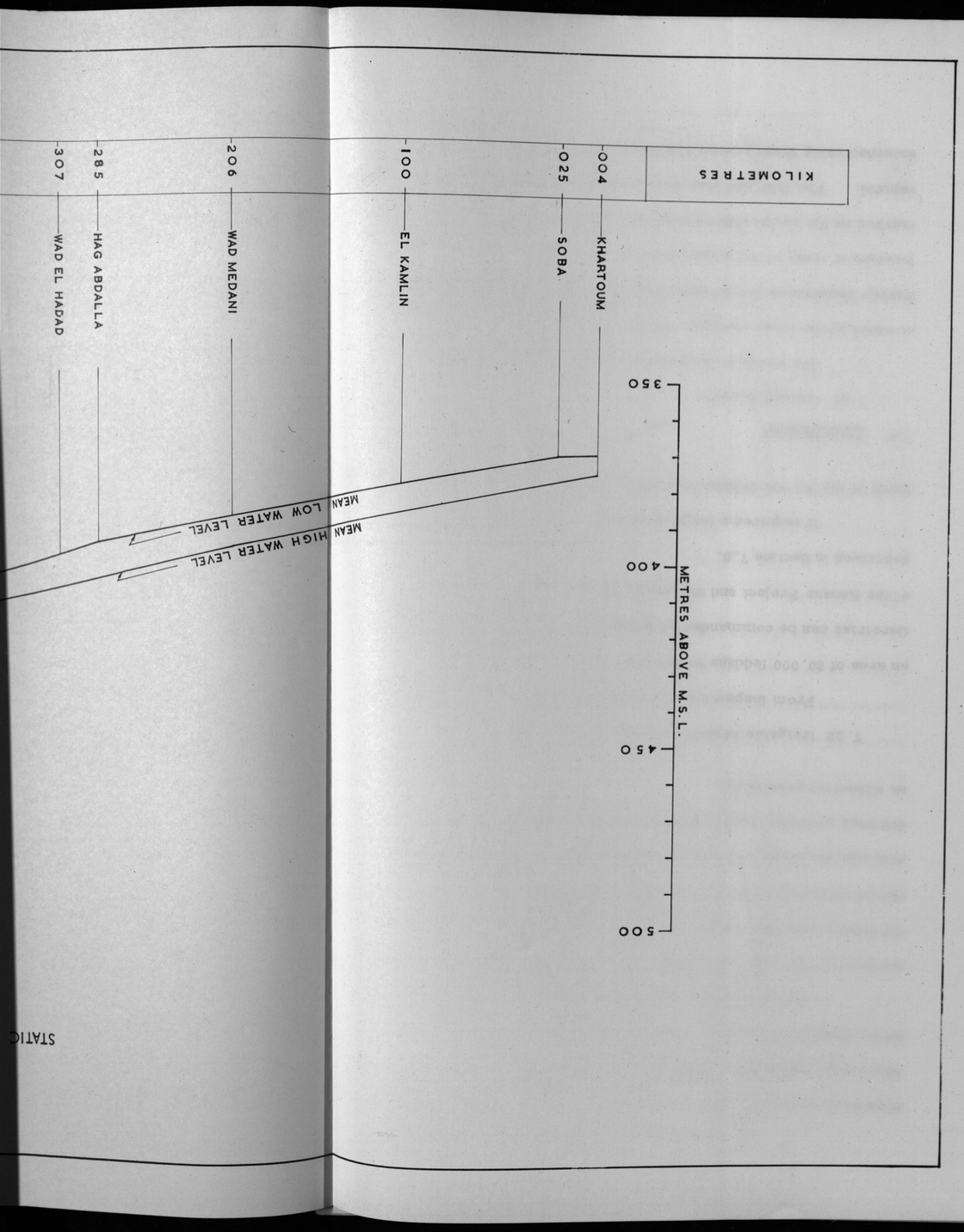
The annual range of the Blue Nile varies from $5\frac{1}{2}$ to $9\frac{1}{2}$ metres with the range increasing uniformly upstream from the White Nile confluence. The normal flood stage discharge is about 6,000 cumecs which is contained in a channel 400 metres wide and 10 metres deep; the low stage base flow is approximately 120 cumecs which flows in a 200 metre wide channel to a depth of two or three metres. The maximum and minimum recorded discharges are 10,800 and 40 cumecs respectively. The river slope between Roseires and Singa is 12 centimetres per kilometre for both high and low stages of the flood, but downstream of Sennar the river slope decreases and the average slope is between nine and ten centimetres, see figure 7.2.

There are river gauges on the Blue Nile at Roseires, Wad el Ais, Singa, Sennar (2 No.), Wad el Haddad and Hag Abdullah. The gauge at Wad el Ais is only read during the period July to November.

7.5 Office Studies

7.51 Location of Project Boundaries

The physical limitations for the boundaries of the project



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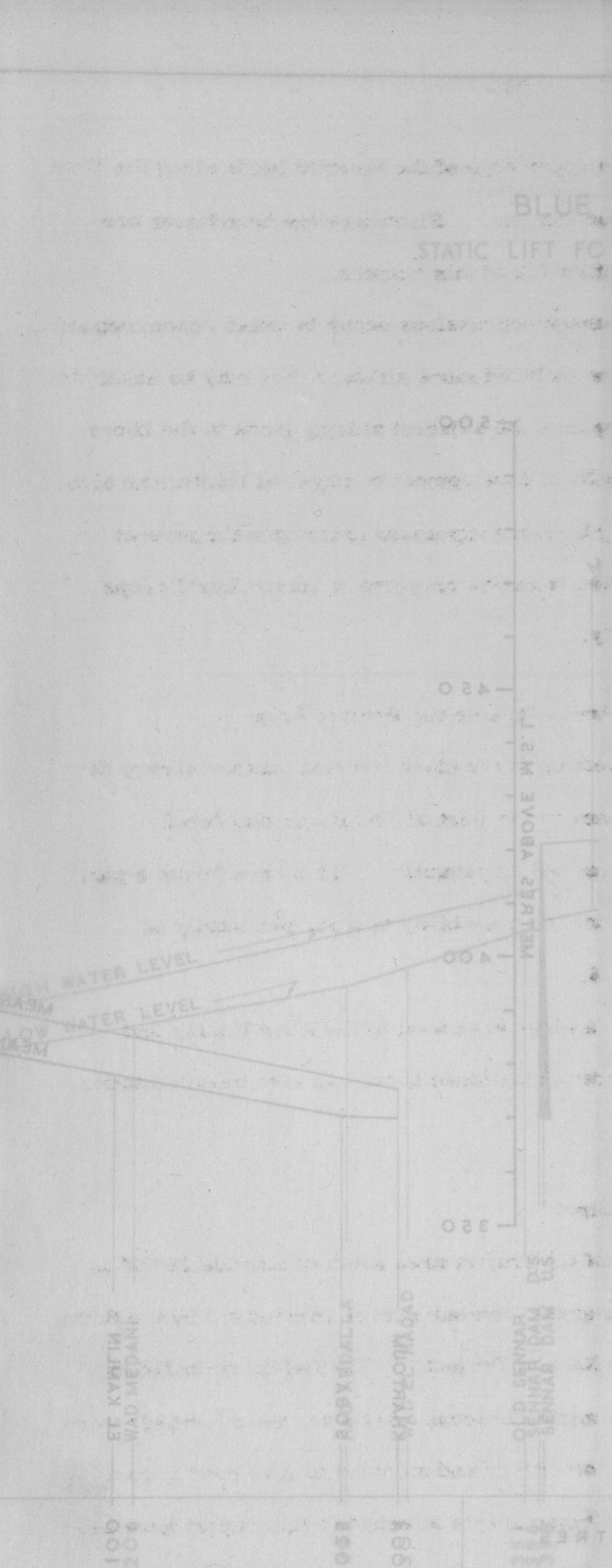
BLUE
STATIC LIFT FO
500
450
400
350
METRES ABOVE M.S.L.
WATER LEVEL
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KHARTOUM
OLD SENNAR
SENNAR DAM
KILOMETRES

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Where drainage depressions occur in areas recommended for soil survey they are included since although they may be unsuitable for Gezira type development the adjacent sloping lands to the khors should not be excluded from development on physical limitations alone. Although the lands may be more expensive to irrigate the natural drainage provided makes intensive cropping of horticultural crops an attractive possibility.

7.52 Irrigable Areas Outside the Project Area

From inspection of the close interval contour survey data an area of 30,000 feddans to the west of Abu Hugar and Jebel Gereirisa can be commanded by pumping. This area forms a part of the Kenana Project and the possibility of a pumped supply is described in Section 7.6.

If required a large area west of the Khor Um Ish and north of the 30,000 feddans mentioned above can also be commanded.

7.6 Field Studies

7.61 Ground Control

The whole of the project area south of latitude 13°22' is covered by the close interval contour survey carried out by the Sudan Survey Department for Kenana Project. The fieldwork included location of many of the minute beacons and these, when located, were marked on the aerial photographs and mosaics to give good ground control. The 1:50,000 map sheets attached to this report have been amended using these ground control points. The boundaries of

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existing schemes and areas recommended for development are therefore well defined. However, delay in obtaining some of the mapping and damage to many of the beacons caused some difficulties. North of latitude 13°22' the project area is a narrow strip of land lying between the railway and the Blue Nile and is already well developed. Therefore control in this region is relatively simple but, unfortunately, no contour information is available.

7.62 Existing Private Pump Schemes

During the field studies, all the pump schemes along the west bank of the Blue Nile were visited and with the help of photo-interpretation the boundaries of the present irrigated areas were located and transferred to the air photo cover. Six operating and two abandoned secondary pump stations were located. Bad management or poor soil conditions was probably the reason for the two no longer being operative.

In Area 2B there are 37 private pump schemes and one Government scheme. The private schemes vary immensely in size. The numbers of schemes and areas are given in Table 7.1. The total gross area of existing schemes in Area 2B is about 80,000 feddans.

Table 7.1. Licensed Private Pump Schemes

Gross Area (Feddans)	No. of Schemes
0 - 200	1
201 - 500	9
501 - 1,000	7
1,001 - 2,000	9
2,001 - 3,000	2
3,001 - 4,000	2
4,001 - 5,000	5
Over 5,000	2

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3,001 - 4,000	2
4,001 - 5,000	5
Over 5,000	2

7.63 Location of Pump Station Sites

The availability of suitable pump station sites on the Blue Nile is affected by four factors:-

(a) Meandering of the river channel.

(b) Location of maya's and low lying flood plains.

(c) Extent of 'kerrib' lands.

(d) Operating schedule of Sennar Dam.

(a) The meandering of the Blue Nile is a normal progression of river across a uniform alluvial plain with the Maiurno-Sennar gorge forming the only notch in the valley profile. The recent influence of Sennar Dam is small since the bulk of the flood waters pass through the dam with very little afflux.

The pattern and distribution of the meanders within the project boundaries is not regular; upstream of Sennar irregularities in the pattern are no doubt closely connected with the movement of the river within recent geological times from the Khor Um Ish to its present course. There are also beds of cemented gravels with occasional conglomerate, many of which are now to be seen at about low water level along the river, and these have some effect on the meander pattern.

The location of pump houses and intakes in relation to the meander pattern is important to both the design and operation of pump stations, since both desilting of intakes and river bank protection can become expensive items in pump station operating costs. While the low rate of lateral erosion taking place at low water levels creates the usual zones of erosion and accretion it is the flood erosion which is the more serious factor. The high river flood erosion operates in two directions; first the maximum current tends to leave the concave area

7.63 Location of Pump Station Sites

The availability of suitable pump station sites on the Blue Nile is affected by four factors:-

(a) Meandering of the river channel.

(b) Location of wadi's and low lying flood plains.

(c) Extent of 'kerrib' lands.

(d) Operating schedule of Sennar Dam.

(a) The meandering of the Blue Nile is a normal progression of river across a uniform alluvial plain with the Maiurno-Sennar gorge forming the only notch in the valley profile. The recent influence of Sennar Dam is small since the bulk of the flood waters pass through the dam with very little influx.

The pattern and distribution of the meanders within the project boundaries is not regular; upstream of Sennar irregularities in the pattern are no doubt closely connected with the movement of the river within recent geological times from the Khor Um lab to its present course. There are also beds of cemented gravels with occasional conglomerate, many of which are now to be seen at about low water level along the river, and these have some effect on the meander pattern.

The location of pump houses and intakes in relation to the meander pattern is important to both the design and operation of pump stations, since both dealiting of intakes and river bank protection can become expensive items in pump station operating costs. While the low rate of lateral erosion taking place at low water levels creates the usual zones of erosion and accretion it is the flood erosion which is the more serious factor. The high river flood erosion operates in two directions; first the maximum current tends to leave the concave area

of the meander and the point of maximum erosion moves downstream causing increased turbulence as the river then flows through an unnatural hydraulic cross-section. Secondly the rise in the level of the stream causes saturation of the river bank which, when the flood subsides and the external water pressure is withdrawn, causes the bank to collapse. The maximum current returning to the concave bank provides ample facilities for the material to be removed downstream.

Hence proposed pump station sites have been chosen upstream of the point of maximum erosion since it can be expected that bank protection would be required only for low level flows and that at higher levels the station would be relatively secure.

(b) The regime character of the Blue Nile has led to the formation of extensive areas of maya's and low lying flood plains. Apart from use by small pumps for horticultural schemes, these areas are unsuitable for the siting of pump stations, since the nature of the ground, being generally recently deposited sands and silts, is unlikely to provide the bearing pressures required for a pump station foundation; also at high flood the pump station site would become isolated with rising mains liable to flotation. While the construction of intake channels across the flood plains and maya's is a possibility, especially within the backwater reaches of Sennar Dam, the average depth of cut would be 8 to 10 metres, and this would require protecting by bunds and a head sluice to prevent heavy silting during the flood season.

(c) The extent of the 'kerrib', or eroded lands between the river bank and the high clay plain, is a major factor when considering the capital cost of a pump station. Since the height of a canal embankment in the Sudan is usually limited to between 2 and 3 metres above

ground level, the distance which the canal can be brought towards the pump house is limited, and the water has to be pumped into the canal through a rising main. At present in existing schemes within the project area, the lengths of rising mains are limited in length, usually to less than 200 metres, but a rising main on the scale of Guneid (over 1 kilometre) adds substantially to the capital charges of a scheme. With the lack of soil conservation measures along the Blue Nile valley, the 'kerrib' lands are increasing in extent, and it has been noted that at a number of existing pump stations seepage from the canal headreach, combined with soil erosion, has caused the washout of the headreach.

(d) Sennar Dam has a considerable influence on the siting of pump stations in the reaches immediately upstream of the Dam but south of Singa the effect of the Dam is small and at Abu Hugar it is negligible. By raising the water level above the normal high flood level a reservoir is formed behind the dam covering a large area of sloping ground on each side of the river. Hence pump stations are difficult to site unless long intake channels are built and the pump station is protected by bund walls. Where the higher ground comes close to the river this problem is not so severe but there is still a much higher range in the river levels than is encountered further upstream.

It can be seen, therefore, that the operating schedule at Sennar Dam is important because, if the water levels are held at the higher levels for the whole period during which water is required, the problems mentioned above do not arise. If the levels are not held over the whole period then either intake channels have to be dug and maintained or the schemes lose their water supply at an earlier date than is desirable. There are several schemes in Area 2B which lose

their water supply in March or April under the present operating schedule which is described below.

On the 1st January the upstream water level is at its higher holding level of 421.7 metres A.S.L. This level is held until 11th January when emptying begins. The level drops to 417.2 by the end of March and continues to drop until 1st June when the sluices are opened completely for one or two weeks. The level on the 11th July is 410.4 and on 15th July the filling of the Dam commences. The first holding level of 417.2 is reached on 25th July and is held until mid October when the level starts to rise again until on 30th November the higher holding level 421.7 is reached and this is maintained throughout December.

7.64 Selected Project Areas

Eight project areas with a gross area of over 60,000 feddans were selected as potentially suitable for development by pumping from the Blue Nile.

These areas are shown on figure 7.3 and a description of each pump scheme follows :-

TABIT PUMP SCHEME

The Tabit scheme lies immediately north of Abu Hugar and has a gross area of 7,000 feddans. Its northern boundaries are the Sieru and Layouna schemes. The pump station site lies between Tabit Village and the Sieru pump station. The 'kerrib' lands are narrow at this point and 200 metres of rising main takes the water to a headpond 2.5 metres above ground level. The headreach passes on to higher ground within 150 metres and enters the scheme at K0.600. A line was surveyed due west across the project area to the railway; this line crosses the only depression in the area which is 3 metres

their water supply in March or April under the present operating schedule which is described below.

On the 1st January the upstream water level is at its higher holding level of 421.7 metres A.S.L. This level is held until 11th January when emptying begins. The level drops to 417.2 by the end of March and continues to drop until 1st June when the sluices are opened completely for one or two weeks. The level on the 11th July is 410.4 and on 15th July the filling of the Dam commences. The first holding level of 417.2 is reached on 25th July and is held until mid October when the level starts to rise again until on 30th November the higher holding level 421.7 is reached and this is maintained throughout December.

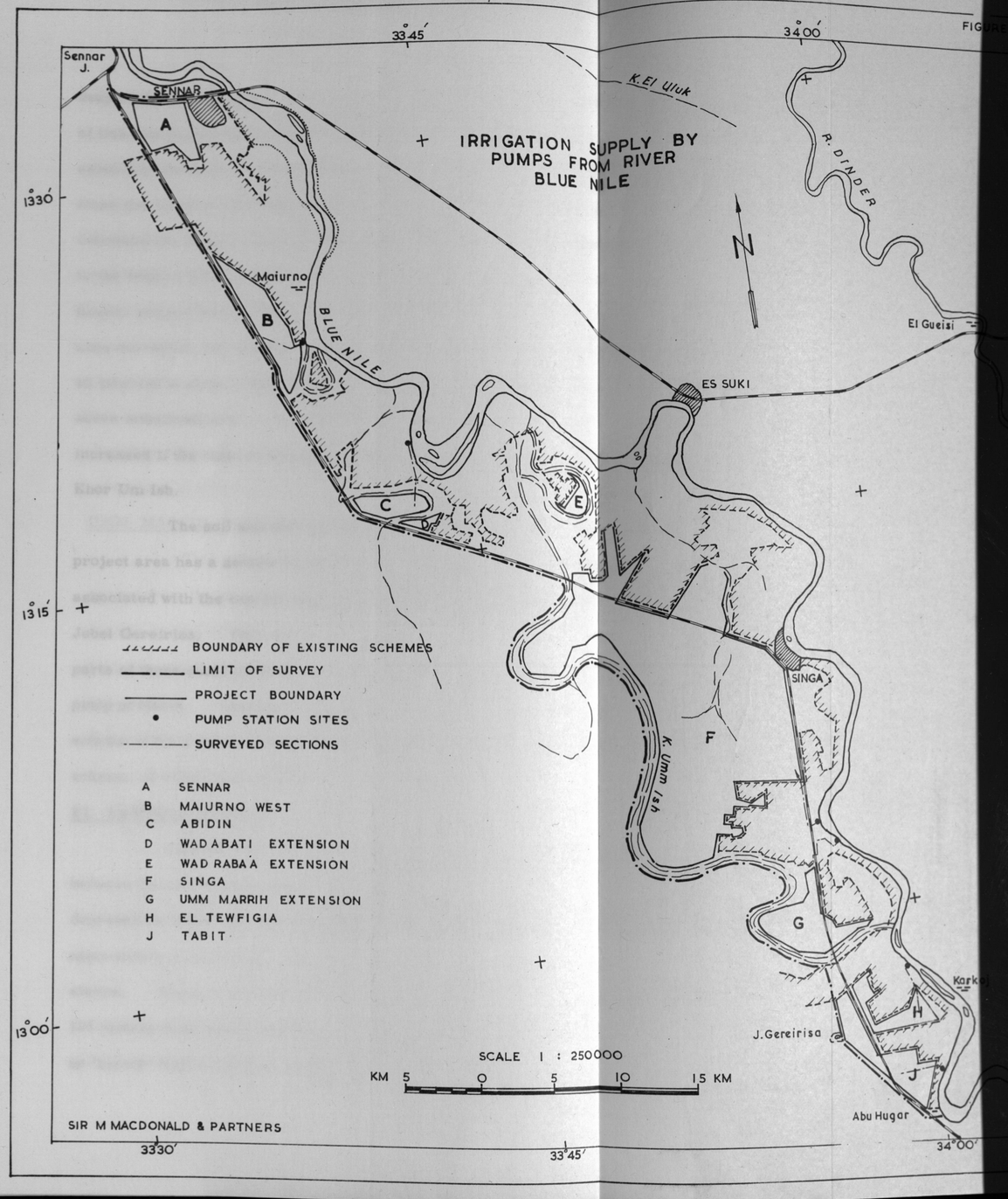
7.84 Selected Project Areas

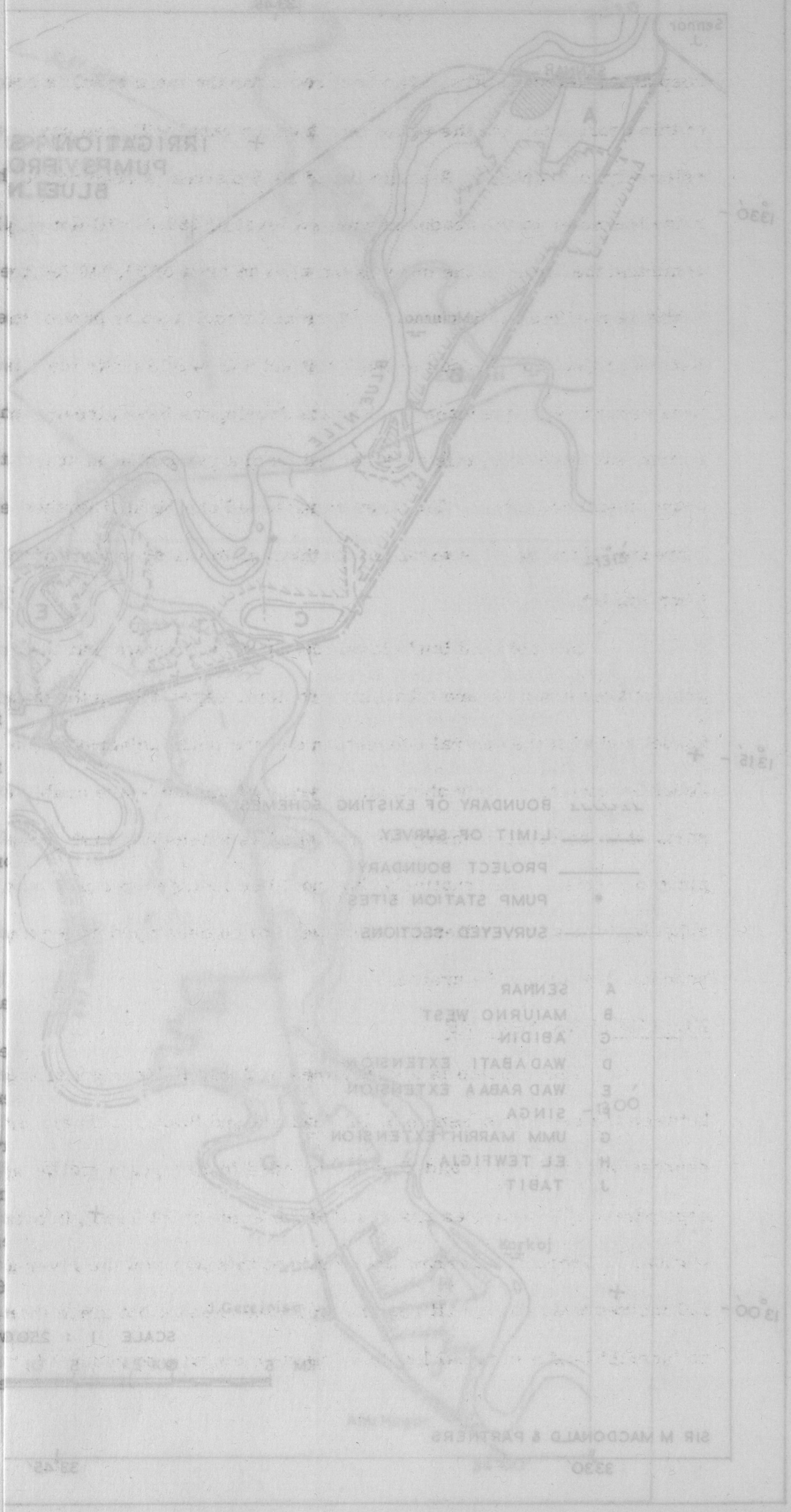
Eight project areas with a gross area of over 80,000 feddans were selected as potentially suitable for development by pumping from the Blue Nile.

These areas are shown on figure 7.3 and a description of each pump scheme follows :-

TABIT PUMP SCHEME

The Tabit scheme lies immediately north of Abu Hugar and has a gross area of 7,000 feddans. Its northern boundaries are the Sierr and Layouna schemes. The pump station site lies between Tabit Village and the Sierr pump station. The 'kerrib' lands are narrow at this point and 200 metres of rising main takes the water to a headpond 2.5 metres above ground level. The headreach passes on to higher ground within 150 metres and enters the scheme at KO. 800. A line was surveyed due west across the project area to the railway; this line crosses the only depression in the area which is 3 metres





deep at its lowest point. The best route for the main canal is south of this depression and the whole length of the canal will then have relatively low banks. A static lift of 19.5 metres is required to raise the water to the headpond where a level of 439.0 will not only command the whole of the scheme but also an area of 30,000 feddans to the west of the project area. This additional area is part of the Kenana project but if added to the Tabit scheme would make the total area served 37,000 feddans. Private developers have already shown an interest in some of this area served from a pump station at the above mentioned site. The area commanded can be still further increased if the canal is extended northwards to the area west of the Khor Um Ish.

The soil and land classification survey shows that the project area has a severe alkalinity problem, especially in those lands associated with the central depression and the lands adjacent to the Jebel Gereirisa. Only about one quarter of the lands are arable and parts of these could probably be developed as extensions to the existing pump projects. Alternatively they could be included in a new pump scheme if the adjacent Kenana lands were to be developed as a pump scheme, if shown to be arable.

EL TEWFIGIA SCHEME

This scheme is a small area of 2,300 feddans gross lying between the existing schemes of El Tewfigia and Sieru. There are no depressions in the area and it is commanded from a pump station site approximately 100 metres upstream of the existing El Tewfigia pump station. There is a narrow flood plain at this point on the river about 100 metres wide which will require an intake channel but since there is no 'kerrib' land a minimal length of rising main will be required.

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EL TEWFIGIA SCHEME

This scheme is a small area of 2,300 feddans grossly lying between the existing schemes of El Tewfigia and Siera. There are no depressions in the area and it is commanded from a pump station site approximately 100 metres upstream of the existing El Tewfigia pump station. There is a narrow flood plain at this point on the river about 100 metres wide which will require an intake channel but since there is no 'kerrib' land a minimal length of rising main will be required.

The main canal which has been surveyed for the first 3 kilometres, enters the proposed scheme at K1.5 after passing the eastern boundary of the existing scheme. The static lift is 19.0 metres.

This area could also be developed from the existing El Tewfigia scheme or the Sieru scheme by the construction of secondary pump stations and increasing the capacities of the pump canals.

The soil and land classification survey shows that most of these lands are arable and are suitable for cultivation of a long staple cotton rotation similar to that practised on the adjacent El Tewfigia and Sieru pump schemes. The proposed new pump scheme is therefore feasible or, alternatively, these lands could be developed as extensions to existing schemes by low-lift pumps.

UMM MARRIH EXTENSION SCHEME

This scheme having a gross area of 4,000 feddans is best served from the existing secondary pump station of the Umm Marrih Scheme by low-lift pump. This pump station is situated near the highest ground in the area. However, if the area is to be developed as a separate scheme the best route is to follow the existing Umm Marrih canal but this has the following disadvantages :-

(a) A rising main of 350 metres is required.

(b) There will either have to be high banks for at least 3 kilometres or a secondary pump station for the higher ground.

(c) The canal does not reach the main part of the project area until K6.0.

If the area were to be served from Sabunabi which is just north of the Khor Um Ish there would be a shorter headreach but a 600 metres long rising main would be required and for this reason was

The main canal which has been surveyed for the first 3 kilometres, enters the proposed scheme at K1.5 after passing the eastern boundary of the existing scheme. The static lift is 19.0 metres.

This area could also be developed from the existing El Tewfigia scheme or the Siem scheme by the construction of secondary pump stations and increasing the capacities of the pump canals.

The soil and land classification survey shows that most of these lands are arable and are suitable for cultivation of a long staple cotton rotation similar to that practised on the adjacent El Tewfigia and Siem pump schemes. The proposed new pump scheme is therefore feasible or, alternatively, these lands could be developed as extensions to existing schemes by low-lift pumps.

UMM MARRIH EXTENSION SCHEME

This scheme having a gross area of 4,000 feddans is best served from the existing secondary pump station of the Umm Marrih Scheme by low-lift pump. This pump station is situated near the highest ground in the area. However, if the area is to be developed as a separate scheme the best route is to follow the existing Umm Marrih canal but this has the following disadvantages :-

(a) A rising main of 850 metres is required.

(b) There will either have to be high banks for at least 3 kilometres or a secondary pump station for the higher ground.

(c) The canal does not reach the main part of the project area until K6.0.

If the area were to be served from Sabunabi which is just north of the Khor Um Ish there would be a shorter headreach but a 600 metres long rising main would be required and for this reason was

not considered.

The soil and land classification survey shows that most of the lands are arable and are suitable for the cultivation of a long staple cotton rotation similar to that at present practised on the existing Umm Marrih pump scheme. The proposed extension scheme is therefore feasible.

SINGA PUMP SCHEME

This scheme covers the largest undeveloped part of the project area and the gross area recommended for soil survey was 37,000 feddans. The scheme is surrounded by existing pump schemes and the Khor Umm Ish and for this reason the choice of site for a pump station was very restricted. The site chosen lies between the existing pump stations of the Naira and Umm Benein (Government Dairy) Schemes. The clay plain comes very close to the river at this point and a rising main of only 150 metres is required. The static lift is 16.5 metres. The canal route has been surveyed for 3.2 kilometres at which point it enters the proposed development area. There are several depressions in the area but by careful planning of the minor canalization the slopes of some of these depressions can be irrigated. The area recommended for soil survey included an area of approximately 3,000 feddans which is at present claimed as grazing rights by the Umm Benein (Government Dairy) Scheme. Most of this area appears level enough for irrigation and the best route for the main canal passes through it. It is understood that the area under cultivation in the Umm Benein Scheme cannot get water from the pump station after mid-March because the intakes are too high; the new pump station could extend this cultivation period considerably.

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The soil and land classification survey shows that most of the lands are arable and are suitable for the cultivation of a long staple cotton rotation similar to that at present practised on the existing Umm Marrih pump scheme. The proposed extension scheme is therefore feasible.

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The soil and land classification survey shows that there is considerable variation in soil quality within this large block of land. Lands north-east of the railway line, together with a strip west of the railway line from Kewkab to Umm Benein, suffer from a severe alkalinity problem and are classed as non-arable. The higher lands adjacent to the Khor Umm Ish are of reasonable quality, however, and about 15,000 feddans of land extending from the Umm Marih pump scheme northwards to the railway line are classed as arable. This block would be suitable for a long staple cotton rotation similar to that practised on the existing pump schemes of the Blue Nile west bank. The proposed Singa pump scheme is therefore considered a feasible proposition although the area to be irrigated is a little under half of that originally proposed.

WAD RABAA EXTENSION

This area of 650 feddans lies to the south of the existing Wad Rabaa scheme within an oxbow. It could be commanded by low-lift pump from the existing canal and the surrounding oxbow gives excellent drainage.

These lands are arable (Class 3) and the proposed extension to the existing Wad Rabaa pump scheme is therefore feasible. Because two of the sites examined have clay contents between 35 and 50 per cent, however, it may prove more profitable to substitute other arable crops such as groundnuts for part of the long staple cotton in the rotation.

WAD ABATI EXTENSION

Lying to the west of the Wad Abati scheme is a small triangular area of 650 feddans which can be irrigated as an extension to the existing scheme.

These lands are arable (Class 2 and 3) and the proposed extension to the existing Wad Abati pump scheme is therefore feasible.

ABIDIN PUMP SCHEME

South west of Abidin an area of 2,500 feddans is enclosed by the Khor Um Ish and the railway. This area can be irrigated from a site immediately upstream of the existing Abidin pump station. There is no 'kerrib' land at this part of the river and therefore there is a minimal length of rising main. However, to cross the Khor Umm Ish a 400 metre siphon would be required although the whole area can be commanded from the pump station with a static lift of 11.3 metres.

The soil and land classification survey shows considerable soil variation, with severe alkalinity in places. Over half the sites are classified as arable (Class 3 and 4 lands), however, and it should be possible to plan a new pump scheme on about 1,500 feddans of arable land.

MAIURNO WEST AND SENNAR SCHEMES

These two areas are taken together since they can be irrigated from the same pump station. The Maiurno West scheme has a gross area of 3,800 feddans and the Sennar scheme an area of 2,800 feddans. The pump station site suggested at Maiurno is immediately south of the three existing pump stations. A rising main of 250 metres is required and the intake pipes will also have to be at least 60 metres long; however, this will depend on the future operating schedule of Sennar Dam. The area at Maiurno cannot be commanded directly from the river and a secondary low-lift pump station would be required to command the area. No information concerning levels was available for the Sennar area, but it is considered possible that this can be irrigated direct from Maiurno pump

These lands are arable (Class 2 and 3) and the proposed extension to the existing Wad Abati pump scheme is therefore feasible.

ABIDIN PUMP SCHEME

South west of Abidin an area of 2,500 feddans is enclosed by the Khor Um Iab and the railway. This area can be irrigated from a site immediately upstream of the existing Abidin pump station. There is no 'Kerrib' land at this part of the river and therefore there is a minimal length of rising main. However, to cross the Khor Umm Iab a 400 metre siphon would be required although the whole area can be commanded from the pump station with a static lift of 11.3 metres.

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station. A static lift of 13.3 metres at Maiurno gives a headpond water level of 430.5.

The soil and land classification survey shows these lands to be of uniformly high quality (66 per cent of Class 2 land). Development to a long staple cotton rotation should give economic returns under good management and the lands should, therefore, be included in a development project.

These two schemes by themselves probably do not justify the building of such a long canal. However, if the undeveloped area north of Sennar of which about 40,000 feddans could be commanded direct from Maiurno is included, the economic feasibility appears to be much enhanced. These areas are shown on figure 7.2.

The following Table 7.2 sets out the pump scheme projects proposed for the development of lands in Area 2B.

Table 7.2 Proposed Pump Scheme Projects

Scheme	Gross Area (feddans)	Normal Minimum Water Level (Metres A.S.L.)	Water Level in Discharge Pond (Metres A.S.L.)	Static Lift (Metres)
Tabit	7,000	419.50	439.00	19.50
El Tewfigia	2,300	419.00	438.00	19.00
Umm Marrih	4,000	418.00	437.00	19.00
Singa	37,000	417.50	434.00	16.50
Wad Rabaa Extension	650	417.20	429.00	11.80
Wad Abati Extension	650	417.20	430.50	13.30
Abidin	2,500	417.20	428.50	11.30
Maiurno West and Sennar	2,800	417.20	430.50	13.30

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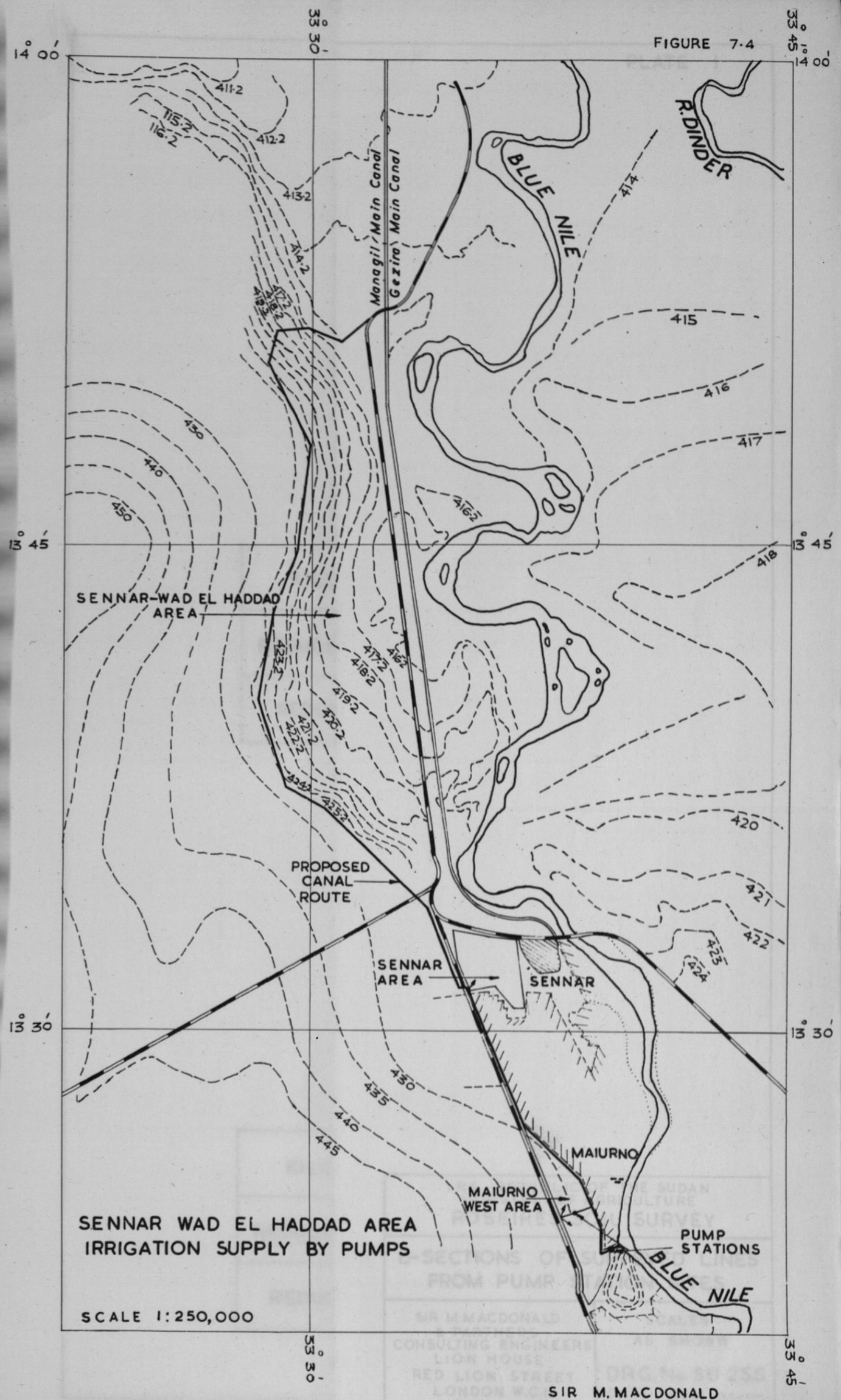
FIGURE 7·4


33° 30'
33° 45'
14° 00'
13° 45'
13° 30'
R. DINDER
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Managil Main Canal
Gezira Main Canal
SENNAR-WAD EL HADDAD AREA
PROPOSED CANAL ROUTE
SENNAR AREA
SENNAR
MAIURNO
MAIURNO WEST AREA
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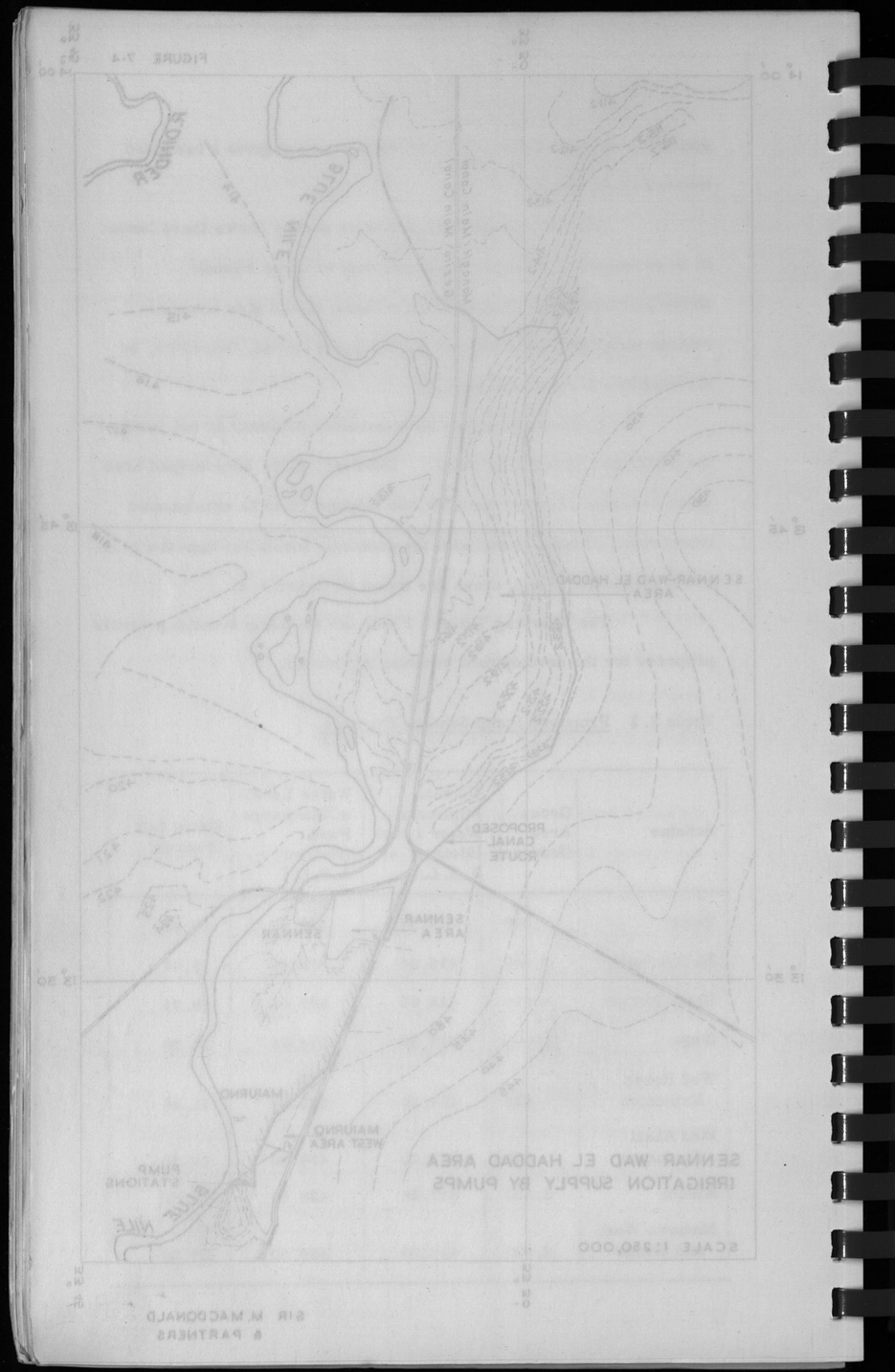
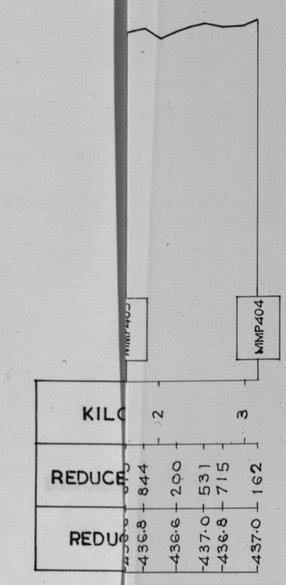
SCALE 1:250,000
SIR M. MACDONALD & PARTNERS





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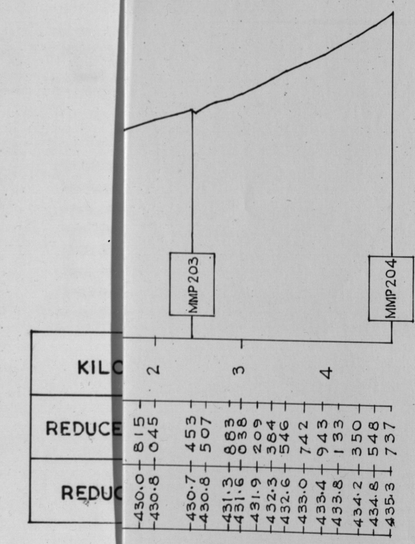

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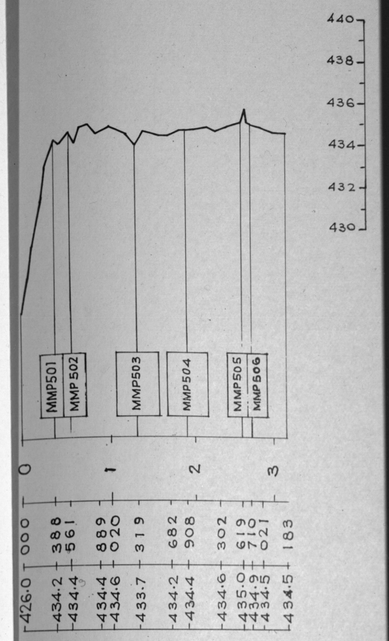
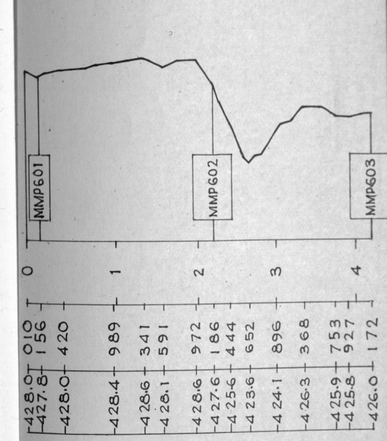
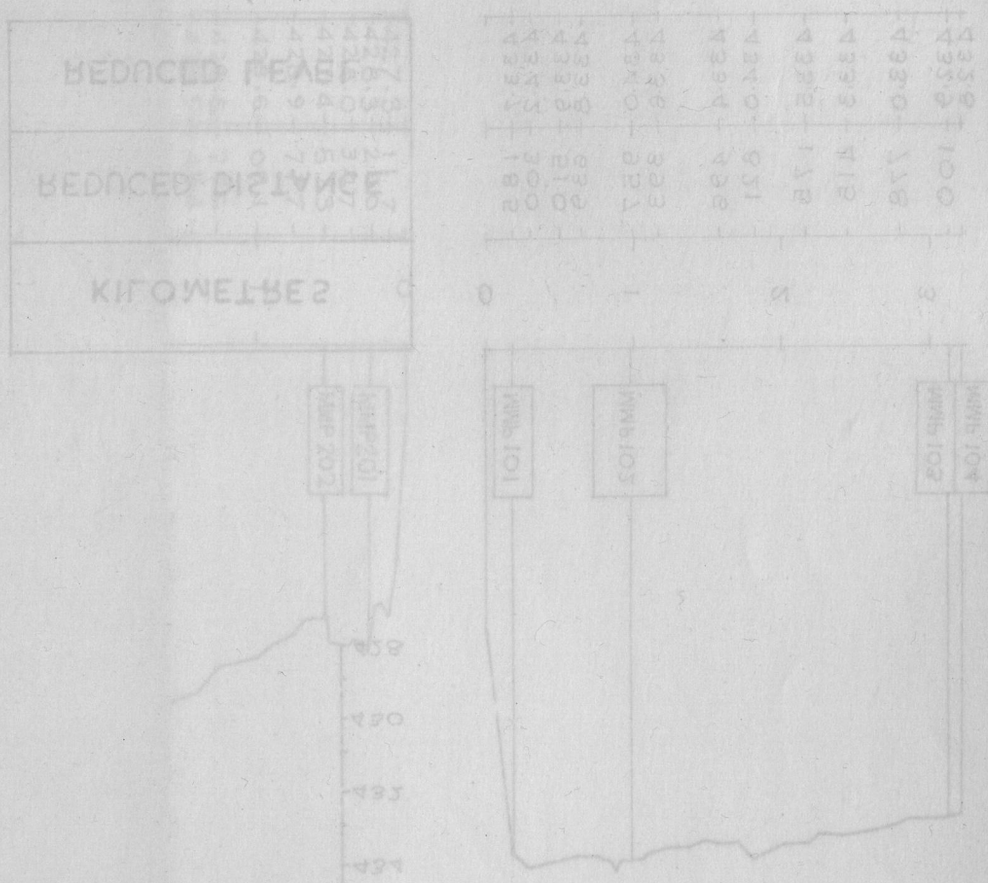
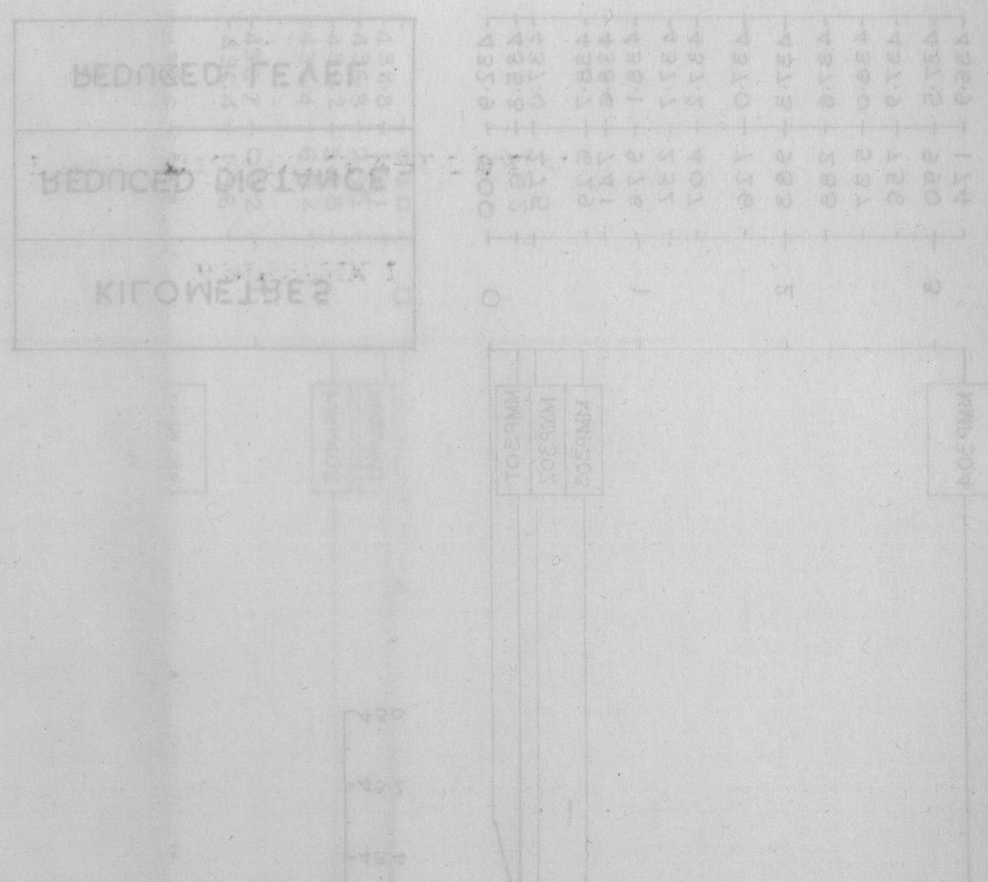


UMM MARRIH SCHEME SECTION



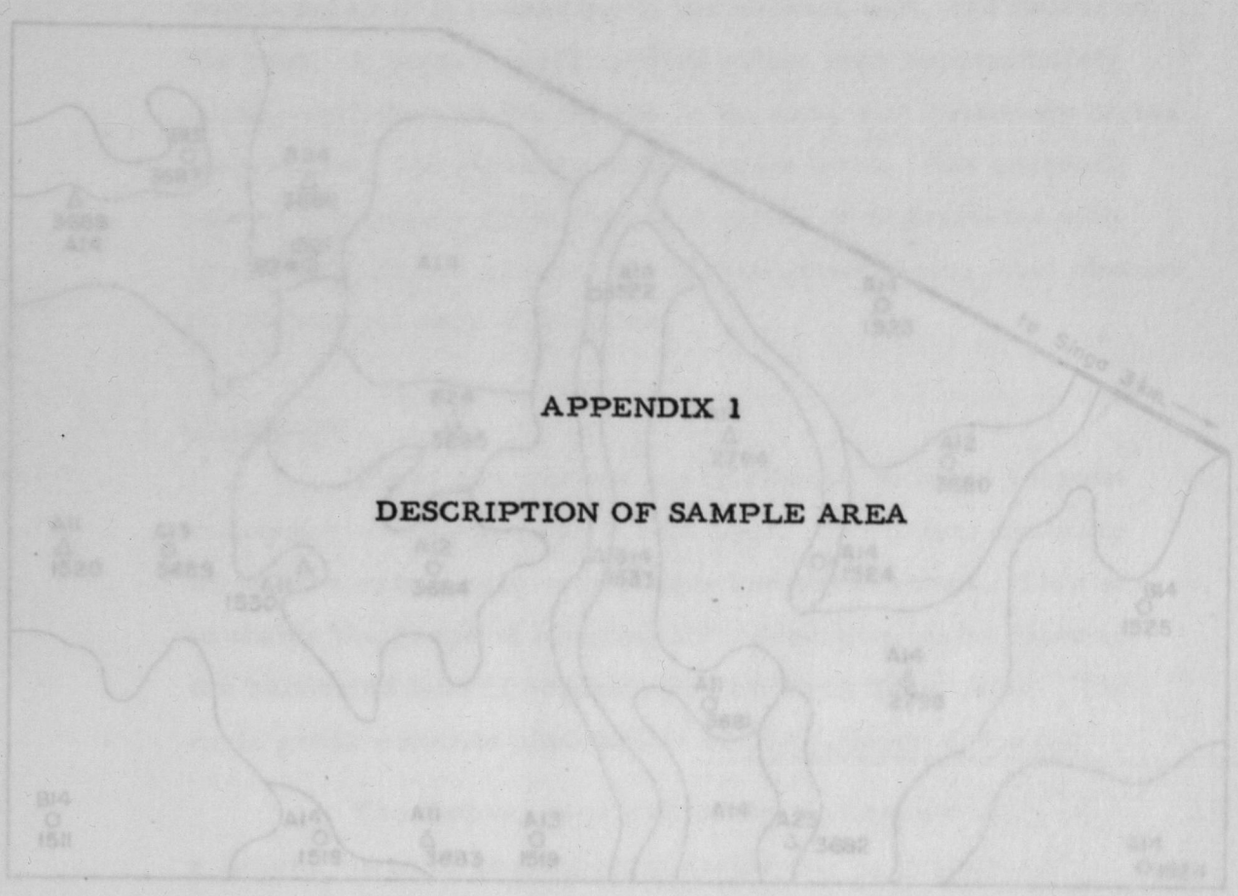
ABIDIN SCHEME SECTION


REDUCED LEVEL
KILOMETRES


REDUCED LEVEL
KILOMETRES

APPENDIX 1

DESCRIPTION OF SAMPLE AREA



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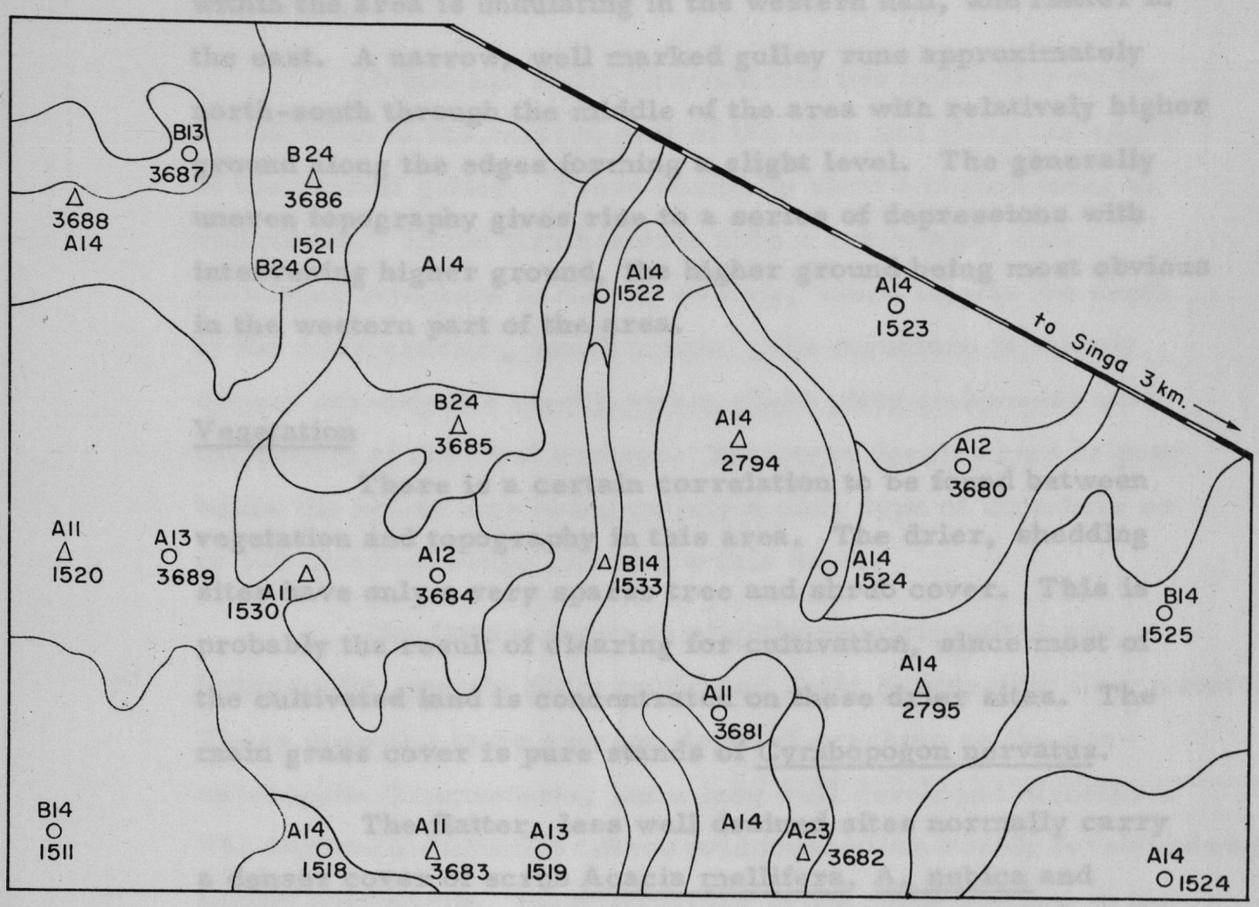


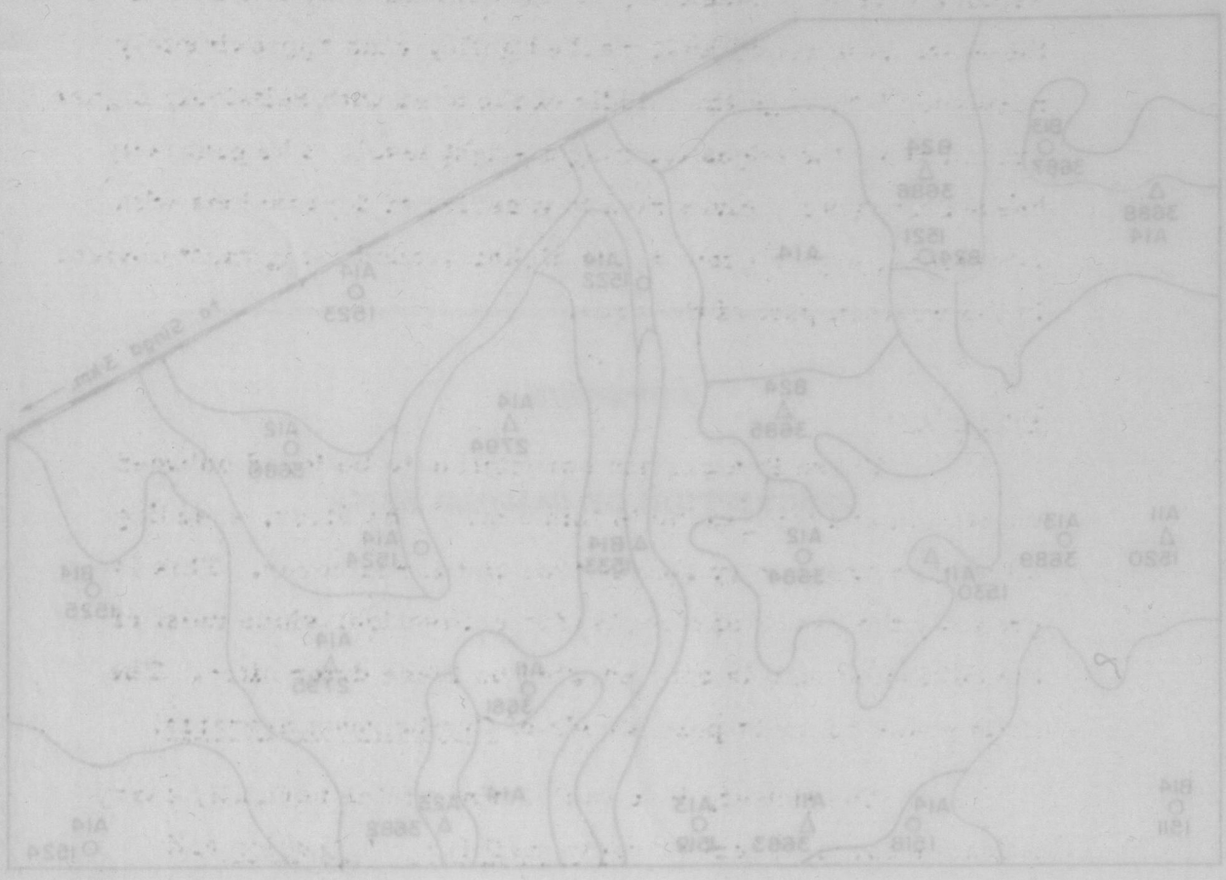
SCALE 1 : 25,000

LEGEND

Orthic Grumustert	A11
Natrargidic Grumustert	A12
Entic Grumustert	A13
Entic Natrargidic Grumustert	A14
Entic Mazustert	A23
Entic Grumaquert	B13
Entic Natrargidic Grumaquert	B14
Entic Natrargidic Mazaquert	B24

2 Metre bore ..... O

2 Metre pit ..... Δ



Location

The sample area, some 10 sq km in area is located along the railway line, approximately 3 km west of Singa.

Topography

The area is generally slightly low-lying between the Blue Nile and a major relic river course. The topography within the area is undulating in the western half, and flatter in the east. A narrow, well marked gulley runs approximately north-south through the middle of the area with relatively higher ground along the edges forming a slight level. The generally uneven topography gives rise to a series of depressions with intervening higher ground, the higher ground being most obvious in the western part of the area.

Vegetation

There is a certain correlation to be found between vegetation and topography in this area. The drier, shedding sites have only a very sparse tree and shrub cover. This is probably the result of clearing for cultivation, since most of the cultivated land is concentrated on these drier sites. The main grass cover is pure stands of Cymbopogon nervatus.

The flatter, less well drained sites normally carry a denser cover of scrub Acacia mellifera, A. nubica and A. seyal and the grass vegetation, while still dominantly Cymbopogon nervatus, is more mixed, with Cyperus rotundus an important constituent.

The well marked receiving, depressional sites have a fairly dense scrub cover of Acacia mellifera and A. nubica with varying amounts of A. seyal. The dominant close cover vegetation is the sedge Cyperus rotundus with some Cymbopogon nervatus.

In certain parts of the gulley bottom, there is little or no vegetation cover, probably due to the lengthy period that there is standing water in this gulley.

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Soils

10 pits and 14 bores were sited within the area after photo-interpretation to cover all patterns on the photograph which were thought to indicate soil variations.

The majority of the soils are Natrargidic. This is a reflection of the topography, not only in the small scale undulations within the area, but in the low-lying nature of the area as a whole.

Orthic and Entic Grumusterts are found only on the driest sites in the eastern part of the area and along the edges of the central gulley. These normally show a higher level of cultivation. These Grumusterts have a reasonably well developed structure in the top 40 cms, which is also the depth of the main cracking development. The structure is mainly coarse sub-angular blocky with a slight platy component near the bottom of the first horizon. Structure development is poor below the top 40 cms being mainly a platy type of structure up to 100 cms and wedge like below this depth.

The flatter datum to slightly receiving sites are Natrargidic, mainly Natrargidic and Entic Natrargidic Grumusterts. These show the same average depth of cracking as the non-natrargidic Grumusterts, but a less well developed structure. The surface structure is coarse prismatic with a weakly developed angular blocky component. Platy structure is the main element in the second horizon and wedge in the third.

The more obvious depressional sites are classed as Entic Natrargidic Grumaquerts or Entic Natrargidic Mazaquerts. These show very weak structural development, the structural elements being extremely coarse in the top horizon. The profiles are, in general, moist to wet below the top 30-40 cms, and very compact throughout.

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The following table shows the distribution of land classes within the various soil classes.

Soil Class / Land Class	A11	A12	A13	A14	A23	B13	B14	B24	Total
2	1								1
3a	3		1		1				5
4a		2		1			2		5
6a(2)			1			1			2
6a(4a)				2				1	3
6a				5			1	2	8
Total	4	2	2	8	1	1	3	3	24

Most of the poor class 6a(4a) and 6a land occurs as either Entic Natrargidic Grumusterts or Entic Natrargidic Grumaquerts and Mazaquerts, while the good classes 2 and 3a occur as Orthic or Entic Grumusterts.

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2	1								1
3a	3		1		1				5
4a		2		1			2		5
6a(2)			1			1			2
6a(4a)				[illegible]				1	3
6a				5			1	2	8
Total	4	2	2	8	1	1	3	3	24

Most of the poor class 6a(4a) and 6a land occurs as either Entic Natrargidic Grumusterts or Entic Natrargidic Grumaquerts and Mazaquerts, while the good classes 2 and 3a occur as Orthic or Entic Grumusterts.

APPENDIX 2

SUBGROUP EXAMPLES
DESCRIPTION AND ANALYSES

APPENDIX 2

SUBGROUP EXAMPLES

DESCRIPTION AND ANALYSES

Pit: 2794

Location:

Topography: Flat and very slight slope to west.

Cultivation and Land Use: Lightly grazed grass savannah near a village.

Vegetation: A. Nil

B. Moderate

C. Cymbopogon nervatus (100)

Surface: Fairly even. 2 cm granular mulch under 5 mm soft raincrust. Occasional grey calcium carbonate nodules up to 1 mm. Few sand grains up to 0.5 mm.

Profile Description:

0 - 55 cm: 10YR 4/ Clay. Dry, very hard moderate coarse prismatic. Occasional cracks up to 3 cm. Moderately moisture absorbent. Common roots up to 0.5 mm. Common grey calcium carbonate nodules up to 3 mm. Few sand grains up to 1 mm.

55 - 130 cm: 10YR 4/1. Clay. Very slightly moist firm, massive. Few 10-20 cm slickensides. Occasional up to 2 cm cracks to a depth of 90 cm. Slowly moisture absorbent. Rare 0.1 mm roots. Occasional grey calcium carbonate nodules up to 7 mm. Rare sand grains up to 0.5 mm. Rare 5 cm vertical sand lenses.

130 - 185 cm: 10YR3/1. Clay. Moist firm, massive. No cracks. Slowly moisture absorbent. Rare 0.2 mm roots. Occasional grey 1 cm patches of up to 3 mm calcium carbonate septaria. Occasional grey calcium carbonate nodules up to 4 mm.

(200 - 300 cm in bore)

185 - 300 cm: 10YR 5/2.5 with common small faint 10YR 5/1 mottles. Clay. Moist friable, massive. No cracks. Slowly moisture absorbent. No roots. Few black and white calcium carbonate septaria up to 4 mm. Rare 2 mm black calcium carbonate nodules. Rare 1 mm sand grains.

Soil Class: Entic Natrargidic Grumustert.

Pit: 2794

Location:

Topography: Flat and very slight slope to west.

Cultivation and Land Use: Lightly grazed grass savannah near a village.

Vegetation: A. Nil

B. Moderate

C. Cymbopogon nervatus (100)

Surface: Fairly even. 2 cm granular mulch under 5 mm soft raincrust. Occasional grey calcium carbonate nodules up to 1 mm. Few sand grains up to 0.5 mm.

Profile Description:

0 - 55 cm 10YR 4/ Clay. Dry, very hard moderate coarse prismatic. Occasional cracks up to 3 cm. Moderately moisture absorbent. Common roots up to 0.5 mm. Common grey calcium carbonate nodules up to 3 mm. Few sand grains up to 1 mm.

55 - 130 cm 10YR 4/1. Clay. Very slightly moist firm, massive. Few 10-20 cm slickensides. Occasional up to 2 cm cracks to a depth of 90 cm. Slowly moisture absorbent. Rare 0.1 mm roots. Occasional grey calcium carbonate nodules up to 7 mm. Rare sand grains up to 0.5 mm. Rare 5 cm vertical sand lenses.

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(200 - 300 cm in bore)

185 - 300 cm 10YR 5/2.5 with common small faint 10YR 5/1 mottles. Clay. Moist friable, massive. No cracks. Slowly moisture absorbent. No roots. Few black and white calcium carbonate septaria up to 4 mm. Rare 2 mm black calcium carbonate nodules. Rare 1 mm sand grains.

Soil Class: Entic Natrargidic Grumustert.

Pit No: 3685

Location:

Topography: Slight depression

Cultivation: Grassland not grazed

Vegetation: Acacia seyal) Acacia nubica) many small bushes.

Surface: Firm with many large cracks.

Profile Description:

0 - 44 cm — 10YR 5/1 - 4/1 rapidly moisture absorbent clay. Extremely hard. Strong coarse to very coarse prismatic with moderate fine platy secondary structure, frequent coarse and fine cracks. Abundant medium quartz grains. Frequent sand in cracks, rare kankars.

44 - 90 cm — 10YR 4/1-4/2, 25 per cent Mottles 10YR4/2, slightly moisture absorbent clay, moist, very firm. Weak medium coarse angular blocky, rare fine cracks. Frequent fine medium calcium carbonate concretion. Rare medium kankars.

90 - 180 cm — 10YR 5/1-5/2 Slightly moisture absorbent, clay, massive, few fine cracks. Common coarse kankars. Rare fine calcium carbonate concretions.

(200 - 300 cm in bore)

180 - 300 cm — Moist 10YR6/1 - 5/1 Slightly moisture absorbent clay, moist, extremely firm. Massive few fine cracks. Common coarse kankars. Rare fine calcium carbonate concretions. Rare fine sand pockets.

Soil Class: Entic Natrargidic Mazaquert

Pit No: 3685

Location:

Topography: Slight depression

Cultivation: Grassland not grazed

Vegetation: *Acacia seyal* } many small bushes.
Acacia nubica }

Surface: Firm with many large cracks.

Profile Description:

0 - 44 cm 10YR 5/1 - 4/1 rapidly moisture absorbent clay. Extremely hard. Strong coarse to very coarse prismatic with moderate fine platy secondary structure, frequent coarse and fine cracks. Abundant medium quartz grains. Frequent sand in cracks, rare kankara.

44 - 90 cm 10YR 4/1-4/2, 25 per cent Mottles 10YR4/2, slightly moisture absorbent clay, moist, very firm. Weak medium coarse angular blocky, rare fine cracks. Frequent fine medium calcium carbonate concretion. Rare medium kankara.

90 - 180 cm 10YR 5/1-5/2 Slightly moisture absorbent, clay, massive, few fine cracks. Common coarse kankara. Rare fine calcium carbonate concretions.

(200 - 300 cm in bore)

180 - 300 cm Moist 10YR6/1 - 5/1 Slightly moisture absorbent clay, moist, extremely firm. Massive few fine cracks. Common coarse kankara. Rare fine calcium carbonate concretions. Rare fine sand pockets.

Soil Class: Entic Natrargidic Maraquert

Pit No: 2795

Location:

Topography: Flat with very slight slope to south-west

Cultivation and Land Use: Partly grazed grass savannah near cattle route from a nearby village to the river. Some nahl collection.

Vegetation: A. Acacia mellifera (6)
Acacia seyal (2)
B. Moderate
C. Cymbopogon nervatus 100 cm

Surface: Fairly even. 1-2 cm medium granular mulch. Common cracks up to 8 cm. Occasional grey calcium carbonate nodules up to 2 mm. Few sand grains up to 1 mm.

Profile Description:

0 - 45 cm 10YR 4/2. Clay. Dry hard, weak medium prismatic with moderate coarse subangular blocky component. Occasional cracks up to 3 cm. Moderately moisture absorbent. Occasional roots up to 1 mm. Occasional grey calcium carbonate nodules up to 2 mm. Few sand grains up to 0.5 mm.

45 - 150 cm 10YR 4/2. Clay. Slightly moist, very firm, massive, 10 cm slickensides. Few cracks up to 1 cm. Slowly moisture absorbent. Few roots up to 1 cm. Occasional grey calcium carbonate nodules up to 2 mm. Few sand grains up to 1 mm. Rare 2 cm sand lenses between 50 - 70 cm. Rare shell fragments.

(200 - 300 cm in bore)

150 - 205 cm 10YR 2.5/1 with common medium distinct 10YR 2/2 mottling. Clay. Moist, friable, massive. No cracks. Moderately moisture absorbent. No roots. Common black and white calcium carbonate septaria up to 4 mm. Occasional 2 cm 10YR 4/4 patches.

205 - 300 cm 10YR 5/3 with common increasing to many below 280 cm small faint 10YR 5/1 mottles. Clay. Slightly moist very slightly firm. No cracks. Slowly moisture absorbent. No roots. Occasional black and white calcium carbonate nodules.

Soil Class: Entic Natrargidic Grumustert

Pit No: 2795

Location:

Topography: Flat with very slight slope to south-west

Cultivation and Land Use: Partly grazed grass savannah near cattle route from a nearby village to the river.

Some mail collection.

Vegetation: A. Acacia mellifera (6)

Acacia seyal (2)

B. Moderate

C. Cymbopogon nervatus 100 cm

Surface: Fairly even. 1-2 cm medium granular mulch. Common cracks up to 8 cm. Occasional grey calcium carbonate nodules up to 2 mm. Few sand grains up to 1 mm.

Profile Description:

0 - 45 cm 10YR 4/2. Clay. Dry hard, weak medium prismatic with moderate coarse subangular blocky component. Occasional cracks up to 3 cm. Moderately moisture absorbent. Occasional roots up to 1 mm. Occasional grey calcium carbonate nodules up to 2 mm. Few sand grains up to 0.5 mm.

45 - 150 cm 10YR 4/2. Clay. Slightly moist, very firm, massive, 10 cm slickensides. Few cracks up to 1 cm. Slowly moisture absorbent. Few roots up to 1 cm. Occasional grey calcium carbonate nodules up to 2 mm. Few sand grains up to 1 mm. Rare 2 cm sand lenses between 50 - 70 cm. Rare shell fragments.

(200 - 300 cm in bore)

150 - 205 cm 10YR 2.5/1 with common medium distinct 10YR 2/2 mottling. Clay. Moist,friable, massive. No cracks. Moderately moisture absorbent. No roots. Common black and white calcium carbonate septaria up to 4 mm. Occasional 2 cm 10YR 4/4 patches.

205 - 300 cm 10YR 5/3 with common increasing to many below 280 cm small faint 10YR 5/1 mottles. Clay. Slightly moist very slightly firm. No cracks. Slowly moisture absorbent. No roots. Occasional black and white calcium carbonate nodules.

Soil Class: Entic Natrargidic Grumusert

Pit No: 3686

Location:

Topography: Flat and level depression

Cultivation: Grassland not grazed

Vegetation: Acacia seyal, many small bushes.

Surface: Firm with large cracks, few shells and loose kankars.

Profile Description:

0 - 70 cm 10YR 5/1-4/1. Moderately moisture absorbent clay, very slightly moist, very firm. Strong coarse to very coarse prismatic with weak secondary fine platy, rare fine cracks, common 3 cm crack. Rare sand in cracks, common coarse calcium carbonate concretions. Common medium kankars, frequent fine-medium calcium carbonate concretions.

(200 - 300 cm in bore)

70 - 300 cm 10YR 5/1 - 2.5Y5/2; slightly moisture absorbent clay. Moist, extremely firm. Massive to weak medium angular blocky, common fine cracks. Rare sand in cracks, rare coarse calcium carbonate concretions. Common fine calcium carbonate concretions.

Soil Class: Entic Natrargidic Mazaquert

Pit No: 3686

Location:

Topography: Flat sand level depression

Cultivation: Grassland not grazed

Vegetation: Acacia seyal, many small bushes.

Surface: Firm with large cracks, few shells and loose kankara.

Profile Description:

0 - 70 cm 10YR 5/1-4/1. Moderately moisture absorbent clay, very slightly moist, very firm. Strong coarse to very coarse prismatic with weak secondary fine platy, rare fine cracks, common 3 cm crack. Rare sand in cracks, common coarse calcium carbonate concretions. Common medium kankara, frequent fine-medium calcium carbonate concretions.

(200 - 300 cm in bore)

70 - 300 cm 10YR 5/1 - 2.5Y5/2; slightly moisture absorbent clay. Moist, extremely firm. Massive to weak medium angular blocky, common fine cracks. Rare sand in cracks, rare coarse calcium carbonate concretions. Common fine calcium carbonate concretions.

Soil Class: Entic Natrargidic Margaquert

Pit No: 3688

Location:

Cultivation: Grassland not grazed

Vegetation: A. Balanites aegyptiaca (2)

C. Cymbopogon nervatus - pure stand.

Surface: Shallow mulch, many large cracks 0-3 cm

Profile Description:

0 - 50 cm 10YR 5/2 - 4/2; rapidly moisture absorbent clay, moist, firm. Strong coarse to very coarse prismatic with weak fine secondary platy structure, many fine secondary cracks, few fine pores, frequent grass roots. Common fine calcium carbonate concretions.

50 - 137 cm 10YR 4/2 - 3/2; moderately, moisture absorbent clay. Moist very firm. Moderate medium to coarse angular blocky, many fine cracks and slickensides. Rare sand in cracks; frequent fine calcium carbonate concretions.

(200 - 300 cm in bore)

137 - 300 cm 10YR 4/2 - 3/3; rapidly moisture absorbent clay; slightly moist, very firm. Massive. Rare sand pockets; rare coarse calcium carbonate concretions. Common medium calcium carbonate concretions.

Soil Class: Entic Natrargidic Grumustert.

Pit No: 368B

Location:

Cultivation: Grassland not grazed

Vegetation: A. Balanites aegyptiaca (2)

C. Cymbopogon nervatus - pure stand.

Surface: Shallow mulch, many large cracks 0-3 cm

Profile Description:

0 - 50 cm 10YR 5/2 - 4/2; rapidly moisture absorbent clay, moist, firm. Strong coarse to very coarse prismatic with weak fine secondary platy structure, many fine secondary cracks, few fine pores, frequent grass roots. Common fine calcium carbonate concretions.

50 - 137 cm 10YR 4/2 - 3/2; moderately, moisture absorbent clay. Moist very firm. Moderate medium to coarse angular blocky, many fine cracks and slickensides. Rare sand in cracks; frequent fine calcium carbonate concretions.

(200 - 300 cm in bore)

137 - 300 cm 10YR 4/2 - 3/3; rapidly moisture absorbent clay; slightly moist, very firm. Massive. Rare sand pockets; rare coarse calcium carbonate concretions. Common medium calcium carbonate concretions.

Soil Class: Entic Natrargidic Grumustert.

Pit No: 3683

Location:

Topography: Flat level.

Cultivation: Grassland not grazed

Vegetation: A. Acacia nubica)
Acacia mellifera) many small bushes.
Acacia seyal)
C. Cymbopogon nervatus pure stand.

Surface: Shallow mulch many large cracks.

Profile description:

0 - 42 cm 10YR 4/2 - 3/2; rapidly moisture absorbent clay, slightly moist, very firm, strong coarse to very coarse prismatic with strong fine platy secondary structure, common large cracks 0 - 3 cm and rare pores. Few roots. Frequent sand in cracks; common coarse quartz grains, rare fine calcium carbonate concretions.

42 - 88 cm 10YR 3/2; rapidly moisture absorbent clay moist firm, strong moist to coarse angular blocky with secondary weak fine platy. Frequent fine cracks. Common sand in cracks. Common medium quartz grains. Rare fine calcium carbonate concretions.

88 - 165 cm 10YR 4/2 - 3/3; moderately moisture absorbent, moist, very firm. Moderate medium coarse angular blocky, common cracks and slickensides. Rare roots. Frequent sand cracks, rare coarse $CaCo_3$ concretions. Frequent fine calcium carbonate concretions.

(200 - 300 cm in bore)

168 - 300 cm 10YR 6/4 - 5/3; rapidly moisture absorbent clay; moist friable, massive, rare cracks and rare fine pores. Occasional medium calcium carbonate concretions common medium kankars. Rare sand in cracks.

Soil Class: Orthic Grumustert.

Pit No: 3683

Location:

Topography: Flat level.

Cultivation: Grassland not grazed

Vegetation: A. *Acacia nubica*) many small bushes.
Acacia mellifera)
Acacia seyal)

C. *Cymbopogon nervatus* pure stand.

Surface: Shallow mulch many large cracks.

Profile description:

0 - 42 cm 10YR 4/2 - 5/2; rapidly moisture absorbent clay, slightly moist, very firm, strong coarse to very coarse prismatic with strong fine platy secondary structure, common large cracks 0 - 3 cm and para pores. Few roots. Frequent sand in cracks common coarse quartz grains, rare fine calcium carbonate concretions.

42 - 88 cm 10YR 3/2; rapidly moisture absorbent clay moist firm, strong moist to coarse angular blocky with secondary weak fine platy. Frequent fine cracks. Common sand in cracks. Common medium quartz grains. Rare fine calcium carbonate concretions.

88 - 165 cm 10YR 4/2 - 3/3; moderately moisture absorbent, moist, very firm. Moderate medium coarse angular blocky, common cracks and slickensides. Rare roots. Frequent sand cracks, rare coarse $CaCO_3$ concretions. Frequent fine calcium carbonate concretions.

(200 - 300 cm *in bore*)

168 - 300 cm 10YR 6/4 - 5/3; rapidly moisture absorbent clay moist friable, massive, rare cracks and rare fine pores. Occasional medium calcium carbonate concretions common medium kankars. Rare sand in cracks.

Soil Class: Orthic Grumusoter.

Pit No: 1533

Location:

Topography: Near edge of Mays depression.

Cultivation and Land Use: Scrub/grassland, heavily grazed.

Vegetation: A. Acacia nubica (4)

B. & C. nearly bare.

Surface: Thin coarse mulch. Frequent kankars. Few quartz grains. Frequent very large cracks. Few shell fragments.

Profile description:

0 - 80 cm 10YR4/1. Clay. Dry very hard top 40 cm, then moist, very firm, moderate coarse prismatic with weak medium platy component. Common large cracks and few pores. At 50 cm common slickensides. Slowly moisture absorbent. Few roots. Common shell fragments. Many fine Calcium Carbonate concretions. Common kankars.

80 - 150 cm 10YR 3/1. Few mottles 7.5YR4/4. Clay. Moist very firm. Weak coarse angular blocky with few wedges. Many slickensides. No cracks and pores. Slowly moisture absorbent. Occasional roots. Common kankars, common fine calcium carbonate concretions. Occasional shell fragments. In transition few calcium carbonate streaks. Few sand pockets 10YR4/1.

(200 - 300 cm in bore)

150 - 300 cm 5Y4/1. Few mottles 7.5YR4/4. Clay. Wet non plastic. Massive. Few slickensides. No cracks and pores. Slowly moisture absorbent. No roots. Common calcium carbonate concretions and streaks. Sand pockets. Common kankars. Few shell fragments.

Soil Class: Entic Natrargidic Grumaquert.

Pit No: 1533

Location:

Topography: Near edge of Maya depression.

Cultivation and Land Use: Scrub/grassland, heavily grazed.

Vegetation: A. Acacia nubica (4)

B. & C. nearly bare.

Surface: Thin coarse mulch. Frequent kankara. Few quartz grains. Frequent very large cracks. Few shell fragments.

Profile description:

0 - 80 cm 10YR4/1. Clay. Dry very hard top 40 cm, then moist, very firm, moderate coarse prismatic with weak medium platy component. Common large cracks and few pores. At 50 cm common slickensides. Slowly moisture absorbent. Few roots. Common shell fragments. Many fine Calcium Carbonate concretions. Common kankara.

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(200 - 300 cm in bore)

150 - 300 cm 5Y4/1. Few mottles 7.5YR4/4. Clay. Wet non plastic. Massive, few slickensides. No cracks and pores. Slowly moisture absorbent. No roots. Common calcium carbonate concretions and streaks. Sand pockets. Common kankara. Few shell fragments.

Soil Class: Entic Natrargidic Grumusquert.

Pit No: 1530

Location:

Topography: Flat and gently sloping.

Cultivation and Land Use: Rain dura.

Vegetation: A. Nil
B. 100%
C. Nil

Surface: Soft broken crust. Common large cracks 3-8 cm, coarse mulch. Occasional kankars. Few fine calcium carborate concretions. Few shell fragments.

Profile Description:

0 - 35 cm: 10YR 4/2-3/2. Clay. Dry very hard, moderate coarse subangular blocky. Common large cracks 3-5 cm and pores. Moderately to slowly moisture absorbent. Common roots. Common fine Calcium Carbonate concretions. Common kankars.

35 - 130 cm: 10YR 3/2. Clay. Moist firm. Moderate medium angular blocky with platy component. Common slickensides common large cracks (3 cm) up to 450 cm. No pores. Slowly moisture absorbent. No roots. Few common fine calcium carbonate concretions. Few kankars.

130 - 160 cm: 10YR 3/1. Common mottles 10YR 5/4 and few 10YR 5/3. Clay. Moist, friable, weak medium angular blocky. Many slickensides. No cracks and few pores. Slowly moisture absorbent. No roots. Common calcium carbonate concretions and streaks. Few kankars.

(200 - 300 cm in bore)

160 - 300 cm: 10YR 4/2-4/3. Clay. Moist firm, massive. Occasional slickensides. No cracks or pores. Slowly moisture absorbent. No roots. Common shell fragments and calcium carbonate concretions and streaks in transition. Common kankars.

Soil Class: Orthic Grumustert.

Pit No: 1530

Location:

Topography: Flat and gently sloping.

Cultivation and Land Use: Rain dura.

Vegetation: A. Nil

B. 100%

C. Nil

Surface: Soft broken crust. Common large cracks 3-8 cm, coarse mulch. Occasional kankara. Few fine calcium carbonate concretions. Few shell fragments.

Profile Description:

0 - 35 cm 10YR 4/2-3/2. Clay. Dry very hard, moderate coarse subangular blocky. Common large cracks 3-5 cm and pores. Moderately to slowly moisture absorbent. Common roots. Common fine Calcium Carbonate concretions. Common kankara.

35 - 130 cm 10YR 3/2. Clay. Moist firm. Moderate medium angular blocky with platy component. Common slickensides common large cracks (3 cm) up to 450 cm. No pores. Slowly moisture absorbent. No roots. Few common fine calcium carbonate concretions. Few kankara.

130 - 160 cm 10YR 3/1. Common mottles 10YR 5/4 and few 10YR 5/3. Clay. Moist, friable, weak medium angular blocky. Many slickensides. No cracks and few pores. Slowly moisture absorbent. No roots. Common calcium carbonate concretions and streaks. Few kankara.

(200 - 300 cm in bore)

160 - 300 cm 10YR 4/2-4/3. Clay. Moist firm, massive. Occasional slickensides. No cracks or pores. Slowly moisture absorbent. No roots. Common shell fragments and calcium carbonate concretions and streaks in transition. Common kankara.

Soil Class: Orthic Grumusterf.

Pit No: 1520

Location:

Topography: Flat and gently sloping

Cultivation and Land Use: Grassland not grazed.

Vegetation: A. Acacia nubica (1)
Acacia seyal var fistula (1)
B. Bare ground 60%
C. Cymbopogon nervatus 90 cm

Surface: Common large cracks 5-10 cm. Fine mulch. Common kankars. Few shell fragments.

Profile Description:

0 - 40 cm 10YR 4/2-3/3. Clay. Dry very hard, moderate coarse sub-angular blocky with platy component. Common large cracks (3-5 cm). Common pores. Moderately to slowly moisture absorbent. Common roots. Many fine calcium carbonate concretions. Common kankars. Occasional shell fragments.

40 - 120 cm 10YR 3/2. At 100 cm few mottles 10YR 4/3. Clay; slightly moist firm, moderate medium angular blocky, with platy component. Common slickensides. No cracks and few pores. Slowly moisture absorbent. No roots. Few kankars. Occasional fine calcium carbonate concretions.

120 - 165 cm 10YR 3/1. Clay. Moist, firm, weak angular blocky with parallelepipeds. Common slickensides. No cracks, no pores. Slowly moisture absorbent. No roots. Few kankars. Few calcium carbonate streaks.

(200 - 300 cm in bore)

165 - 300 cm 10YR 4/2 - 4/3. Clay. Slightly moist, firm. Massive. Few to common slickensides. No cracks or pores. Slowly moisture absorbent. No roots. In transition commnn calcium carbonate streaks. Occasional kankars. Few mica. At 270 cm many kankars.

Soil Class: Orthic Grumustert.

Pit No: 1520

Location:

Topography: Flat and gently sloping

Cultivation and Land Use: Grassland not grazed.

Vegetation: A. Acacia nubica (1)

Acacia seyal var fistula (1)

B. Bare ground 60%

C. Cymbopogon nervatus 90 cm

Surface: Common large cracks 5-10 cm. Fine mulch. Common kankara. Few shell fragments.

Profile Description:

0 - 40 cm 10YR 4/2-3/3. Clay. Dry very hard, moderate coarse sub-angular blocky with platy component. Common large cracks (3-5 cm). Common pores. Moderately to slowly moisture absorbent. Common roots. Many fine calcium carbonate concretions. Common kankara. Occasional shell fragments.

40 - 120 cm 10YR 3/2. At 100 cm few mottles 10YR 4/3. Clay; slightly moist firm, moderate medium angular blocky, with platy component. Common slickensides. No cracks and few pores. Slowly moisture absorbent. No roots. Few kankara. Occasional fine calcium carbonate concretions.

120 - 165 cm 10YR 3/1. Clay. Moist, firm; weak angular blocky with parallelopipeds. Common slickensides. No cracks, no pores. Slowly moisture absorbent. No roots. Few kankara. Few calcium carbonate streaks.

(200 - 300 cm in bore)

165 - 300 cm 10YR 4/2 - 4/3. Clay. Slightly moist, firm. Massive. Few to common slickensides. No cracks or pores. Slowly moisture absorbent. No roots. In transition common calcium carbonate streaks. Occasional kankara. Few mica. At 270 cm many kankara.

Soil Class: Orthic Grumusterk.

Pit No: 3682

Location:

Topography: Shallow Khor

Cultivation: Much cattle grazed.

Vegetation: Heglig (1)

Acacia mellifera)
Acacia seyal) many small trees and bushes.
Acacia nubica)

Surface: Firm few large cracks 0 - 5 cm.

Profile Description:

0 - 70 cm 10YR 4/2-2.5Y5/2. Rapidly moisture absorbent. Clay; very slightly moist, extremely firm. Strong coarse to very coarse prismatic with moderate medium platy structure, coarse 3 cm cracks, many fine cracks. Many Cyperus bulbs. Common very coarse kankars. Common coarse quartz pebbles, rare shells frequent fine $CaCO_3$ concretions, common sand in cracks.

(200 - 300 cm in bore)

70 - 245 cm 2.5Y 5/2 - 4/2 rapidly moisture absorbent clay. Moist, extremely firm. Moderate medium coarse angular blocky, frequent fine calcium carbonate concretions.

245 - 300 cm 2.5Y 5/2-4/2. Slightly moisture absorbent clay, moist and very firm, rare coarse calcium carbonate concretions, common fine calcium carbonate concretions.

Pit No: 3682

Location:

Topography: Shallow khor

Cultivation: Much cattle grazed.

Vegetation: Hoglig (f)

Acacia mellifera, Acacia seyal, Acacia mubica } many small trees and bushes.

Surface: Firm few large cracks 0 - 5 cm.

Profile Description:

0 - 70 cm 10YR 4/2-2.5Y5/2. Rapidly moisture absorbent. Clay; very slightly moist, extremely firm. Strong coarse to very coarse prismatic with moderate medium platy structure, coarse 3 cm cracks, many fine cracks. Many Cyperus bulbs. Common very coarse kankara. Common coarse quartz pebbles, rare shells frequent fine CaCO3 concretions, common sand in cracks.

(200 - 300 cm in bore)

70 - 245 cm 2.5Y 5/2 - 4/2 rapidly moisture absorbent clay. Moist, extremely firm. Moderate medium coarse angular blocky, frequent fine calcium carbonate concretions.

245 - 300 cm 2.5Y 5/2-4/2. Slightly moisture absorbent clay, moist and very firm, rare coarse calcium carbonate concretions, common fine calcium carbonate concretions.

Pit No: 1520

Location: Area 2B

Topography: Flat and gently sloping

Cultivation and Land Use: Grassland not grazed.

Vegetation: A. Acacia nubica (1)
Acacia seyal var. fistula (1)
B. 60%
C. Cymbopogon nervatus (90 cm)

Surface: Common large cracks 5-10 cm. Fine mulch. Common kankars. Few shell fragments.

Profile Description:

0 - 40 cm: 10YR 4/2-3/3. Clay. Dry, very hard, moderate coarse sub-angular blocky with platy component. Common large cracks (3-5 cm). Common pores. Moderately to slowly moisture absorbent. Common roots. Many fine calcium carbonate concretions. Common kankars. Occasional shell fragments.

40 - 120 cm: 10YR 3/2. At 100 cm few mottles 10YR 4/3. Clay. Slightly moist, firm, moderate medium angular blocky, with platy component. Common slickensides. No cracks and few pores. Slowly moisture absorbent. No roots. Few kankars. Occasional fine calcium carbonate concretions.

120 - 165 cm: 10YR3/1. Clay. Moist, firm, weak angular blocky with parallelepipeds. Common slickensides. No cracks or pores. Slowly moisture absorbent. No roots. Few kankars. Few calcium carbonate streaks.

(200 - 300 cm in bore)

165 - 300 cm: 10YR 4/2-4/3. Clay. Slightly moist, firm, massive. Few to common slickensides. No cracks and pores. Slowly moisture absorbent. No roots. In transition common calcium carbonate streaks. Occasional kankars. Few mica. At 270 cm, many kankars.

Soil Class: Orthic Grumustert. A11

Pit No: 1520

Location: Area 2B

Topography: Flat and gently sloping

Cultivation and Land Use: Grassland not grazed.

Vegetation: A. *Acacia nubica* (1)

Acacia senyal var. fistula (1)

B. 60%

C. *Cymbopogon nervatus* (90 cm)

Surface: Common large cracks 5-10 cm. Fine mulch. Common kankara. Few shell fragments.

Profile Description:

0 - 40 cm 10YR 4/2-3/3. Clay. Dry, very hard, moderate coarse sub-angular blocky with platy component. Common large cracks (3-5 cm). Common pores. Moderately to slowly moisture absorbent. Common roots. Many fine calcium carbonate concretions. Common kankara. Occasional shell fragments.

40 - 120 cm 10YR 3/2. At 100 cm few mottles 10YR 4/3. Clay. Slightly moist, firm, moderate medium angular blocky, with platy component. Common slickensides. No cracks and few pores. Slowly moisture absorbent. No roots. Few kankara. Occasional fine calcium carbonate concretions.

120 - 165 cm 10YR3/1. Clay. Moist, firm, weak angular blocky with parallelepipeds. Common slickensides. No cracks or pores. Slowly moisture absorbent. No roots. Few kankara. Few calcium carbonate streaks.

(200 - 300 cm in bore)

165 - 300 cm 10YR 4/2-4/3. Clay. Slightly moist, firm, massive. Few to common slickensides. No cracks and pores. Slowly moisture absorbent. No roots. In transition common calcium carbonate streaks. Occasional kankara. Few mica. At 270 cm, many kankara.

Soil Class: Orthic Grumusol. A11

LABORATORY ANALYSIS PIT - 1520

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	pH Incorp. Carbonate	Soil Paste	1:5 suspension
0-40	6	13	11	70	2.35	7.79	8.65
40-120	8	13	11	67	1.70	7.85	8.60
120-165	10	14	14	62	3.65	7.69	8.38
165-300	9	7	24	60	6.10	7.93	8.91

Sat. %	E.C. mmhos cm Sat. Ext.	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
69	1.2	0.039	0.81	45	520
73	1.8	0.042	0.72	23	745
70	3.4	0.039	0.63	43	465
75	1.8	0.039	0.63	60	550

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.4	3.2	5	12	15	0.35	2	1
	0.4	4.0	11	15	21	0.2	3.3	1.2
	0.6	4.2	20	36	45	0.25	7.5	3
	0.6	4.0	6	26	23	0.2	2.5	2

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Na	K	Ca	Mg	Sol+Exch. Na	E.S.P.	Exchange Capacity Meq/100g. soil
	11.0	1.6	42	16	12.0	16	70
	11.2	2.2	36	15	12.8	17	66
	16.2	1.2	34	12	19.4	27	61
	18.5	1.2	25	15	20.2	31	59

LABORATORY ANALYSIS PIT - 1529

Depth (cm)	Soil particles % Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	Soil Paste pH	1:5 suspension pH
0-40	6	13	11	70	2.55	7.79	8.65
40-120	8	13	11	67	1.70	7.85	8.60
120-165	10	14	14	62	3.65	7.69	8.38
165-300	9	7	24	60	6.10	7.95	8.91

Sat: %	E.C. mmhos cm Sat. Ext.	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
69	1.2	0.039	0.81	45	520
73	1.8	0.042	0.72	23	745
70	3.4	0.039	0.63	43	465
75	1.8	0.039	0.63	60	590

Depth (cm)	Soluble Anions m. e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m. e./litre Na	K	Ca	Mg
	0.4	3.2	5	12	15	0.35	2	1
	0.4	4.0	11	15	21	0.2	3.3	1.2
	0.6	4.2	20	36	45	0.25	7.5	3
	0.6	4.0	6	26	23	0.2	2.5	2

Depth (cm)	Exchangeable Cations m. e.% per 100 gm soil. Na	K	Ca	Mg	Soil Exch. E.S.P. Na	Exchange Capacity Meq/100g. soil
	11.0	1.6	42	16	12.0	16	70
	11.2	2.2	36	15	12.8	17	66
	16.2	1.2	34	12	19.4	27	61
	18.5	1.2	25	15	20.2	31	59

Pit No: 5224

Location: Area 2A

Topography: Flat and level

Cultivation and Land Use: Simsim field

Vegetation: A. Nil

B. Nearly bare

C. Sparse Ocimum basilicum

Surface: Loose mulch, few kankars, common fine quartz grains, occasional moderate cracks, few shells.

Profile Description:

0 - 26 cm: 2.5Y 4/2-3/2. Clay, slightly moist and very firm, moderate coarse angular blocky structure, few pores, occasional - common moderate vertical cracks, moderately moisture absorbent, occasional tree roots, occasional kankars, common quartz grains in pockets and lenses, occasional small carbonate concretions, occasional shells.

26 - 122 cm: 2.5Y 4/2. Clay, wet and non-plastic, massive, no pores, few fine cracks in top, occasional slickensides, slowly moisture absorbent, few fine roots in top, few kankars, few quartz grains in pockets and along old cracks, occasional small carbonate concretions, rare carbonate concretions near bottom, few shells.

(200-300 cm in bore)

122 - 245 cm: 2.5Y 4/2-5/2. Clay, wet non-plastic, massive, no pores, no cracks, few slickensides, slowly moisture absorbent, no roots, occasional kankars, rare quartz grains, occasional - common carbonate concretions, few shells.

245 - 300 cm: 2.5Y 5/2 - 10YR 5/3. Clay, moist and very firm, no structure visible, slowly moisture absorbent, no roots, common kankars, occasional carbonate concretions decreasing downwards, few shells.

Soil Class: Orthic Grumustert. A11

Pit No: 5224

Location: Area 2A

Topography: Flat and level

Cultivation and Land Use: Simsim field

Vegetation: A. Nil

B. Nearly bare

C. Sparse *Ocimum basilicum*

Surface: Loose mulch, few kankara, common fine quartz grains, occasional moderate cracks, few shells.

Profile Description:

0 - 26 cm 2.5Y 4/2-3/2. Clay, slightly moist and very firm, moderate coarse angular blocky structure, few pores, occasional - common moderate vertical cracks, moderately moisture absorbent, occasional tree roots, occasional kankara, common quartz grains *in* pockets and lenses, occasional small carbonate concretions, occasional shells.

26 - 122 cm 2.5Y 4/2. Clay, wet and non-plastic, massive, no pores, few fine cracks *in* top, occasional slickensides, slowly moisture absorbent, few fine roots *in* top, few kankara, few quartz grains *in* pockets and along old cracks, occasional small carbonate concretions, rare carbonate concretions near bottom, few shells.

(200-300 cm *in* bore)

122 - 245 cm 2.5Y 4/2-5/2. Clay, wet *non*-plastic, massive, no pores, no cracks, few slickensides, slowly moisture absorbent, no roots, occasional kankara, rare quartz grains, occasional - common carbonate concretions, few shells.

245 - 300 cm 2.5Y 5/2 - 10YR 5/3. Clay, moist and very firm, no structure visible, slowly moisture absorbent, no roots, common kankara, occasional carbonate concretions decreasing downwards, few shells.

Soil Class: Orthic Grumusol. A11

LABORATORY ANALYSIS PIT - 5224

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	pH Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-26	2	11	17	70	1.0	7.77	8.39
26-122	8	11	14	67	4.9	7.98	8.78
122-245	6	11	13	70	8.7	8.00	8.77

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
72	0.5	0.048	0.87	25	280
73	1.1	0.042	0.69	40	400
75	1.25	0.034	0.75	43	350

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.8	3.6	1.5	3	7	0.2	1.0	0
	1.2	5.5	4.0	7	15	0.2	1.5	0.5
	1.0	3.6	2.5	16	17	0.2	2.5	1.0

Depth (cm)	Exchangeable Cations m.e.% per 100gm soil. Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	8.5	2.0	37	19	8.8	13	65
	14.2	3.2	25	16	14.0	23	63
	19.0	2.0	27	19	21.2	29	65

LABORATORY ANALYSIS PIT - 5224

Depth (cm)	Soil particles %					pH
	Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-26	2	11	17	70	1.0	7.77	8.39
26-122	8	11	14	67	4.9	7.98	8.78
122-245	6	11	13	70	8.7	8.00	8.77

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
72	0.5	0.068	0.87	25	280
73	1.1	0.062	0.69	40	400
75	1.25	0.034	0.75	43	350

Depth (cm)	Soluble Anions m.e./litre				Soluble Cations m.e./litre			
	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
	0.8	3.6	1.5	3	7	0.2	1.0	0
	1.2	5.5	4.0	7	15	0.2	1.5	0.5
	1.0	3.6	2.5	16	17	0.2	2.5	1.0

Depth (cm)	Exchangeable Cations m.e.% per 100g soil.				Sol+Exch E.S.P.	Exchange Capacity Meq/100g. soil
	Na	K	Ca	Mg	Na	
	8.5	2.0	37	19	8.8	13	65
	14.2	3.2	29	16	14.0	23	63
	19.0	2.0	27	19	21.2	29	65

Pit: 1178

Location: Area 2A

Topography: Flat and level

Cultivation and Land Use: Raingrown dura

Vegetation: A. At edge of field Balanites aegyptiaca (1)
Acacia seyal (40)
Acacia nubica (5)
B. 50%
C. Dura
Cymbopogor nervatus (100 cm)

Surface: Common cracks 2 cm mulch. Occasional quartz grains. Common kankars. Common small calcium carbonate concretions.

Profile Description:

0 - 40 cm 10YR 3/2 Clay. Top 5 cm dry loose. Moist, friable to firm, weak medium - coarse sub-angular blocky. Few cracks. Common pores, moderately moisture absorbent. Common fine and big roots. Common small calcium carbonate concretions. Common kankars. Few quartz grains. Few shell fragments.

40 - 125 cm 10YR 3/2 Clay. Moist, firm, massive. Unopened cracks filled in with sand. No pores. Few slickensides, increasing with depth. Slowly moisture absorbent. Occasional roots. Sand pockets. Occasional quartz grains. Few kankars. Occasional calcium carbonate streaks.

125 - 170 cm 10YR 3/1. Clay. Moist, firm, massive. No cracks and pores. Common abundant large slickensides. Slowly moisture absorbent. No roots. At bottom of horizon common calcium carbonate streaks increasing with depth. Few small calcium carbonate concretions. Occasional kankars.

(200 - 300 cm in bore.)

170 - 300 cm 10YR 4/3 Clay. Moist, firm, massive. No cracks and pores. Common slickensides. Slowly moisture absorbent. No roots. Common sand pockets.

Pit: 1178

Location: Area 2A

Topography: Flat and level

Cultivation and Land Use: Raingrown dura

Vegetation: A. At edge of field Balanites aegyptiaca (1)

Acacia seyal (40)

Acacia nubica (5)

B. 50%

C. Dura

Cyanbopogor nervatus (100 cm)

Surface: Common cracks 2 cm mulch. Occasional quartz grains. Common kankara. Common small calcium carbonate concretions.

Profile Description:

0 - 40 cm 10YR 3/2 Clay. Top 5 cm dry loose. Moist, friable to firm, weak medium - coarse sub-angular blocky. Few cracks. Common pores, moderately moisture absorbent. Common fine and big roots. Common small calcium carbonate concretions. Common kankara. Few quartz grains. Few shell fragments.

40 - 125 cm 10YR 3/2 Clay. Moist, firm, massive. Unopened cracks filled in with sand. No pores. Few slickensides, increasing with depth. Slowly moisture absorbent. Occasional roots. Sand pockets. Occasional quartz grains. Few kankara. Occasional calcium carbonate streaks.

125 - 170 cm 10YR 3/1. Clay. Moist, firm, massive. No cracks and pores. Common abundant large slickensides. Slowly moisture absorbent. No roots. At bottom of horizon common calcium carbonate streaks increasing with depth. Few small calcium carbonate concretions. Occasional kankara.

(200 - 300 cm in bore.)

170 - 300 cm 10YR 4/3 Clay. Moist, firm, massive. No cracks and pores. Common slickensides. Slowly moisture absorbent. No roots. Common sand pockets.

Few kankars. Occasional - few calcium carbonate concretions and streaks, decreasing with depth. Occasional shell fragments. Few kankars increasing with depth.

Soil Class: Natrargidic Grumustert. A12

Few kankara. Occasional - few calcium carbonate concretions and streaks, decreasing with depth. Occasional shell fragments. Few kankara increasing with depth.

Soil Class: Natragidic Grumusol. A12

LABORATORY ANALYSIS PIT - 1178

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	pH Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-40	4	9	12	75	3.45	8.32	9.37
40-125	3	10	10	77	2.55	8.25	9.21
125-170	3	2	13	82	6.35	8.31	9.23
170-300	9	11	15	65	7.1	8.21	9.25

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
79	0.75	0.045	0.90	50	390
90	1.7	0.064	0.93	53	390
104	2.1	0.032	1.05	63	490
79	3.0	0.042	0.78	50	410

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.7	4.2	4.0	TRACE	10	0.7	1.0	0.5
	0.8	4.4	3.5	23	26	1.4	2.5	1.5
	0.4	4.6	4.5	17	29	0.8	3.0	1.0
	0.6	5.5	7.5	35	36	0.8	5.0	3.0

Depth (cm)	Exchangeable Cations m.e. % per 100 gm soil Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	24	1.8	37	12	24.8	32	75
	27	1.8	29	18	29.2	36	74
	23	2.0	31	20	23.6	29	78
	17	2.0	24	16	20.0	29	59

LABORATORY ANALYSIS PIT - 1178

Depth (cms)	Soil particles % Coarse sand 2.0- 0.2 mms.	Fine sand 0.2- 0.02 mms.	Silt 0.02- 0.002 mms.	Clay under 0.002 mms.	Incorp. Carbonate	pH Soil Paste	1 : 5 suspension
0-40	4	9	12	75	3.45	8.32	9.37
40-125	3	10	10	77	2.55	8.25	9.21
125-170	3	2	13	82	6.35	8.31	9.23
170-300	9	11	15	65	7.1	8.21	9.25

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
79	0.75	0.045	0.90	50	390
90	1.7	0.064	0.93	53	390
104	2.1	0.032	1.05	63	490
79	3.0	0.042	0.78	50	410

Soluble Anions m.e./litre Soluble Cations m.e./litre

Depth (cms)	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
	0.7	4.2	4.0	TRACE	10	0.7	1.0	0.5
	0.8	4.4	3.5	23	26	1.4	2.5	1.5
	0.4	4.6	4.5	17	29	0.8	3.0	1.0
	0.6	5.5	7.5	35	36	0.8	5.0	3.0

Depth (cms)	Exchangeable Cations m.e. % Soil+Excn per 100 gms soil Na	K	Ca	Mg	Na	E.S.P.	Exchange Capacity Meq/100g. soil
	24	1.8	37	12	24.8	32	75
	27	1.8	29	18	29.8	36	74
	23	2.0	31	20	23.6	29	78
	17	2.0	24	16	20.0	29	59

Pit: 1494

Location: Area 2B

Topography: Flat and level

Cultivation and Land Use: Raingrown dukhn

Vegetation: A. Nil

B. 100%

C. Nil

Surface: Many large cracks, soft brown crust. Granular mulch. Few shell fragments. Abundant quartz grains. Few gravel.

Profile Description:

0 - 30 cm: 10YR 4/3-2.5Y5/4. Clay. Dry, hard, moderate coarse sub-angular blocky with platy component. Common cracks (2-3 cm) and pores. Moderately moisture absorbent. Few roots. Abundant quartz grains. Few fine calcium carbonate concretions. Few gravel.

30 - 105 cm: 2.5Y 5/4-10YR 4/3. Clay. Slightly moist, firm, moderate angular blocky with platy component. Few slickensides. Few large cracks (1-2 cm) and pores. Slowly moisture absorbent. Few roots. Common quartz grains. Occasional gravel. Few fine calcium carbonate concretions.

105 - 150 cm: 2.5Y 4/2. Common mottles 7.5YR 5/6 and 10YR 5/6. Moist, very firm. Parallelepipeds with little platy component. Many slickensides. No cracks and few pores. Slowly moisture absorbent. No roots. Few calcium carbonate streaks and concretions. Few kankars. Few gypsum crystals. Common quartz grains.

150 - 250 cm: 2.5Y 4/4. Many mottles 10YR 5/6 decreasing to common after 180 cm. Few 2.5Y 4/2 (150-180 cm). Clay. Moist, firm, massive. Many slickensides. Slowly moisture absorbent. No roots. Few calcium carbonate streaks and concretions. Common kankars. Common quartz grains. Manganese stains. At 240 cm few gypsum crystals.

Pit: 1494

Location: Area 2B

Topography: Flat and level

Cultivation and Land Use: Raingrown dalbin

Vegetation: A. Nil

B. 100%

C. Nil

Surface: Many large cracks, soft brown crust. Granular mulch. Few shell fragments. Abundant quartz grains. Few gravel.

Profile Description:

0 - 30 cm: 10YR 4/3-2. 5Y5/4. Clay. Dry, hard, moderate coarse sub-angular blocky with platy component. Common cracks (2-3 cm) and pores. Moderately moisture absorbent. Few roots. Abundant quartz grains. Few fine calcium carbonate concretions. Few gravel.

30 - 105 cm: 2.5Y 5/4-10YR 4/3. Clay. Slightly moist, firm, moderate angular blocky with platy component. Few slickensides. Few large cracks (1-2 cm) and pores. Slowly moisture absorbent. Few roots. Common quartz grains. Occasional gravel. Few fine calcium carbonate concretions.

105 - 150 cm: 2.5Y 4/2. Common mottles 7.5YR 5/6 and 10YR 5/6. Moist, very firm. Parallelepipeds with little platy component. Many slickensides. No cracks and few pores. Slowly moisture absorbent. No roots. Few calcium carbonate streaks and concretions. Few kankara. Few gypsum crystals. Common quartz grains.

150 - 250 cm: 2.5Y 4/4. Many mottles 10YR 5/6 decreasing to common after 180 cm. Few 2.5Y 4/2 (150-180 cm). Clay. Moist, firm, massive. Many slickensides. Slowly moisture absorbent. No roots. Few calcium carbonate streaks and concretions. Common kankara. Common quartz grains. Manganese stains. At 240 cm few gypsum crystals.

(200-300 cm in bore)

250 - 300 cm — 2.5Y 5/4. Common mottles 10YR 5/6. Clay. Moist, firm, massive. Slowly moisture absorbent. No roots. Common calcium carbonate concretions and streaks. Common gypsum crystals. Common manganese stains. Occasional quartz grains.

Soil Class: Entic Grumustert. A13

(200-300 cm in bore)

250 - 300 cm 2.5Y 5/4. Common mottles 10YR 5/6. Clay. Moist, firm, massive. Slowly moisture absorbent. No roots. Common calcium carbonate concretions. cm; streaks. Common gypsum crystals. Common manganese stains. Occasional quartz grains.

Soil Class: Entic Cryumustert. A13

LABORATORY ANALYSIS PIT - 1494

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-30	14	14	15	57	0.9	7.81	8.72
30-105	14	13	13	60	1.55	7.85	8.88
105-150	19	15	9	57	11.3	8.28	9.41
150-250	17	17	11	55	4.0	7.80	8.70

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
56	0.3	0.028	0.54	18	210
61	1.4	0.028	0.57	23	280
65	1.5	0.039	0.63	40	600
72	2.6	0.022	0.72	33	425

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.4	2.8	2.0	6	4	0.1	1.0	0
	0.4	3.0	5.5	14	18	0.1	1.8	0.7
	0.4	2.6	5.0	16	19	0.1	2.0	1.0
	0.4	2.6	11.0	33	33	0.15	5.0	3.0

Depth (cm)	Exchangeable Cations m.e.% Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	6.6	0.6	27	14	6.8	12	53
	17.0	0.8	27	14	18.0	30	56
	14.6	1.4	28	13	15.6	26	56
	10.5	1.0	33	9	12.8	19	55

LABORATORY ANALYSIS PIT - 1494

Soil particles %

Depth (cms)	Coarse sand 2.0- 0.2 mms.	Fine sand 0.2- 0.02 mms.	Silt 0.02- 0.002 mms.	Clay under 0.002 mms.	Incorp. Carbonate	Soil Paste	pH 1 : 5 suspension
0-30	14	14	15	57	0.9	7.81	8.72
30-105	14	13	13	60	1.35	7.85	8.88
105-150	19	15	9	57	11.3	8.28	9.41
150-250	17	17	11	55	4.0	7.80	8.70

Total Extractable

Sat. % Sat.	E.C. mmhos cm Ext	Total Nitrogen %	Total Org. Carbon %	Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
56	0.3	0.028	0.54	18	210
61	1.4	0.028	0.57	23	280
65	1.5	0.039	0.63	40	600
72	2.6	0.022	0.72	33	425

Soluble Anions m.e./litre Soluble Cations m.e./litre

Depth (cms)	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
	0.4	2.8	2.0	6	4	0.1	1.0	0
	0.4	3.0	5.5	14	18	0.1	1.8	0.7
	0.4	2.6	5.0	16	19	0.1	2.0	1.0
	0.4	2.6	11.0	33	33	0.15	5.0	3.0

Exchangeable Cations m.e.% Sol+Exch

Depth (cms)	Na	K	Ca	Mg	Na	E.S.P.	Exchange Capacity Meq/100g. soil
	6.6	0.6	27	14	6.8	12	53
	17.0	0.8	27	14	18.0	30	56
	14.6	1.4	28	13	15.6	26	56
	10.5	1.0	33	9	12.8	19	55

Pit: 1510

Location: Area 2B

Topography: Very slightly undulating on slope.

Cultivation and Land Use: Grassland not grazed.

Vegetation: A. Cadaba rotundifolia

B. 30%

C. Cymbopogon nervatus (125 cm)

Surface: Medium coarse mulch. Many large cracks (5-10 cm). Common shell fragments. Common kankars. Few fine calcium carbonate concretions.

Profile Description:

0 - 30 cm: 10YR 4/2. Clay. Dry very hard moderate coarse sub-angular blocky with platy component. Common large cracks (5 cm) and pores. Slowly moisture absorbent. Common roots. Few sand pockets. Many kankars. Common fine calcium carbonate concretions.

30 - 122 cm: 10YR 4/2-3/2. Clay. Moist, firm, weak coarse angular blocky with parallelepipeds and wedge structure. Common slickensides. Few large cracks up to 60 cm. Common pores. Slowly moisture absorbent. Occasional roots. Common kankars. Few fine calcium carbonate concretions. In transition few calcium carbonate streaks.

122 - 177 cm: 10YR 3/1. Clay. Moist, firm. Parallelepipeds. Common slickensides. No cracks and pores. Slowly moisture absorbent, No roots. At 180 cm common shells and shell fragments. Common calcium carbonate streaks and concretions in transition. Common kankars.

177 - 200 cm: 10YR 4/2-5/2. Common mottles 10YR 5/1. Clay. Moist, firm, massive. No cracks and pores. Common slickensides. Slowly moisture absorbent. No roots. At 180 cm common shells and shell fragments especially in transition. Common kankars. Common calcium carbonate streaks and concretions.

Pit: 1S10

Location: Area 2B

Topography: Very slightly undulating on slope.

Cultivation and Land Use: Grassland not grazed.

Vegetation: A. Cymbopogon nervatus

B. 30%

C. Cymbopogon nervatus (125 cm)

Surface: Medium coarse mulch. Many large cracks (5-10 cm). Common shell fragments. Common kankara. Few fine calcium carbonate concretions.

Profile Description:

0 - 30 cm: 10YR 4/2. Clay. Dry very hard moderate coarse sub-angular blocky with platy component. Common large cracks (5 cm) and pores. Slowly moisture absorbent. Common roots. Few sand pockets. Many kankara. Common fine calcium carbonate concretions.

30 - 122 cm: 10YR 4/2-3/2. Clay. Moist, firm, weak coarse angular blocky with parallelepipeds and wedge structure. Common slickensides. Few large cracks up to 60 cm. Common pores. Slowly moisture absorbent. Occasional roots. Common kankara. Few fine calcium carbonate concretions. In transition few calcium carbonate streaks.

122 - 177 cm: 10YR 3/1. Clay. Moist, firm. Parallelepipeds Common slickensides. No cracks and pores. Slowly moisture absorbent. No roots. At 180 cm common shells and shell fragments. Common calcium carbonate streaks and concretions in transition. Common kankara.

177 - 200 cm: 10YR 4/2-5/2. Common mottles 10YR 5/1. Clay. Moist, firm, massive. No cracks and pores. Common slickensides. Slowly moisture absorbent No roots. At 180 cm common shells and shell fragments especially in transition. Common kankara. Common calcium carbonate streaks and concretions.

(200-300 cm in bore)

200 - 300 cm — 10YR 5/3-5/2. Common mottles 10YR 6/6. Clay; moist, firm, massive; slowly moisture absorbent. No roots. Few calcium carbonate concretions and streaks. Common kankars.

Soil Class: Entic Natrargidic Grumustert. A14

(200-300 cm in bore)

200 - 300 cm 10YR 5/3-5/2. Common mottles 10YR 6/6. Clay; moist, firm, massive; slowly moisture absorbent. No roots. Few calcium carbonate concretions and streaks. Common kankara.

Soil Class: Entic Natrargidic Grumustert. A14

LABORATORY ANALYSIS PIT - 1510

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-30	6	8	14	72	3.3	7.96	9.21
30-122	8	11	14	67	3.4	7.72	8.52
122-177	8	9	16	67	3.8	7.70	8.28
177-200	28	16	11	45	2.0	7.57	8.36

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Total Extractable Potassium Mg/100g. soil
76	0.38	0.039	0.86	35	510
66	3.2	0.042	0.71	40	505
83	2.7	0.053	0.68	55	615
57	2.7	0.032	0.46	60	600

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	1.0	4.0	3.5	0	6	0.1	1	0.5
	0.2	2.3	16.5	38	43	0.15	6	2.0
	0.4	3.2	7.5	36	34	0.2	4.5	2.5
	0.6	3.7	15.5	24	29	0.95	6	3.5

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	18.5	1.2	33	15	19.0	26	71
	17.5	1.0	34	14	20.4	26	66
	14.0	1.2	35	17	16.8	21	68
	5.6	3.0	31	10	7.2	14	40

LABORATORY ANALYSIS PIT - 1510

Depth (cms)	Soil particles % Coarse sand 2.0- 0.2 mms.	Fine sand 0.2- 0.02 mms.	Silt 0.02- 0.002 mms.	Clay under 0.002 mms.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-30	6	8	14	72	3.3	7.96	9.21
30-122	8	11	14	67	3.4	7.72	8.52
122-177	8	9	16	67	3.8	7.70	8.28
177-200	28	16	11	45	2.0	7.57	8.36

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
76	0.38	0.039	0.86	35	510
66	3.2	0.042	0.71	40	505
83	2.7	0.053	0.68	55	615
57	2.7	0.032	0.46	60	600

Soluble Anions m. e./litre

Depth (cms)	CO_3	HCO_3	Cl	SO_4
	1.0	4.0	3.5	0
	0.2	2.3	16.5	38
	0.4	3.2	7.5	36
	0.6	3.7	15.5	24

Soluble Cations m. e./litre

Na	K	Ca	Mg
6	0.1	1.	0.5
43	0.15	6	2.0
34	0.2	4.5	2.5
29	0.95	6	3.5

Exchangeable Cations m. e. % per 100 gms soil

Depth (cms)	Na	K	Ca	Mg
	18.5	1.2	33	15
	17.5	1.0	34	14
	14.0	1.2	35	17
	5.6	3.0	31	10

Sol+Exch

Na	E.S.P.	Exchange Capacity Meq/100g. soil
19.0	26	71
20.4	26	66
16.8	21	68
7.2	14	40

Pit: 4240

Location: Area 2A

Topography: Flat with slight undulations to south

Cultivation and Land Use: Rain sim-sim

Vegetation: A. Ziziphus spina-christi (12)
Acacia mellifera (20)
Acacia seyal (26)
Balanites aegyptiaca (1)

B. Bare ground 98%

C. (Umm belil 105)

Surface: No mulch, frequent fine cracks.

Profile Description:

0 - 15 cm — Moist 10YR 3/2. Clay. Dry and hard, strong coarse sub-angular blocky; rare pores, frequent fine cracks, occasional medium vertical cracks. Common fine and occasional medium sized roots. Moderately moisture absorbent. Common quartz grains, rare fine rounded calcium concretions. Clear smooth lower boundary.

15 - 141 cm — Moist 10YR 3/2. Clay. Moist firm, massive tending to weak fine angular blocky. Rare pores; occasional fine cracks, rare medium vertical cracks. Common slickensides. Occasional fine, rare medium roots. Moderately moisture absorbent. Common fine quartz grains, rare rounded fine calcium concretions, occasional pockets of fine sand, rare shell fragments. Diffuse smooth lower boundary.

141 - 210 cm — Moist 10YR4/1. Clay. Frequent mottling moist 10YR5/6. Moist firm, moderate medium blocky. Rare medium and fine cracks, very rare pinhole pore. Slickensides. Rare fine root. Slowly moisture absorbent. Frequent fine quartz grains, few medium calcium concretions.

(200 - 300 cm in bore)

Pit: 1240

Location: Area 2A

Topography: Flat with slight undulations to south

Cultivation and Land Use: Rain-rain

Vegetation: A. Ziziphus spina-christi (12)

Acacia mellifera (20)

Acacia seyal (26)

Balanites aegyptica (1)

B. Bare ground 98%

C. (Unm bell 105)

Surface: No mulch, frequent fine cracks.

Profile Description:

0 - 15 cm — Moist 10YR 3/2. Clay. Dry and hard, strong coarse sub-angular blocky; rare pores, frequent fine cracks, occasional medium vertical cracks. Common fine and occasional medium sized roots. Moderately moisture absorbent. Common quartz grains, rare fine rounded calcium concretions. Clear smooth lower boundary.

15 - 141 cm — Moist 10YR 3/2. Clay. Moist firm, massive tending to weak fine angular blocky. Rare pores; occasional fine cracks, rare medium vertical cracks. Common slickensides. Occasional fine, rare medium roots. Moderately moisture absorbent. Common fine quartz grains, rare rounded fine calcium concretions, occasional pockets of fine sand, rare shell fragments. Diffuse smooth lower boundary.

141 - 210 cm — Moist 10YR4/1. Clay. Frequent mottling moist 10YR5/6. Moist firm, moderate medium blocky. Rare medium and fine cracks, very rare pinhole pore. Slickensides. Rare fine root. Slowly moisture absorbent. Frequent fine quartz grains, few medium calcium concretions.

(200 - 300 cm in bore)

210 - 300 cm — Moist 10YR 3/1-4/1. Clay. Rare mottling moist 10YR 4/3. Moist firm, massive; rare pores, slickensides. No roots. Slowly moisture absorbent. Occasional medium calcium concretions, rare mica and quartz grains.

Soil Class: Orthic Mazustert. A21

210 - 300 cm Moist 10YR 3/1-4/1. Clay. Rare mottling moist 10YR 4/3. Moist firm, massive; rare pores, slickensides. No roots. Slowly moisture absorbent. Occasional medium calcium concretions, rare mica and quartz grains.

Soil Class: Orthic Mazustert. A21

LABORATORY ANALYSIS PIT - 4240

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-15	8	16	11	65	0.62	7.40	7.40
15-141	8	9	13	70	0.65	7.68	8.08
141-210	20	12	13	55	2.55	7.69	7.95

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
78	0.48	0.032	0.87	28	210
69	0.80	0.025	0.84	19	212
69	4.20	0.050	0.87	10	200

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.86	3.4	2.0	4	5	0.2	2.0	0.5
	0.46	4.2	2.5	6	9	0.2	1.5	0.5
	0	4.8	17	37	46	0.5	11.0	8.0

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	2.0	2.0	37	20	0.4	3	61
	7.5	1.8	28	29	4.8	11	68
	7.0	1.4	26	15	10.0	15	47

LABORATORY ANALYSIS PIT - 4240

Depth (cm)	Soil particles % Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	Soil Paste	pH 1 : 5 suspension
0-15	8	16	11	65	0.62	7.40	7.40
15-141	8	9	13	70	0.65	7.68	8.08
141-210	20	12	13	55	2.55	7.69	7.95

Sat. %	E. C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
78	0.48	0.032	0.87	28	210
69	0.80	0.025	0.84	19	212
69	4.20	0.050	0.87	10	260

Soluble Anions m. e./litre Soluble Cations m. e./litre

Depth (cm)	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
	0.86	3.4	2.0	4	5	0.2	2.0	0.5
	0.46	4.2	2.3	6	9	0.2	1.5	0.5
	0	4.8	17	37	46	0.5	11.0	8.0

Exchangeable Cations m. e.% Soil+Exch per 100 gm soil. E. S. P. Exchange Capacity Meq/100g. soil

Depth (cm)	Na	K	Ca	Mg	Na		
	2.0	2.0	37	20	0.4	3	61
	7.5	1.8	28	29	4.8	11	68
	7.0	1.4	26	15	10.0	15	47

Pit: 2449

Location: Area 2A

Topography: Flat and level

Cultivation and Land Use: Partly overgrown harvested rain-fed dura, some Sorghum sudanense contamination.

Vegetation: A. Ziziphus spina-christi (7)
Acacia seyal (22)
Acacia nubica (9)
B. Sparse
C. Dura crossed with Sorghum sudanense (200 cm)

Surface: Fairly even. Few 10-20 cm shallow sinkholes. Occasional 2-3 cm cracks. Hard massive surface. Few grey calcium carbonate nodules up to 3 mm. Occasional sand grains up to 1 mm.

Profile Description:

0 - 45 cm: 10YR 3.5/2. Clay. Dry, very hard, moderate medium sub-angular blocky with weak columnar component. Occasional 1 cm cracks. Moderately moisture absorbent. Few 2 mm and occasional 1 mm roots. Common white calcium carbonate nodules up to 1 mm. Few 1 mm sand grains.

45 - 140 cm: 10YR 4/2. Clay. Dry, very hard, massive. Few 5-10 mm cracks down to 80 cm. Moderately moisture absorbent. Few 1 mm roots decreasing to rare with depth. Occasional grey calcium carbonate nodules up to 1 mm. Few black and white calcium septaria up to 4 mm with associated 1 cm patches of diffuse white calcium carbonate. Rare 1 mm sand grains.

140 - 185 cm: 10YR 3.5/1. Clay. Very slightly moist, firm, massive with parallelepipeds. No cracks. Slowly moisture absorbent. No roots. Occasional 2 mm black and white calcium carbonate septaria with associated 5-10 mm patches diffuse white calcium carbonate. Rare 1 mm black calcium carbonate nodules.

(200 - 300 cm in bore)

Pit: 2449

Location: Area 2A

Topography: Flat and level

Cultivation and Land Use: Partly overgrown harvested rain-fed dura, some *Sorghum sudanense* contamination.

Vegetation: A. *Ziziphus spina-christi* (7)
Acacia seyal (22)
Acacia nubica (9)

B. Sparse

C. Dura crossed with *Sorghum sudanense* (200 cm)

Surface: Fairly even. Few 10-20 cm shallow sinkholes. Occasional 2-3 cm cracks. Hard massive surface. Few grey calcium carbonate nodules up to 3 mm. Occasional sand grains up to 1 mm.

Profile Description:

0 - 45 cm 10YR 3.5/2. Clay. Dry, very hard, moderate medium sub-angular blocky with weak columnar component. Occasional 1 cm cracks. Moderately moisture absorbent. Few 2 mm and occasional 1 mm roots. Common white calcium carbonate nodules up to 1 mm. Few 1 mm sand grains.

45 - 140 cm 10YR 4/2. Clay. Dry, very hard, massive. Few 5-10 mm cracks down to 80 cm. Moderately moisture absorbent. Few 1 mm roots decreasing to rare with depth. Occasional grey calcium carbonate nodules up to 1 mm. Few black and white calcium septaria up to 4 mm with associated 1 cm patches of diffuse white calcium carbonate. Rare 1 mm sand grains.

140 - 185 cm 10YR 3.5/1. Clay. Very slightly moist, firm, massive with parallelepipeds. No cracks. Slowly moisture absorbent. No roots. Occasional 2 mm black and white calcium carbonate septaria with associated 5-10 mm patches diffuse white calcium carbonate. Rare 1 mm black calcium carbonate nodules.

(200 - 300 cm in bore)

185 - 300 cm — 10YR 5/4 with common small faint 10YR 4/1 mottles. Clay. Slightly moist, friable, massive. No cracks. Moderately moisture absorbent. No roots. Occasional to common 2 mm black and white calcium carbonate nodules and septaria with associated 5 mm patches of white diffuse calcium carbonate. Rare kankars. Occasional fine to medium quartz grains. Rare medium black and white kankars. Rare large shell fragments.

Soil Class: Natrargidic Mazustert. A22

LABORATORY ANALYSIS PIT - 2449

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-45	19	15	10	56	1.4	8.35	8.91
45-140	18	13	10	59	1.45	8.45	9.30
140-185	7	24	8	61	4.9	8.30	9.18
185-300	18	13	8	61	6.8	8.50	9.17

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Total Extractable Potassium Mg/100g. soil
82	0.48	0.050	0.9	23	1.70
66	0.75	0.036	0.66	23	1.90
75	1.35	0.042	0.69	33	3.05
77	0.82	0.034	0.54	38	2.90

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.8	5.6	2.5	TRACE	8.0	0.2	1.0	0.5
	0.4	5.4	3.0	8	10.5	0.4	0.8	0.2
	1.4	5.1	5.5	11	16.5	0.4	2.0	1.0
	1.0	5.3	4.0	8	14.0	0.2	1.5	0.5

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Na	K	Ca	Mg	Sol+Exch. Na	E.S.P.	Exchange Capacity Meq/100g. soil
	10.0	1.4	27	17	11.2	19	53
	18.5	1.2	19	18	19.2	33	56
	16.5	2.2	23	19	17.6	28	59
	15.7	2.2	18	20	16.8	28	56

LABORATORY ANALYSIS PIT - 2449

Depth (cm)	Soil particles %					pH
	Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-45	19	15	10	56	1.4	8.35	8.91
45-140	18	13	10	59	1.45	8.45	9.30
140-185	7	24	8	61	4.9	8.30	9.18
185-300	18	13	8	61	6.8	8.50	9.17

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
82	0.48	0.050	0.9	23	1.70
66	0.75	0.036	0.66	23	1.90
75	1.35	0.042	0.69	33	3.05
77	0.82	0.034	0.54	38	2.90

Depth (cm)	Soluble Anions m. e./litre				Soluble Cations m. e./litre		
	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
	0.8	5.6	2.5	TRACE	8.0	0.2	1.0	0.5
	0.4	5.4	3.0	8	10.5	0.4	0.8	0.2
	1.4	5.1	5.5	11	16.5	0.4	2.0	1.0
	1.0	5.3	4.0	8	14.0	0.2	1.5	0.5

Depth (cm)	Exchangeable Cations m. e.% per 100 gms soil.				Sol+Exch. Na E.S.P.	Exchange Capacity Meq/100g. soil
	Na	K	Ca	Mg		
	10.0	1.4	27	17	11.2	53
	18.5	1.2	19	18	19.2	36
	16.5	2.2	23	19	17.6	59
	15.7	2.2	18	20	16.8	56

Pit: 2771

Location: Area 2B

Topography: Very gentle slope into a small depression to the west.

Cultivation and Land Use: Ungrazed grass savannah near rain-fed dura.

Vegetation:

A. Nil

B. Dense

C. Sorghum sudanense (120 cm)
Cymbopogon sp. (100 cm)
Hibiscus sp. (100 cm)

Surface: Fairly even. Hard massive surface, occasional cracks up to 5 cm. Abundant grey and black calcium carbonate nodules up to 2 mm. Rare sand grains up to 1 mm.

Profile Description:

0 - 45 cm: 2.5Y 5/2. Clay. Dry very hard to 35 cm then very slightly moist firm. Moderate coarse prismatic with weak medium subangular blocky component down to 15 cm. Occasional cracks up to 2 cm. Slowly moisture absorbent. Common roots up to 1 mm. Common to abundant grey calcium carbonate nodules up to 2 mm. Rare sand grains up to 1 mm.

45 - 80 cm: 2.5Y 5/2. Clay. Slightly moist firm, massive. Few cracks up to 5 mm. Slowly moisture absorbent. Common roots up to 1 mm. Common grey calcium carbonate nodules up to 2 mm. Rare sand grains up to 1 mm. Few calcium carbonate septaria up to 1 cm.

(200 - 300 cm in bore)

80 - 300 cm: 10YR 6/4, distinct 10YR 5/1 mottles; clay, slightly moist and very firm; massive; no cracks or pores; slowly moisture absorbent; occasional roots; occasional brown calcium carbonate septaria up to 2 cm; rare shell fragments; rare 3 mm black carbonate nodules.

Soil Class: Entic Natrargidic Mazustert. A24

Pit: 2771

Location: Area 2B

Topography: Very gentle slope into a small depression to the west.

Cultivation and Land Use: Ungrazed grass savannah near rain-fed dura.

Vegetation: A. Nil

B. Dense

C. Sorghum sudanense (120 cm)

Cymbopogon sp. (100 cm)

Hibiscus sp. (100 cm)

Surface: Fairly even. Hard massive surface, occasional cracks up to 5 cm. Abundant grey and black calcium carbonate nodules up to 2 mm. Rare sand grains up to 1 mm.

Profile Description:

0 - 45 cm 2.5Y 5/2. Clay. Dry very hard to 35 cm then very slightly moist firm. Moderate coarse prismatic with weak medium subangular blocky component down to 15 cm. Occasional cracks up to 2 cm. Slowly moisture absorbent. Common roots up to 1 mm. Common to abundant grey calcium carbonate nodules up to 2 mm. Rare sand grains up to 1 mm.

45 - 80 cm 2.5Y 5/2. Clay. Slightly moist firm, massive. Few cracks up to 5 mm. Slowly moisture absorbent. Common roots up to 1 mm. Common grey calcium carbonate nodules up to 2 mm. Rare sand grains up to 1 mm. Few calcium carbonate septaria up to 1 cm.

(200 - 300 cm in bore)

80 - 300 cm 10YR 6/4, distinct 10YR 5/1 mottles; clay, slightly moist and very firm; massive; no cracks or pores; slowly moisture absorbent; occasional roots; occasional brown calcium carbonate septaria up to 2 cm; rare shell fragments; rare 3 mm black carbonate nodules.

Soil Class: Entic Natrargidic Mazustert. A24

LABORATORY ANALYSIS PIT - 2771

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	1 : 5 suspension
0-45	15	9	14	62	11.5	8.22	9.02
45-80	11	20	16	53	5.5	7.99	8.95
80-300	18	1	14	67	5.35	7.71	8.51

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
68	1.8	0.05	0.84	35	575
65	2.2	0.042	0.69	38	585
62	2.9	0.032	0.57	30	450

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.5	3.2	5	20	23	0.3	2.5	0.5
	0.4	2.4	10	23	28	0.35	3.0	2.0
	1.2	5.24	10	33	38	0.3	4.5	2.0

Depth (cm)	Exchangeable Cations m.e.% Sol+Exch. Na	K	Ca	Mg	E.S.P. Na	Exchange Capacity Meq/100g. soil
	21.4	1.4	24	14	22.9	36	60
	13.4	1.0	28	13	15.4	25	53
	17.2	0.8	33	13	19.6	26	64

LABORATORY ANALYSIS PIT - 2771

Depth (cm)	Soil particles %					pH	
	Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-45	15	9	14	62	11.5	8.22	9.02
45-80	11	20	16	53	5.5	7.99	8.95
80-300	18	1	14	67	5.35	7.71	8.51

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
68	1.8	0.05	0.84	35	575
65	2.2	0.042	0.69	38	585
62	2.9	0.032	0.57	30	450

Soluble Anions m.e./litre Soluble Cations m.e./litre

Depth (cm)	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
0.5	3.2	5	20	23	0.3	2.5	0.5
0.4	2.4	10	23	28	0.35	3.0	2.0
1.2	5.24	10	33	38	0.3	4.5	2.0

Exchangeable Cations m.e. % Sol+Exch.

Depth (cm)	Na	K	Ca	Mg	Na	E.S.P.	Exchange Capacity Meq/100g. soil
21.4	1.4	24	14	22.9	36	60
13.4	1.0	28	13	15.4	25	53
17.2	0.8	33	13	19.6	26	64

Pit: 1219

Location: Area 2A

Topography: Flat and level in slight depression

Cultivation and Land Use: Raingrown simsim

Vegetation: A. Nil

B. 95%

C. Herbs

Surface: Common large cracks (1-2 cm). 1-2 cm mulch. Soft broken crust. Common kankars. Common small calcium carbonate concretions.

Profile Description:

0 - 50 cm — 10YR3/1. Clay. Top 2 cm dry loose, slightly moist, firm, moderate medium-coarse sub-angular blocky. Common cracks and common pores. Slowly moisture absorbent. Common roots. Common shell fragments. Common small calcium carbonate concretions. Common-few sand pockets, 10YR4/4, with mica. Few kankars.

50 - 120 cm — 10YR3/2. Clay. Slightly moist, firm, massive. Occasional cracks down to 70 cm. Few pores. Slowly moisture absorbent. Occasional roots. Common shell fragments. Few sand pockets and mica. Few kankars. Occasional quartz. Few small calcium carbonate concretions.

120 - 170 cm — 10YR 3/1-4/1. Clay slightly moist, firm, massive. No cracks and no pores. Slowly moisture absorbent. No roots. Common mica. Common-few sand pockets. Few-common calcium carbonate concretions and streaks. Occasional kankars.

(200 - 300 cm in bore)

170 - 300 cm — 10YR 4/3-4/4. Fine sandy clay loam. Slightly moist, firm, massive. No cracks, common pores. Moderately moisture absorbent. No roots. Common mica. Abundant sand pockets. Common-abundant calcium carbonate concretions.

Soil Class: Orthic Grumaquert. B11

Pit: 1219

Location: Area 2A

Topography: Flat and level in slight depression

Cultivation and Land Use: Raingrown alfalfa.

Vegetation: A. Nil

B. 95%

C. Herbs

Surface: Common large cracks (1-2 cm). 1-2 cm mulch. Soft broken crust. Common kankara. Common small calcium carbonate concretions.

Profile Description:

0 - 50 cm — 10YR3/1. Clay. Top 2 cm dry loose, slightly moist, firm, moderate medium-coarse sub-angular blocky. Common cracks and common pores. Slowly moisture absorbent. Common roots. Common shell fragments. Common small calcium carbonate concretions. Common-few sand pockets, 10YR4/4, with mica. Few kankara.

50 - 120 cm — 10YR3/2. Clay. Slightly moist, firm, massive. Occasional cracks down to 70 cm. Few pores. Slowly moisture absorbent. Occasional roots. Common shell fragments. Few sand pockets and mica. Few kankara. Occasional quartz. Few small calcium carbonate concretions.

120 - 170 cm — 10YR 3/1-4/1. Clay slightly moist, firm, massive. No cracks and no pores. Slowly moisture absorbent. No roots. Common mica. Common-few sand pocket. Few-common calcium carbonate concretions and streaks. Occasional kankara.

(200 - 300 cm in bore)

170 - 300 cm — 10YR 4/3-4/4. Fine sandy clay loam. Slightly moist, firm, massive. No cracks, common pores. Moderately moisture absorbent. No roots. Common mica. Abundant sand pockets. Common-abundant calcium carbonate concretions.

Soil Class: Orthic Grumusquert. B11

LABORATORY ANALYSIS PIT - 1219

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-50	6	22	15	57	2.9	8.27	9.09
50-120	2	25	13	60	3.3	8.30	9.56
120-170	2	25	15	58	3.9	8.40	9.39
170-200	9	39	15	42	7.0	8.35	9.45

Sat. %	E.C. mmhos cm Sat. Ext.	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Total Extractable Potassium Mg/100g. soil
68	0.65	0.056	1.05	60	520
79	0.96	0.050	0.93	63	535
73	0.70	0.039	0.99	73	545
72	0.65	0.028	0.72	68	390

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	1.2	6.3	2	TRACE	8.5	0.3	2	0
	0.4	5.6	4	TRACE	11.5	0.6	1.5	0.5
	1.6	6.0	2	TRACE	9	0.2	1	0.5
	1.6	6.3	2	TRACE	8	0.2	1	0

Depth (cm)	Exchangeable Cations m.e.% Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	7	2.4	31	14	7.6	13	54
	11.5	2.6	29	15	12.4	20	59
	12	2.2	27	15	12.8	21	57
	9.6	2.0	19	16	10.0	21	46

Pit: 1219

Location: Area 2A

Topography: Flat and level in slight depression

Cultivation and Land Use: Raingrown simsim

Vegetation: A. Nil

B. 95%

C. Herbs

Surface: Common large cracks (1-2 cm). 1-2 cm mulch. Soft broken crust. Common kankars. Common small calcium carbonate concretions.

Profile Description:

0 - 50 cm 10YR3/1. Clay. Top 2 cm dry loose, slightly moist, firm, moderate medium-coarse sub-angular blocky. Common cracks and common pores. Slowly moisture absorbent. Common roots. Common shell fragments. Common small calcium carbonate concretions. Common-few sand pockets, 10YR4/4, with mica. Few kankars.

50 - 120 cm 10YR3/2. Clay. Slightly moist, firm, massive. Occasional cracks down to 70 cm. Few pores. Slowly moisture absorbent. Occasional roots. Common shell fragments. Few sand pockets and mica. Few kankars. Occasional quartz. Few small calcium carbonate concretions.

120 - 170 cm 10YR 3/1-4/1. Clay slightly moist, firm, massive. No cracks and no pores. Slowly moisture absorbent. No roots. Common mica. Common-few sand pockets. Few-common calcium carbonate concretions and streaks. Occasional kankars.

(200 - 300 cm in bore)

170 - 300 cm 10YR 4/3-4/4. Fine sandy clay loam. Slightly moist, firm, massive. No cracks, common pores. Moderately moisture absorbent. No roots. Common mica. Abundant sand pockets. Common-abundant calcium carbonate concretions.

Soil Class: Orthic Grumaquert. B11

LABORATORY ANALYSIS PIT - 1219

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-50	6	22	15	57	2.9	8.27	9.09
50-120	2	25	13	60	3.3	8.30	9.56
120-170	2	25	15	58	3.9	8.40	9.39
170-200	9	39	15	42	7.0	8.35	9.45

Sat. %	E.C. mmhos cm Sat. Ext.	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
68	0.65	0.056	1.05	60	520
79	0.96	0.050	0.93	63	535
73	0.70	0.039	0.99	73	545
72	0.65	0.028	0.72	68	390

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	1.2	6.3	2	TRACE	8.5	0.3	2	0
	0.4	5.6	4	TRACE	11.5	0.6	1.5	0.5
	1.6	6.0	2	TRACE	9	0.2	1	0.5
	1.6	6.3	2	TRACE	8	0.2	1	0

Depth (cm)	Exchangeable Cations m.e.% Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	7	2.4	31	14	7.6	13	54
	11.5	2.6	29	15	12.4	20	59
	12	2.2	27	15	12.8	21	57
	9.6	2.0	19	16	10.0	21	46

LABORATORY ANALYSIS PIT - 1219

Depth (cm)	Soil particles %					pH
	Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-50	6	22	15	57	2.9	8.27	9.09
50-120	2	25	13	60	3.3	8.30	9.56
120-170	2	25	15	58	3.9	8.40	9.39
170-200	9	39	15	42	7.0	8.35	9.45

Sat. Ext.	E:C. cm mmhos	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
68	0.65	0.058	1.05	60	520
79	0.96	0.050	0.93	63	535
73	0.70	0.039	0.99	73	545
72	0.65	0.028	0.72	68	590

Depth (cm)	Soluble Anions m. e./litre				Soluble Cations m. e./litre			
	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
	1.2	6.3	2	TRACE	8.5	0.3	2	0
	0.4	5.6	4	TRACE	11.5	0.6	1.5	0.5
	1.6	6.0	2	TRACE	9	0.2	1	0.5
	1.6	6.3	2	TRACE	8	0.2	1	0

Depth (cm)	Exchangeable Cations m. e. % Soil+Exch					E. S. P.	Exchange Capacity
	Na	K	Ca	Mg	Na		Meq/100g. soil
	7	2.4	31	14	7.6	13	54
	11.5	2.6	29	15	12.4	20	59
	12	2.2	27	15	12.8	21	57
	9.6	2.0	19	16	10.0	21	46

Pit: 2411

Location: Area 2A

Topography: Flat and level

Cultivation and Land Use: Recently burnt grass savannah just north of harvested rain-fed simsim and east of rain-fed dura fields.

Vegetation: A. Acacia senegal (14)

B. 99%

C. Nil nearby Cymbopogon nervatus (100 cm)
Beckeropsis sp. (80 cm)

Surface: Slightly uneven, with occasional 40 cm across shallow depressions. 2 mm soft raincrust over 1 cm hard angular mulch. Few 2 cm short cracks. Common grey calcium carbonate nodules up to 2 mm.

Profile Description:

0 - 40 cm: 10YR 3.5/1. Clay. Dry, slightly hard, strong coarse sub-angular blocky with strong columnar component. Occasional 1-2 cm cracks. Moderately moisture absorbent. Common 1 mm and occasional 1 cm roots. Common grey calcium carbonate nodules up to 2 mm. Rare 1 mm sand grains.

40 - 140 cm: 10YR 3/1. Few fine faint 10YR 6/2 mottles. Clay. Slightly moist, very firm, massive with common parallelepipeds. Few 5 mm cracks down to 70 cm. Slowly moisture absorbent. Occasional 0.5 mm roots. Occasional grey calcium carbonate nodules up to 4 mm. Few 2 cm flecks of white diffuse calcium carbonate between 120 - 140 cm.

(200 - 300 cm in bore)

140 - 300 cm: 10YR 5/4. Common medium faint 10YR 4/1 mottles. Clay. Moist, firm, massive with parallelepipeds. No cracks. Slowly moisture absorbent. No roots. Occasional white calcium carbonate septaria up to 2 mm with associated 2 cm patches of white diffuse calcium carbonate. Occasional 2 mm black stains, possible manganese. Few 1 mm black calcium carbonate nodules.

Soil Class: Natrargidic Grumaquert. B12

Pit: 2411

Location: Area 2A

Topography: Flat and level

Cultivation and Land Use: Recently burnt grass savannah just north of harvested rain-fed sorghum and east of rain-fed dura fields.

Vegetation: A. Acacia senegal (14)

B. 99%

C. Nil nearby Cymbopogon nervatus (100 cm)

Beckeropsis sp. (80 cm)

Surface: Slightly uneven, with occasional 40 cm across shallow depressions. 2 mm soft raincrust over 1 cm hard angular mulch. Few 2 cm short cracks. Common grey calcium carbonate nodules up to 2 mm.

Profile Description:

0 - 40 cm 10YR 3.5/1. Clay. Dry, slightly hard, strong coarse sub-angular blocky with strong columnar component. Occasional 1-2 cm cracks. Moderately moisture absorbent. Common 1 mm and occasional 1 cm roots. Common grey calcium carbonate nodules up to 2 mm. Rare 1 mm sand grains.

40 - 140 cm 10YR 3/1. Few fine faint 10YR 6/2 mottles. Clay. Slightly moist, very firm, massive with common parallelepipeds. Few 5 mm cracks down to 70 cm Slowly moisture absorbent. Occasional 0.5 mm roots. Occasional grey calcium carbonate nodules up to 4 mm. Few 2 cm flecks of white diffuse carbonate between 120 - 140 cm.

(200 - 300 cm in bore)

140 - 300 cm 10YR 5/4. Common medium faint 10YR 4/1 mottles. Clay. Moist, firm, massive with parallelepipeds. No cracks. Slowly moisture absorbent. No roots. Occasional white calcium carbonate nepkaria up to 2 mm with associated 2 cm patches of white diffuse calcium carbonate. Occasional 2 mm black stains, possible manganese. Few 1 mm black calcium carbonate nodules.

Soil Class: Natrargidic Grumesquept. BI2

LABORATORY ANALYSIS PIT - 2411

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	pH Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-40	9	10	12	69	0.8	8.11	8.66
40-140	12	9	13	66	5.3	8.25	9.05
140-300	16	8	12	64	2.75	8.33	9.10

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
67	0.4	0.045	0.84	23	205
72	1.05	0.042	0.81	33	305
73	1.08	0.039	0.81	33	320

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	1.0	40	1.5	TRACE	6	0.6	1.0	0.3
	1.4	5.4	3.5	9	15	0.4	1.5	0.5
	0.6	4.8	4.5	8	13	0.4	1.5	1.5

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	11	1.0	24	21	13.6	17	65
	18	1.8	26	20	19.2	28	65
	16	1.6	26	16	16.8	27	59

LABORATORY ANALYSIS PIT - 2411

Depth (cm)	Soil particles % Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	1 : 5 suspension
0-40	9	10	12	69	0.8	8.11	8.66
40-140	12	9	13	66	5.3	8.25	9.05
140-300	16	8	12	64	2.75	8.33	9.10

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg\100g. soil	Potassium Mg\100g. soil
67	0.4	0.045	0.84	23	295
72	1.05	0.042	0.81	33	305
73	1.08	0.039	0.81	33	320

Soluble Anions m. e.\litre Soluble Cations m. e.\litre

Depth (cm)	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
	1.0	40	1.5	TRACE	6	0.6	1.0	0.3
	1.4	5.4	3.5	9	15	0.4	1.5	0.5
	0.6	4.8	4.5	8	13	0.4	1.5	1.5

Exchangeable Cations m. e.% per 100 gm soil. Soil+Exch E.S.P.

Depth (cm)	Na	K	Ca	Mg	Na	Exchange Capacity Meq\100g. soil
	11	1.0	24	21	13.6	17	65
	18	1.8	26	20	19.2	28	65
	16	1.6	26	16	16.8	27	59

Pit: 5295

Location: Area 2A

Topography: Flat and level

Cultivation and Land Use: Scrub/grassland; grazed

Vegetation: A. Acacia seyal (7)
Acacia senegal (4)
Acacia mellifera (8)
B. 50%
C. Cymbopogon nervatus (80 cm)

Surface: Thin coarse mulch, rare kankars, occasional quartz grains, few shells, common moderate cracks.

Profile Description:

0 - 51 cm: 10YR 4/1. Clay, slightly moist and very firm, moderate coarse angular blocky structure, rare pores, common vertical cracks, slowly moisture absorbent, common tree roots and fine grass roots, rare kankars, common quartz grains in pockets and cracks, few fine carbonate concretions, few shells.

51 - 102 cm: 10YR 4/1-3/1. Clay, moist and firm to very firm, massive, no cracks, no pores, few slickensides, slowly moisture absorbent, occasional tree roots, rare kankars, few fine carbonate concretions, few quartz grains in pockets, few shells.

102 - 147 cm: 10YR 3/1. Clay, moist and very firm, massive, no cracks, no pores, rare slickensides, slowly moisture absorbent, rare tree roots, rare kankars, occasional carbonate concretions and diffuse carbonate in streaks, rare quartz grains, few shells.

147 - 205 cm: 10YR 4/2. Clay, moist and firm, massive, no cracks, no pores, moderately moisture absorbent, no roots, few kankars, common carbonate concretions, some diffuse carbonate, few shells.

(200 - 300 cm in bore)

205 - 255 cm: 10YR 4/3. Very fine sandy clay, slightly moist and friable, no structure visible, rapidly moisture absorbent, no roots, no kankars, frequent fine quartz grains and occasional mica, frequent carbonate both concretions and diffuse.

Pit: 5295

Location: Area 2A

Topography: Flat and level

Cultivation and Land Use: Scrub/grassland; grazed

Vegetation: A. Acacia seyal (7)

Acacia senegal (4)

Acacia mellifera (8)

B. 50%

C. Cymbopogon nervatus (80 cm)

Surface: Thin coarse mulch, rare kankara, occasional quartz grains, few shells, common moderate cracks.

Profile Description:

0 - 51 cm 10YR 4/1. Clay, slightly moist and very firm, moderate coarse angular blocky structure, rare pores, common vertical cracks, slowly moisture absorbent, common tree roots and fine grass roots, rare kankara, common quartz grains in pockets and cracks, few fine carbonate concretions, few shells.

51 - 102 cm 10YR 4/1-3/1. Clay, moist and firm to very firm, massive, no cracks, no pores, few slickensides, slowly moisture absorbent, occasional tree roots, rare kankara, few fine carbonate concretions, few quartz grains in pockets, few shells.

102 - 147 cm 10YR 3/1. Clay, moist and very firm, massive, no cracks, no pores, rare slickensides, slowly moisture absorbent, rare tree roots, rare kankara, occasional carbonate concretions and diffuse carbonate in streaks, rare quartz grains, few shells.

147 - 205 cm 10YR 4/2. Clay, moist and firm, massive, no cracks, no pores, moderately moisture absorbent, no roots, few kankara, common carbonate concretions, some diffuse carbonate, few shells.

(200 - 300 cm in hole)

205 - 255 cm 10YR 4/3. Very fine sandy clay, slightly moist and friable, no structure visible, rapidly moisture absorbent, no roots, no kankara, frequent fine quartz grains and occasional mica, frequent carbonate both concretions and diffuse.

255 - 300 cm — Moist 10YR 4/3. Very fine sandy loam. Dry very hard, no visible structure. Few large pores. Rapidly moisture absorbent. Abundant quartz grains; common mica. Common calcium carbonate concretions decreasing with depth.

Soil Class: Entic Grumaquert. B13

255 - 300 cm Moist 10YR 4/3. Very fine sandy loam. Dry very hard, no visible structure. Few large pores. Rapidly moisture absorbent. Abundant quartz grains; common mica. Common calcium carbonate concretions decreasing with depth.

Soil Class: Entic Durmagnept. B13

LABORATORY ANALYSIS PIT - 5295

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	1 : 5 suspension
0-51	5	14	16	65	1.1	7.8	8.4
51-102	7	17	13	63	3.15	8.0	8.7
102-147	10	17	13	60	6.5	8.0	8.8
147-205	4	18	15	65	3.4	7.8	8.5

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
73	0.4	0.05	1.05	48	440
70	0.75	0.053	0.75	38	430
80	0.86	0.045	0.84	55	530
86	0.7	0.042	0.96	60	380

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0	4.6	1.5	TRACE	5	0.1	1	0
	0.6	5.1	3.0	5	10	0.1	2	1
	0.8	4.4	4.5	4	11	0.2	2	0
	0.6	4.5	1.5	7	9	0.1	1.5	0.5

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	6.8	2.4	35	16	7.2	11	61
	12.1	2.0	23	16	17.0	20	60
	16.0	2.4	23	12	16.4	27	59
	12.1	2.8	32	13	10.8	20	61

LABORATORY ANALYSIS PIT - 5295

Depth (cms)	Soil particles % Coarse sand 2.0- 0.2 mms.	Fine sand 0.2- 0.02 mms.	Silt 0.02- 0.002 mms.	Clay under 0.002 mms.	Incorp. Carbonate	pH Soil Paste	1 : 5 suspension
0-51	5	14	16	65	1.1	7.8	8.4
51-102	7	17	13	63	3.15	8.0	8.7
102-147	10	17	13	60	6.5	8.0	8.8
147-205	4	18	15	65	3.4	7.8	8.5

Sat. %	E. C. mmhos cms Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
73	0.4	0.05	1.05	48	440
70	0.75	0.053	0.75	38	430
80	0.86	0.045	0.84	55	530
86	0.7	0.042	0.96	60	380

Depth (cms)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0	4.6	1.5	TRACE	5	0.1	1	0
	0.6	5.1	3.0	5	10	0.1	2	1
	0.8	4.4	4.5	4	11	0.2	2	0
	0.6	4.5	1.5	7	9	0.1	1.5	0.5

Depth (cms)	Exchangeable Cations m.e.% per 100 gms soil. Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Med/100g. soil
	6.8	2.4	35	16	7.2	11	61
	12.1	2.0	23	16	17.0	20	60
	16.0	2.4	23	12	16.4	27	59
	12.1	2.8	32	13	10.8	20	61

Pit:	5351
Location:	Area 2A
Topography:	In bottom of gully.
Cultivation and Land use:	Scrub grassland: lightly grazed.
Vegetation	A. Acacia seyal (12) Acacia mellifera (6) Capparis decidua (1) B. 30% C. Sorghum spp. (180 cm)
Surface:	Soft granular top, common moderate to large cracks, few nodules, few shells, occasional to common shells.

Profile Description:

0-33 cm	10YR 4/1. Clay. Moist and very firm, moderate medium to coarse sub-angular blocky structure, common moderate to fine cracks, rare pores, slowly moisture absorbent, occasional Acacia seyal roots. Occasional fine nodules, common quartz grains in pockets, cracks and ped faces, few shells.
33-66 cm	10YR 4/1-3/1. Clay. Moist and firm to very firm, strong medium to fine platy, rare vertical cracks, no pores, common slickensides, clay skins, moderately to slowly moisture absorbent, few Acacia seyal roots, common fine nodules, occasional quartz grains in pockets, thin sand lense at bottom of horizon, few shells.
66-134 cm	10YR 4/1-3/1. Clay. Moist and very firm, moderate parallelepíped structure, no cracks, no pores, common slickensides, slowly moisture absorbent, no roots, occasional to common fine nodules, occasional diffuse carbonate in old fine root channels, few quartz grains in pockets, few carbonate concretions at bottom, few shells.

Pit: S351

Location: Area 2A

Topography: In bottom of gully.

Cultivation and

Land use: Scrub grassland; lightly grazed.

Vegetation A. Acacia seyal (12)

Acacia mellifera (6)

Capparis decidua (1)

B. 30%

C. Sorghum spp. (180 cm)

Surface: Soft granular top, common moderate to large cracks, few nodules, few shells, occasional to common shells.

Profile Description:

0-33 cm 10YR 4/1. Clay. Moist and very firm, moderate medium to coarse sub-angular blocky structure, common moderate to fine cracks, rare pores, slowly moisture absorbent, occasional Acacia seyal roots. Occasional fine nodules, common quartz grains in pockets, cracks and ped faces, few shells.

33-66 cm 10YR 4/1-3/1. Clay. Moist and firm to very firm, strong medium to fine platy, rare vertical cracks, no pores, common slickensides, clay skins, moderately to slowly moisture absorbent, few Acacia seyal roots, common fine nodules, occasional quartz grains in pockets, thin sand lense at bottom of horizon, few shells.

66-134 cm 10YR 4/1-3/1. Clay. Moist and very firm, moderate parallelpiped structure, no cracks, no pores, common slickensides, slowly moisture absorbent, no roots, occasional to common fine nodules, occasional diffuse carbonate in old fine root channels, few quartz grains in pockets, few carbonate concretions at bottom, few shells.

134-200 cm — 10YR 4/1-3/1. Clay. Moist and very firm to extremely firm, massive, no cracks, no pores, occasional slickensides, clay skins, slowly moisture absorbent, few nodules, few quartz grains, lenses showing faint bedding, occasional concretions slightly concentrated in top 50 cm, rare shells.

Soil Class: Entic Natrargidic Grumaquert. B 14.

134-200 cm 10YR 4/1-3/1. Clay. Moist and very firm to extremely firm, massive, no cracks, no pores, occasional slickensides, clay skins, slowly moisture absorbent, few nodules, few quartz grains, lenses showing faint bedding, occasional concretions slightly concentrated in top 50 cm, rare shells.

Soil Class: Entic Natrargidic Grumaquert. B 14.

LABORATORY ANALYSIS PIT - 5351

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	pH Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-33	3	9	13	75	2.0	7.77	8.45
33-66	4	8	13	75	1.65	7.91	8.06
66-134	6	6	13	75	1.80	7.86	8.47
134-200	6	13	11	70	2.75	8.0	8.55

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
75	0.44	0.05	0.78	55	590
76	0.52	0.036	0.75	50	640
78	1.0	0.036	0.63	55	585
96	0.9	0.042	0.78	50	480

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.6	4.0	1.5	TRACE	5	0.2	1	0.5
	0.8	4.4	2.5	TRACE	6	0.1	1	0.5
	0.6	3.4	3.5	9	12	0.2	2	1
	0.6	3.7	3.0	8	11	0.2	1.5	1

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	13.2	3.0	39	17	12.8	19	69
	16.5	2.6	33	19	16.8	24	68
	19.5	2.4	30	21	20.4	27	72
	16.0	2.2	30	17	16.0	24	67

LABORATORY ANALYSIS PIT - 5351

Depth (cm)	Soil particles %					pH	
	Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-33	3	9	13	75	2.0	7.77	8.45
33-66	4	8	13	75	1.65	7.91	8.06
66-134	6	6	13	75	1.80	7.86	8.47
134-200	6	13	11	70	2.75	8.0	8.55

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
75	0.44	0.09	0.78	55	590
76	0.52	0.036	0.75	50	640
78	1.0	0.036	0.63	55	585
96	0.9	0.042	0.78	50	480

Depth (cm)	Soluble Anions m.e./litre				Soluble Cations m.e./litre			
	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
	0.6	4.0	1.5	TRACE	5	0.2	1	0.5
	0.8	4.4	2.5	TRACE	6	0.1	1	0.5
	0.6	3.4	3.5	9	12	0.2	2	1
	0.6	3.7	3.0	8	11	0.2	1.5	1

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil.				Sol+Exch		Exchange Capacity
	Na	K	Ca	Mg	Na	E.S.P.	Meq/100g. soil
	13.2	3.0	39	17	12.8	19	69
	16.5	2.6	33	19	16.8	24	68
	19.5	2.4	30	21	20.4	27	72
	16.0	2.2	30	17	16.0	24	67

Pit: 1429

Location: Area 2A

Topography: Slightly depressional

Cultivation and Land Use: Grass/woodland; burned

Vegetation: A. Balanites aegyptiaca (32)
Acacia seyal (121)
B. & C. burned; Hyparrhenia sp. nearby

Surface: Firm broken crust, many 1-3 cm cracks, abundant quartz grains, few shell fragments.

Profile Description:

0 - 40 cm: 10YR 3/2-4/1. Clay, dry and hard, moderate coarse sub-angular blocky with platy component, common cracks, common pores, slowly moisture absorbent, common roots, few shell fragments, common fine nodules, common quartz grains.

40 - 70 cm: 10YT 3/2. Clay, slightly moist and firm, moderate medium angular blocky with wedges, common cracks, no pores, few slickensides, slowly moisture absorbent, few roots, common quartz grains in pockets, occasional shell fragments, few kankars, common nodules.

70 - 150 cm: 10YR 3/2-2.5Y 4/2. Clay, moist and very firm, massive with weak wedges, no cracks and no pores, common slickensides, slowly moisture absorbent, few roots, few kankars, few fine nodules.

150 - 200 cm: 10YR 4/2-4/3, common 10YR 5/6 mottles, clay, moist and firm, massive, no cracks, no pores, slowly moisture absorbent, no roots, common carbonate concretions, rare shell fragments, few quartz grains.

Soil Class: Orthic Mazaquert. B21

Pit: 1429

Location: Area 2A

Topography: Slightly depressional

Cultivation and Land Use: Grass/woodland; burned

Vegetation: A. Balanites aegyptiaca (32)

Acacia seyal (121)

B. & C. burned; Hyparrhenia sp. nearby

Surface: Firm broken crust, many 1-3 cm cracks, abundant quartz grains, few shell fragments.

Profile Description:

0 - 40 cm 10YR 3/2-4/1. Clay, dry and hard, moderate coarse sub-angular blocky with platy component, common cracks, common pores, slowly moisture absorbent, common roots, few shell fragments, common fine nodules, common quartz grains.

40 - 70 cm 10YT 3/2. Clay, slightly moist and firm, moderate medium angular blocky with wedges, common cracks, no pores, few slickensides, slowly moisture absorbent, few roots, common quartz grains in pockets, occasional shell fragments, few kankars, common nodules.

70 - 150 cm 10YR 3/2-2.5Y 4/2. Clay, moist and very firm, massive with weak wedges, no cracks and no pores, common slickensides, slowly moisture absorbent, few roots, few kankars, few fine nodules.

150 - 200 cm 10YR 4/2-4/3, common 10YR 5/6 mottles, clay, moist and firm, massive, no cracks, no pores, slowly moisture absorbent, no roots, common carbonate concretions, rare shell fragments, few quartz grains.

Soil Class: Orthic Mazaquert. B21

LABORATORY ANALYSIS PIT - 1429

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-40	14	18	11	57	1.45	7.65	8.39
40-70	14	15	11	60	1.15	7.77	8.75
70-150	13	11	11	65	2.9	7.80	8.91
150-200	13	19	11	57	2.4	7.48	8.18

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
71	0.25	0.042	0.81	23	585
62	0.38	0.032	0.72	38	625
63	0.96	0.039	0.72	45	690
65	2.20	0.045	0.99	38	550

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.6	2.7	2	0	3	0.15	0.8	0.2
	0.4	3.2	3	0	5	0.2	0.8	0.2
	0.4	2.2	6	5	10	0.3	1.5	1.5
	0.6	3.3	14	14	24	0.45	3.0	3.0

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	3.8	1.8	3.2	14	4.0	7	52
	7.7	1.6	3.0	14	8.0	14	54
	12.0	2.0	3.0	16	12.6	19	63
	7.2	2.4	3.2	14	8.8	13	56

LABORATORY ANALYSIS PIT - 1429

Depth (cm)	Soil particles %					pH
	Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-40	14	18	11	57	1.45	7.65	8.39
40-70	14	15	11	60	1.15	7.77	8.75
70-150	13	11	11	65	2.9	7.80	8.91
150-200	13	19	11	57	2.4	7.48	8.18

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
71	0.25	0.042	0.81	23	585
62	0.38	0.032	0.72	38	625
63	0.96	0.039	0.72	45	890
65	2.20	0.045	0.99	38	550

Depth (cm)	Soluble Anions m.e./litre				Soluble Cations m.e./litre			
	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
	0.6	2.7	2	0	3	0.15	0.8	0.2
	0.4	3.2	3	0	5	0.2	0.8	0.2
	0.4	2.2	6	5	10	0.3	1.5	1.5
	0.6	3.3	14	14	24	0.45	3.0	3.0

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Soil+Exch					Exchange Capacity
	Na	K	Ca	Mg	Na	E.S.P.	Meq/100g. soil
	3.8	1.8	3.2	14	4.0	7	52
	7.7	1.6	3.0	14	8.0	14	54
	12.0	2.0	3.0	16	12.6	19	63
	7.2	2.4	3.2	14	8.8	13	56

Pit: 5451

Location: Area 2A

Topography: Flat, slightly shedding site near gully

Cultivation and Land Use: Grass/ Woodland, grazed

Vegetation: A. Acacia seyal (2)
Balanites aegyptiaca (3)
B. 20%
C. Cymbopogon giganteus (170 cm)

Surface: Very thin sand mulch on hard massive surface, rare shells, abundant quartz grains, common large cracks.

Profile Description:

0 - 51 cm: 10YR 4/1-3/1, slightly sandy clay, slightly moist and firm to very firm, moderate coarse prismatic structure, breaking to weak to moderate coarse angular blocky structure, frequent cracks, occasional pores, few slickensides, moderately moisture absorbent, occasional to common quartz grains in cracks and lenses, few shells.

51 - 86 cm: 10YT 4/1-2.5Y 4/2. Clay, moist and very firm, weak coarse prismatic structure with weak to moderate coarse platy component, few cracks, no pores, common slickensides, slowly moisture absorbent, few roots, occasional fine nodules, occasional quartz grains, specially in lenses, few shells.

86 - 132 cm: 10YR 4/1. Clay, moist and very firm, massive with weak wedge structures, no cracks, no pores, few-occasional slickensides, few fine nodules, occasional quartz grains, few shells, few carbonate concretions below 120 cm, few kankars.

132 - 215 cm: 10YR 4/2 and 10YR 4/1, fine sandy clay, moist and firm, massive, no cracks, no pores, moderately moisture absorbent, no roots, occasional kankars, occasional to common carbonate concretions, common fine quartz grains, rare shells.

Pit: 6451

Location: Area 2A

Topography: Flat, slightly eroding site near gully

Cultivation and Land Use: Grass/Woodland, grazed

Vegetation: A. Acacia seyal (2)

Balanites aegyptiaca (3)

B. 20%

C. Cymbopogon giganteus (170 cm)

Surface: Very thin sand mulch on hard massive surface, rare shells, abundant quartz grains, common large cracks.

Profile Description:

0 - 51 cm — 10YR 4/1-3/1, slightly sandy clay, slightly moist and firm to very firm, moderate coarse prismatic structure, breaking to weak to moderate coarse angular blocky structure, frequent cracks, occasional pores, few slickensides, moderately moisture absorbent, occasional to common quartz grains in cracks and lenses, few shells.

51 - 86 cm — 10YT 4/1-2.5Y 4/2. Clay, moist and very firm, weak coarse prismatic structure with weak to moderate coarse platy component, few cracks, no pores, common slickensides, slowly moisture absorbent, few roots, occasional fine nodules, occasional quartz grains, especially in lenses, few shells.

86 - 132 cm — 10YR 4/1. Clay, moist and very firm, massive with weak wedge structure, no cracks, no pores, few-occasional slickensides, few fine nodules, occasional quartz grains, few shells, few carbonate concretions below 120 cm, few kankara.

132 - 215 cm — 10YR 4/2 and 10YR 4/1, fine sandy clay, moist and firm, massive, no cracks, no pores, moderately moisture absorbent, no roots, occasional kankara, occasional to common carbonate concretions, common fine quartz grains, rare shells.

(200 - 300 cm in bore)

215 - 300 cm — 10YR 5/2-5/3, fine sandy clay loam, slightly moist and firm, moderately moisture absorbent, no structure visible, abundant fine quartz, occasional carbonate concretions in top 20 cm decreasing downwards, rare shells, few patches of 10YR 4/1 material in top.

Soil Class: Entic Mazaquert. B23

(200 - 300 cm in bore)

215 - 300 cm 10YR 5/2-5/3, fine sandy clay loam, slightly moist and firm, moderately moisture absorbent, no structure visible, abundant fine quartz, occasional carbonate concretions in top 20 cm decreasing downwards, rare shells, few patches of 10YR 4/1 material in top.

Soil Class: Entic Haxaquept. B23

LABORATORY ANALYSIS PIT - 5451

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-51	6	19	17	58	1.1	7.45	7.8
51-86	10	19	16	55	2.4	7.7	8.3
86-132	4	3	23	70	2.3	7.85	8.45
132-215	8	20	9	63	3.3	7.8	7.97

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Total Extractable Potassium Mg/100g. soil
61	0.29	0.053	0.87	40	330
72	1.75	0.034	0.96	40	345
72	0.69	0.050	0.93	25	280
69	0.7	0.034	0.84	48	380

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.6	3.0	1.0	TRACE	3.5	0.1	1.5	0
	0.6	2.7	6.5	16	19	0.4	3.0	1.5
	0.6	6.0	3.0	TRACE	9	0.3	1.0	0
	0.6	5.6	2.5	TRACE	9	0.2	1.3	0.2

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	3.8	1.8	30	16	3.2	7	56
	11.4	1.6	26	14	12.8	21	54
	11	1.6	43	15	11.6	16	69
	14.6	1.6	24	16	13.6	24	61

LABORATORY ANALYSIS PIT - 5451

Depth (cm)	Soil particles % Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-51	6	19	17	58	1.1	7.45	7.8
51-86	10	19	16	55	2.4	7.7	8.3
86-132	4	3	23	70	2.3	7.85	8.45
132-215	8	20	9	63	3.3	7.8	7.97

Sat. %	E.C. mmhos cm Sat.	Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
61	0.29		0.053	0.87	40	330
72	1.75		0.034	0.96	40	345
72	0.69		0.050	0.93	25	280
69	0.7		0.034	0.84	48	380

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.6	3.0	1.0	TRACE	3.5	0.1	1.5	0
	0.6	2.7	6.5	16	19	0.4	3.0	1.5
	0.6	6.0	3.0	TRACE	9	0.3	1.0	0
	0.6	5.6	2.5	TRACE	9	0.2	1.3	0.2

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Na	K	Ca	Mg	Soil+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	3.8	1.8	30	16	3.2	7	56
	11.4	1.6	26	14	12.8	21	54
	11	1.6	43	15	11.6	16	69
	14.6	1.6	24	16	13.6	24	61

Pit: 5315

Location: Area 2A.

Topography: Flat and level.

Cultivation and land use: Grass/woodland: not grazed.

Vegetation:

A. Acacia seyal (3)
Balanites aegyptiaca (5)

B. 15%

C. Sorghum spp. (250 cm)
Cymbopogon nervatus (80 cm)

Surface: Hard, broken crust, rare kankars, common quartz grains, rare shells, occasional moderate to large cracks, slightly pitted.

Profile Description:

0-54 cm — 10YR 4/1-4/2, clay dry and very hard, moderate coarse angular blocky structure, few pores, occasional large vertical cracks, moderately moisture absorbent, common tree roots, few kankars, common quartz grains in pockets and along cracks, few to occasional fine carbonate concretions, few shells.

54-133 cm — 10YR 4/1-4/2, clay, moist and very firm, massive, no cracks, no pores, common slickensides in the upper part of the horizon, slowly moisture absorbent, few tree roots down to 90 cm, few kankars, few quartz pockets, few fine carbonate concretions, few large carbonate concretions near bottom of horizon, few shells.

133-205 cm — 10YR 4/1-3/1, clay, moist and very firm, massive, no cracks, no pores, few slickensides, slowly moisture absorbent, no roots, occasional kankars, rare quartz grains, occasional carbonate concretions, few shells.

(200-300 cm in bore)

Pit: S315

Location: Area 2A.

Topography: Flat and level.

Cultivation and land use: Grass/woodland: not grazed.

Vegetation: A. Acacia seyal (3)
Balanites aegyptiaca (5)
B. 15%
C. Sorghum spp. (250 cm)
Cymbopogon nervatus (80 cm)

Surface: Hard, broken crust, rare kankara, common quartz grains, rare shells, occasional moderate to large cracks, slightly pitted.

Profile Description:

0-54 cm — 10YR 4/1-4/2, clay, dry and very hard, moderate coarse angular blocky structure, few pores, occasional large vertical cracks, moderately moisture absorbent, common tree roots, few kankara, common quartz grains in pockets and along cracks, few to occasional fine carbonate concretions, few shells.

54-133 cm — 10YR 4/1-4/2, clay, moist and very firm, massive, no cracks, no pores, common slickensides in the upper part of the horizon, slowly moisture absorbent, few tree roots down to 90 cm, few kankara, few quartz pockets, few fine carbonate concretions, few large carbonate concretions near bottom of horizon, few shells.

133-205 cm — 10YR 4/1-3/1, clay, moist and very firm, massive, no cracks, no pores, few slickensides, slowly moisture absorbent, no roots, occasional kankara, rare quartz grains, occasional carbonate concretions, few shells.

(200-300 cm in bore)

205-300 cm — 10YR 5/2, clay, moist and very firm becoming less firm with depth, no structure visible, slowly moisture absorbent, no roots, occasional kankars, occasional to common carbonate decreasing with depth, few shells.

Soil Class: Entic Natrargidic Mazaquert. B 24

205-300 cm 10YR 5/2, clay, moist and very firm becoming less firm with depth, no structure visible, slowly moisture absorbent, no roots, occasional kankara, occasional to common carbonate decreasing with depth, few shells.

Soil Class: Entic Natrargidic Mazaguert, B 24

LABORATORY ANALYSIS PIT - 5315

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-54	4	25	16	55	1.86	7.8	8.3
54-133	26	11	15	48	4.0	7.4	7.9
133-205	9	5	16	70	3.0	8.1	8.86

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g soil	Total Extractable Potassium Mg/100g. soil
72	0.46	0.053	0.9	25	185
60	6.1	0.067	0.99	43	300
90	1.3	0.036	0.78	28	265

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	1	4.7	1	TRACE	7	0.2	1	0
	0	7.9	34	73	75	0.8	23	13
	0.6	6.6	7	7	16	0.6	3	0

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Na	K	Ca	Mg	Sol+Exch E.S.P. Na	Exchange Capacity Meq/100g. soil
	9	0.8	33	18	9.6	15	59
	12.5	1.6	21	10	18.4	28	44
	18.5	1.2	25	23	16.8	28	66

LABORATORY ANALYSIS PIT - 5315

Depth (cm)	Soil particles %					pH
	Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-54	4	25	16	55	1.86	7.8	8.3
54-133	26	11	15	48	4.0	7.4	7.9
133-205	9	5	16	70	3.0	8.1	8.86

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g soil	Potassium Mg/100g. soil
72	0.46	0.053	0.9	25	185
60	6.1	0.067	0.99	43	300
90	1.3	0.036	0.78	28	265

Depth (cm)	Soluble Anions m.e./litre				Soluble Cations m.e./litre			
	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
1	4.7	1	TRACE	7	0.2	1	0
0	7.9	34	73	75	0.8	23	13
0.6	6.6	7	7	16	0.6	3	0

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil.				Sol+Exch	E.S.P.	Exchange Capacity Meq/100g. soil
	Na	K	Ca	Mg	Na		
	9	0.8	33	18	9.6	15	59
	12.5	1.6	21	10	18.4	28	44
	18.5	1.2	25	23	16.8	28	66

Pit: 1430

Location: Area 2A

Topography: Slightly hummocky

Cultivation and Land Use: Grass/Woodland

Vegetation: A. Dalbergia melanoxylon (81)
Balanites aegyptiaca (41)
Acacia seyal (41)
B. 90%
C. Schoenefeldia gracilis, Aristida sp.

Surface: Firm crust, common small cracks, abundant quartz grains.

Profile Description:

0 - 25 cm: 10YR 3/2-3/1, sandy clay loam, dry and very hard, weak coarse sub-angular blocky, common small cracks, no pores, moderately moisture absorbent, few roots, common mica, abundant quartz grains.

25 - 125 cm: 10YR 3/1, sandy clay loam, slightly moist and indurated, massive, no cracks, no pores, moderately moisture absorbent, no roots, few fine nodules, abundant quartz grains, common mica.

125 - 150 cm: 10YR 3/1, common 10YR 4/3 mottles, sandy clay, slightly moist and indurated, massive, moderately moisture absorbent, no roots, many carbonate concretions, abundant quartz grains, common mica.

150 - 180 cm: 10YR 4/2-4/1, common 10YR 5/4 and 7.5YR 4/4 mottles, sandy clay, slightly moist and very firm, moderately moisture absorbent, no roots, common carbonate concretions, abundant quartz grains, common mica.

180 - 200 cm: 10YR 4/3-4/2, loam, slightly moist and firm, massive, rapidly moisture absorbent, no roots, few carbonate concretions, abundant quartz grains.

Soil Class: Orthic Orthustent. C21

Pit: 1430

Location: Area 2A

Topography: Slightly hummocky

Cultivation and Land Use: Grass/Woodland

Vegetation: A. Dalbergia melanoxylon (81)
Balanites aegyptiaca (41)
Acacia seyal (41)
B. 90%
C. Schoenefeldia gracilis, Aristida sp.

Surface: Firm crust, common small cracks, abundant quartz grains.

Profile Description:

0 - 25 cm 10YR 3/2-3/1, sandy clay loam, dry and very hard, weak coarse sub-angular blocky, common small cracks, no pores, moderately moisture absorbent, few roots, common mica, abundant quartz grains.

25 - 125 cm 10YR 3/1, sandy clay loam, slightly moist and indurated, massive, no cracks, no pores, moderately moisture absorbent, no roots, few fine nodules, abundant quartz grains, common mica.

125 - 150 cm 10YR 3/1, common 10YR 4/3 mottles, sandy clay, slightly moist and indurated, massive, moderately moisture absorbent, no roots, many carbonate concretions, abundant quartz grains, common mica.

150 - 180 cm 10YR 4/2-4/1, common 10YR 5/4 and 7.5YR 4/4 mottles, sandy clay, slightly moist and very firm, moderately moisture absorbent, no roots, common carbonate concretions, abundant quartz grains, common mica.

180 - 200 cm 10YR 4/3-4/2, loam, slightly moist and firm, massive, rapidly moisture absorbent, no roots, few carbonate concretions, abundant quartz grains.

Soil Class: Orthic Orthustent. C21

LABORATORY ANALYSIS PIT - 1430

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-25	31	26	7	36	0.8	6.51	7.61
25-125	36	18	11	35	1.1	7.85	8.95
125-150	34	23	7	36	2.6	8.12	9.13
150-180	26	25	9	40	1.3	7.81	8.78
180-200	14	15	11	60	2.75	7.77	8.62

Sat. %	E.C. mmhos cm Sat. Ext.	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Total Extractable Potassium Mg/100g. soil
53	0.43	0.042	0.81	15	415
34	0.40	0.025	0.45	17	350
51	0.45	0.017	0.33	15	295
62	0.38	0.032	0.63	25	440
69	0.54	0.036	0.75	60	760

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.4	2.8	3.5	0	4	0.35	1	0.5
	0.8	3.8	2.0	0	5	0.15	1	0.5
	0.8	3.8	2.5	0	6	0.1	1	0
	0.4	3.0	2.5	0	4	0.1	1	1
	0.8	3.0	3.5	0	6	0.1	1	0.5

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	4.0	1.2	12	14	4.2	12	33
	7.0	0.8	14	11	7.2	19	37
	6.2	1.0	15	13	6.5	18	34
	3.6	1.2	26	7	3.8	10	36
	6.6	2.2	31	16	7.0	12	55

LABORATORY ANALYSIS PIT - 1430

Depth (cm)	Soil particles %					pH
	Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-25	31	26	7	36	0.8	6.51	7.61
25-125	36	18	11	35	1.1	7.85	8.95
125-150	34	23	7	36	2.6	8.12	9.13
150-180	26	25	9	40	1.3	7.81	8.78
180-200	14	15	11	60	2.75	7.77	8.62

Sat. %	E.C. mmhos cm Sat. Ext.	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
53	0.43	0.042	0.81	15	415
34	0.40	0.025	0.45	17	350
51	0.45	0.017	0.33	15	295
62	0.38	0.032	0.63	25	440
69	0.54	0.036	0.75	60	760

Depth (cm)	Soluble Anions m.e./litre				Soluble Cations m.e./litre		
	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
	0.4	2.8	3.5	0	4	0.35	1	0.5
	0.8	3.8	2.0	0	5	0.15	1	0.5
	0.8	3.8	2.5	0	6	0.1	1	0
	0.4	3.0	2.5	0	4	0.1	1	1
	0.8	3.0	3.5	0	6	0.1	1	0.5

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil.				Soil+Exch E.S.P.	Exchange Capacity
	Na	K	Ca	Mg	Na	Meq/100g. soil
	4.0	1.2	12	14	4.2	12	33
	7.0	0.8	14	11	7.2	19	37
	6.2	1.0	15	13	6.5	18	34
	3.6	1.2	26	7	3.8	10	36
	6.6	2.2	31	16	7.0	12	55

Pit: 1431

Location: Area 2A.

Topography: Very slightly uneven, gently sloping.

Cultivation and land use: Grass/Woodland.

Vegetation: A. Combretum sp. (60)
B. 80%
C. Hyparrhenia sp.

Surface: Firm broken crust, common cracks, 1-3 cm, abundant quartz grains.

Profile Description:

0-45 cm — 10YR 3/2-3/1, sandy clay, slightly moist and firm, moderate coarse sub-angular blocky, common cracks, no pores, slowly moisture absorbent, common roots, abundant quartz grains, common nodules, few mica.

45-145 cm — 10YR 3/2-2.5Y 4/2, clay, slightly moist and firm, massive, occasional cracks, slowly moisture absorbent, rare roots, abundant quartz grains, common nodules, few mica.

145-200 cm — 10YR 4/3-5/4, sandy clay loam, slightly moist and friable, massive, no cracks, no pores, moderately moisture absorbent, no roots, abundant quartz grains, common carbonate concretions, common mica.

Soil Class: Vertic Orthustent. C 23

Pit: 1431

Location: Area 2A.

Topography: Very slightly uneven, gently sloping.

Cultivation and land use: Grass/Woodland.

Vegetation: A. Comptetum sp. (60)
B. 80%
C. Hypatrhenia sp.

Surface: Firm broken crust, common cracks, 1-3 cm, abundant quartz grains.

Profile Description:

0-45 cm 10YR 3/2-3/1, sandy clay, slightly moist and firm, moderate coarse sub-angular blocky, common cracks, no pores, slowly moisture absorbent, common roots, abundant quartz grains, common nodules, few mica.

45-145 cm 10YR 3/2-2.5Y 4/2, clay, slightly moist and firm, massive, occasional cracks, slowly moisture absorbent, rare roots, abundant quartz grains, common nodules, few mica.

145-200 cm 10YR 4/3-5/4, sandy clay loam, slightly moist and friable, massive, no cracks, no pores, moderately moisture absorbent, no roots, abundant quartz grains, common carbonate concretions, common mica.

Soil Class: Vertic Orthusstent. C 23

LABORATORY ANALYSIS PIT 1431

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-45	34	12	10	44	1.3	7.7	8.65
45-145	36	11	12	41	2.2	8.01	9.0
145-200	44	13	9	34	4.7	7.82	8.82

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Total Extractable Potassium Mg/100g. soil
47	0.48	0.028	0.42	33	385
52	0.50	0.025	0.45	13	350
50	0.50	0.022	0.33	28	330

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	0.4	3.0	3	0	5	0.1	1.3	0.2
	0.8	4.0	2.5	0	5	0.05	1.3	0.2
	1.2	5.2	2.5	0	7	0.1	1.3	0.7

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	4.4	0.8	18	9	4.6	14	31
	5.7	1.4	18	4	6.0	14	40
	6.2	0.8	18	16	6.6	19	32

LABORATORY ANALYSIS PIT 1431

Depth (cm)	Soil particles % Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	1 : 5 suspension
0-45	34	12	10	44	1.3	7.7	8.65
45-145	36	11	12	41	2.2	8.01	9.0
145-200	44	13	9	34	4.7	7.82	8.82

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg\100g. soil	Potassium Mg\100g. soil
47	0.48	0.028	0.42	33	385
52	0.50	0.025	0.45	13	350
50	0.50	0.022	0.33	28	330

Depth (cm)	Soluble Anions m.e.\litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e.\litre Na	K	Ca	Mg
	0.4	3.0	3	0	5	0.1	1.3	0.2
	0.8	4.0	2.5	0	5	0.05	1.3	0.2
	1.2	5.2	2.5	0	7	0.1	1.3	0.7

Depth (cm)	Exchangeable Cations m.e.% per 100 gm. soil Na	K	Ca	Mg	Soil+Exch Na	E.S.P.	Exchange Capacity Meq\100g. soil
	4.4	0.8	18	9	4.6	14	31
	5.7	1.4	18	4	6.0	14	40
	6.2	0.8	18	16	6.6	19	32

Pit: 4374

Location: Area 2A

Topography: Flat and level to slightly depressional.

Cultivation and land use: Grassland part grazed, wood collection.

Vegetation:

A. Acacia seyal (27)
Balanites aegyptiaca (5)
Capparis decidua (5)
Acacia nubica (50)
Acacia mellifera (2)

B. 5%

C. Schoenefeldia gracilis (40 cm)
Setaria pallida-fusca (45 cm)

Surface: Dry hard surface, occasional deep, less than 1 cm wide cracks.

Profile Description:

0-36 cm — 10YR 4/1- 3/1 clay, dry, and extremely hard, strong coarse parallelepiped to blocky structure, occasional deep 1 cm wide cracks, rare pores. Frequent fine roots. Moderately moisture absorbent. Occasional sand pockets. Common quartz grains. Rare 2 mm black calcium nodules, few 2-5 mm white and grey calcium nodules.

36-143 cm — 10YR 4/1-3/1 clay, moist and very firm, becoming firm, Massive to moderate fine blocky, few pores, rare deep 0.5 cm wide cracks to 60 cm, occasional fine cracks, very rare slickensides, occasional fine roots. Slowly moisture absorbent. Occasional sand pockets, occasional less than 1 mm and 1-2 mm white calcium septaria below 100 cm. Rare 5 mm black nodules.

143-280 cm — 10YR 4/1 clay, with abundant mottling 10YR 4/3. Slightly moist and very firm. Massive tending to strong fine blocky. Rare pores, no cracks, very rare fine roots. Slowly moisture absorbent. Frequent pockets of 215 mm white calcium nodules, rare 5 mm black nodules, occasional quartz grains.

Pit: 4374

Location: Area 2A

Topography: Flat and level to slightly depressional.

Cultivation and land use: Grassland part grazed, wood collection.

Vegetation:
A. Acacia seyal (27)
Balanites aegyptiaca (5)
Capparis decidua (5)
Acacia nubica (50)
Acacia mellifera (2)
B. 5%
C. Schoenefeldia gracilis (40 cm)
Setaria pallida-fusca (45 cm)

Surface: Dry hard surface, occasional deep, less than 1 cm wide cracks.

Profile Description:

0-36 cm 10YR 4/1- 3/1 clay, dry, and extremely hard, strong coarse parallelepiped to blocky structure, occasional deep 1 cm wide cracks, rare pores. Frequent fine roots. Moderately moisture absorbent. Occasional sand pockets. Common quartz grains. Rare 2 mm black calcium nodules, few 2-5 mm white and grey calcium nodules.

36-143 cm 10YR 4/1-3/1 clay, moist and very firm, becoming firm, Massive to moderate fine blocky, few pores, rare deep 0.5 cm wide cracks to 60 cm, occasional fine cracks, very rare slickensides, occasional fine roots. Slowly moisture absorbent. Occasional sand pockets, occasional less than 1 mm and 1-2 mm white calcium asptaris below 100 cm. Rare 5 mm black nodules.

143-280 cm 10YR 4/1 clay, with abundant mottling 10YR 4/3, Slightly moist and very firm. Massive tending to strong fine blocky. Rare pores, no cracks, very rare fine roots. Slowly moisture absorbent. Frequent pockets of 2IS mm white calcium nodules, rare 5 mm black nodules, occasional quartz grains.

(200-300 cm in bore)

280-300 cm	10YR 4/1 sandy clay with frequent 10YR 4/3 mottling, slightly moist and friable. Substratum. No roots. Common 5-20 mm white calcium nodules, and coarse sand, occasional mica.
Soil Class:	Vertic Natrargidic Orthustent. C24.

(200-300 cm in bore)

280-300 cm 10YR 4/1 sandy clay with frequent 10YR 4/3 mottling, slightly moist and friable. Substratum. No roots. Common 5-20 mm white calcium nodules, and coarse sand, occasional mica.

Soil Class: Vertic Natrargidic Orthustent. C24.

LABORATORY ANALYSIS PIT - 4374

Depth (cm)	Soil particles % Coarse sand 2.0-0.2 mm.	Fine sand 0.2-0.02 mm.	Silt 0.02-0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	pH Soil Paste	pH 1 : 5 suspension
0-36	23	16	16	45	3.4	8.13	8.52
36-143	20	12	13	55	3.65	8.22	8.85
143-280	20	12	15	53	3.8	7.9	8.39

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg/100g. soil	Potassium Mg/100g. soil
62	0.7	0.053	0.84	28	230
66	0.55	0.032	0.78	13	280
68	4.0	0.039	0.96	43	320

Depth (cm)	Soluble Anions m.e./litre CO_3	HCO_3	Cl	SO_4	Soluble Cations m.e./litre Na	K	Ca	Mg
	1.4	5.2	3.5	4	9.5	0.2	1.5	0.5
	0.8	4.7	2.0	TRACE	6.0	0.2	1.0	2.0
	0.8	5.5	20.0	3.5	50.0	0.5	6.0	1.5

Depth (cm)	Exchangeable Cations m.e.% per 100 gm soil. Na	K	Ca	Mg	Sol+Exch Na	E.S.P.	Exchange Capacity Meq/100g. soil
	11.6	1.6	19	17	12.0	26	44
	21.0	2.0	16	14	22.4	42	50
	14.0	2.5	22	13	16.0	26	53

LABORATORY ANALYSIS PIT - 4374

Depth (cm)	Soil particles %					pH	
	Coarse sand 2.0- 0.2 mm.	Fine sand 0.2- 0.02 mm.	Silt 0.02- 0.002 mm.	Clay under 0.002 mm.	Incorp. Carbonate	Soil Paste	1 : 5 suspension
0-36	23	16	16	45	3.4	8.13	8.52
36-143	20	12	13	55	3.65	8.22	8.85
143-280	20	12	15	53	3.8	7.9	8.39

Sat. %	E.C. mmhos cm Sat. Ext	Total Nitrogen %	Total Org. Carbon %	Total Extractable Phosphorus Mg\100g. soil	Potassium Mg\100g. soil
62	0.7	0.053	0.84	28	230
66	0.55	0.032	0.78	13	280
68	4.0	0.039	0.96	43	320

Depth (cm)	Soluble Anions m. e.\litre				Soluble Cations m. e.\litre		
	CO_3	HCO_3	Cl	SO_4	Na	K	Ca	Mg
	1.4	5.2	3.5	4	9.5	0.2	1.5	0.5
	0.8	4.7	2.0	TRACE	6.0	0.2	1.0	2.0
	0.8	5.5	20.0	3.5	50.0	0.5	6.0	1.5

Depth (cm)	Exchangeable Cations m. e. % per 100 gm soil.				Sol+Exch	E. S. P.	Exchange Capacity Meq\100g. soil
	Na	K	Ca	Mg	Na		
	11.6	1.6	19	17	12.0	26	44
	21.0	2.0	16	14	22.4	42	50
	14.0	2.5	22	13	16.0	26	53

APPENDIX 3

LABORATORY ANALYSES OF SOIL SAMPLES

Table 3.1 Laboratory Analyses of Profiles Representative of Mapping Units

Table 3.2 Routine Analyses from Auger Borings

Table 3.1 Laboratory Analyses of Profiles Representative of Mapping Units.

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	Clay				
						CS 2.0-0.2 mm	FS 0.2-0.02 mm	0.02-0.002 mm	0.002 mm				
1494	0-30	8.72	7.81	0.30	56	14	14	15	57	0.21	6.6	53	11
	30-105	8.88	7.85	1.40	61	14	13	13	60	1.00	17.0	56	28
	105-150	9.41	8.28	1.50	65	19	15	9	57	0.98	14.6	56	25
	150-200	8.70	7.80	2.60	72	17	17	11	55	2.30	10.5	55	19
1510	0-57	9.21	7.96	0.38	76	6	8	14	72	0.48	18.5	71	25
	57-122	8.52	7.72	3.20	66	8	11	14	67	2.90	17.5	66	26
	122-177	8.28	7.70	2.70	83	8	9	16	67	2.80	14.0	68	20
	177-200	8.36	7.57	2.70	57	28	16	11	45	1.64	5.6	40	12
1520	0-40	8.65	7.79	1.20	69	6	13	11	70	1.04	11.0	70	15
	40-120	8.60	7.85	1.80	73	8	13	12	67	1.60	11.2	66	16
	120-165	8.38	7.69	3.40	71	10	14	14	62	3.20	16.2	61	26
	165-200	8.91	7.93	1.80	75	9	7	24	60	1.70	18.5	59	30
1530	0-35	8.22	7.66	3.60	75	20	12	11	57	3.00	14.6	59	24
	35-130	8.80	7.91	2.80	73	8	11	11	70	2.90	23.1	70	33
	130-160	8.61	8.40	1.25	69	13	21	11	55	1.12	19.7	56	35
	160-200	8.55	7.62	2.70	86	9	8	16	67	2.70	12.5	66	19
1533	0-80	9.08	8.13	0.48	72	8	6	9	77	0.36	16.0	74	21
	80-150	8.82	7.85	2.10	69	15	17	11	57	1.70	15.1	57.5	26
	150-200	8.73	7.85	3.80	76	16	13	11	60	3.60	19.6	59	33
2753	0-40	8.70	7.71	1.40	75	10	11	12	67	1.30	15.5	69	22
	40-130	8.67	7.78	3.40	64	12	17	19	52	2.90	16.7	52.5	32
	130-180	8.49	7.77	2.40	80	7	4	27	62	2.50	15.1	65	23
	180-200	8.33	7.65	2.10	69	6	15	17	62	1.90	18.5	64	29

Table 3.1 Laboratory Analyses of Drilling Fluids Representative of Mapping Units.

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							
						CS 2.0-0.2 mm	FS 0.2-0.02 mm	Silt 0.02-0.002 mm	Clay 0.002 mm				
2771	0-45	9.02	8.22	1.80	68	15	9	14	62	1.54	21.4	60	34
	45-80	8.95	7.99	2.20	66	11	20	16	53	1.80	13.6	53	25
	80-200	8.51	7.71	2.90	63	18	1	14	67	2.40	17.2	64	26
2794	0-55	8.63	7.75	1.60	77	7	7	14	72	1.44	13.0	71	18
	55-130	8.88	7.88	1.20	90	9	5	14	72	1.40	22.6	70	32
	130-185	8.73	7.88	2.30	74	7	4	12	77	2.20	24.2	75	32
	185-200	8.21	7.55	3.30	66	16	15	12	57	2.60	13.8	60	23
2795	0-45	8.82	7.87	0.48	77	9	7	15	69	0.38	14.8	69	21
	45-150	9.15	8.02	1.10	73	12	12	14	62	1.00	17.4	64	27
	150-200	8.89	7.90	1.35	93	3	13	12	72	1.50	18.5	72.5	25
3668	0-77	8.29	7.66	6.00	64	17	24	10	49	4.80	16.0	50	32
	77-160	8.38	7.77	0.65	45	30	53	3	14	0.22	1.4	14	10
	160-200	8.72	7.82	3.30	73	14	17	17	52	3.10	12.9	52.5	24
3682	0-70	9.02	7.92	0.88	65	12	4	10	74	0.73	18.5	72	26
	70-200	8.43	7.90	1.95	83	5	11	17	67	2.10	16.7	72	23
3683	0-40	8.48	7.87	0.62	72	13	8	17	62	0.54	8.7	61	14
	40-100	8.35	7.70	2.50	72	15	11	10	64	2.30	6.5	66	9
	100-160	8.28	7.63	1.35	44	29	27	10	34	0.66	1.7	33	5
	160-200	8.51	7.83	3.10	87	9	12	10	69	3.50	14.1	70	20
3685	0-44	9.22	8.26	1.08	59	15	18	5	62	0.66	20.1	62.5	35
	44-90	8.90	8.09	3.60	78	9	22	10	59	4.0	24.8	61	40
	90-180	8.91	7.0	1.85	49	19	42	12	27	1.20	8.0	26	30
	180-200	8.11	7.68	3.00	72	12	14	15	59	2.70	13.3	60	22

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							
						CS 2.0-0.2 mm	FS 0.2-0.02 mm	Silt 0.02-0.002 mm	Clay 0.002 mm				
3686	0-50	9.29	8.28	0.94	62	14	7	15	64	0.78	20.0	64	31
	50-300	9.21	8.41	0.60	106	6	7	15	72	1.20	30.0	71	41
3688	0-50	8.65	7.83	1.20	61	8	10	15	67	1.04	14.16	67	23
	50-95	8.71	7.73	2.40	61	13	20	15	52	1.84	9.8	54	18
	95-135	8.50	7.92	4.50	70	16	22	8	54	3.70	6.7	55	12
	135-200	8.93	8.02	1.55	75	6	17	13	64	1.40	11.8	63	18
4653	0-35	9.03	8.12	0.60	59	17	24	13	46	0.44	9.5	47	> 20
	35-100	8.77	7.90	2.30	69	16	16	15	53	2.10	11.0	53	21
	100-200	9.10	8.21	1.15	47	28	41	13	18	0.64	6.1	20	33
5791	0-38	8.42	7.71	2.30	66	16	23	18	43	1.60	8.0	45	21
	38-120	8.82	7.98	0.60	71	7	15	17	61	0.44	12.4	60	20
	120-175	8.82	8.00	0.60	60	23	14	20	43	0.38	7.6	43	16
	175-200	8.72	7.90	2.40	74	11	13	23	53	2.20	10.6	52.5	24
5801	0-37	7.98	7.62	0.50	74	2	25	17	56	0.37	2.8	55	5
	37-91												
	91-153	8.52	7.73	1.10	81	6	16	20	58	1.05	10.1	59	17
	153-200	8.55	7.88	0.65	52	5	32	37	26	0.40	4.4	26	18
5812	0-35	8.90	8.67	0.55	73	6	13	25	56	0.60	21.0	55	38
	35-75	8.78	7.90	2.60	62	20	12	20	48	2.10	16.3	50	32
	75-125	8.16	7.72	2.90	80	6	13	20	61	2.90	17.1	60	28
	125-200	8.70	7.91	3.40	66	8	11	23	58	3.00	20.2	62.5	33

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							
						CS 2.0-0.2 mm	FS 0.2-0.02 mm	Silt 0.02-0.002 mm	Clay 0.002 mm				
5824	0-67	8.69	8.00	0.58	74	10	6	18	66	0.56	14.6	67.5	21
	67-110	8.58	7.69	3.00	68	17	14	16	53	2.30	13.3	51	26
	110-142	8.60	7.88	0.78	70	3	16	23	58	0.70	9.7	59	16
	142-200	9.00	8.11	0.92	70	9	5	25	61	0.88	17.5	62.5	28
5836	0-19	8.48	7.78	0.77	72	7	7	13	73	0.63	11.4	71	16
	19-120	8.49	7.62	1.10	62	20	9	18	53	0.78	7.2	51	14
	120-153	8.20	7.60	3.60	58	29	15	13	43	2.30	8.1	40	20
	153-240	8.55	7.90	2.20	68	12	29	6	53	1.95	12.0	52.5	23
5848	0-67	8.33	7.72	0.40	74	5	4	20	71	0.37	8.8	70	12
	67-126	8.50	7.83	2.95	68	8	18	18	56	2.70	14.1	55	25
	126-200	9.12	8.22	2.50	74	7	12	20	61	2.40	24.0	60	40
6379	0-20	8.82	8.02	0.68	68	11	5	21	63	0.60	14.6	61	23
	20-60	8.97	8.10	0.96	58	14	15	15	56	0.73	20.9	54	38
	60-100	8.33	7.88	5.50	79	10	14	18	58	6.90	24.3	60	40
	100-200	8.10	7.71	4.50	63	19	22	16	43	3.50	12.5	45	27
6390	0-25	8.35	7.65	2.10	68	12	14	16	58	1.60	8.0	60	13
	25-60	8.20	7.14	1.90	77	9	15	18	58	1.90	11.7	57.5	20
	60-140	8.38	7.49	0.95	75	9	12	16	63	0.90	9.1	61	15
	140-200	8.82	7.86	0.85	73	11	10	16	63	0.74	12.1	62.5	19
6408	0-55	8.79	7.86	1.50	70	9	10	15	66	1.40	15.0	64	23
	55-100	8.61	7.86	0.58	58	18	18	13	51	0.44	4.4	50	8
	100-160	8.72	7.82	2.30	65	16	10	23	51	2.10	9.1	51	18
	160-200	8.25	7.66	2.20	67	10	16	16	58	1.90	8.9	61	14

Table 3.2 Routine Analyses from Auger Borings

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.							
1474	0-45	26	15	59	0.40	41	0.10	2.3	4	A13	2
	45-90	29	14	57	1.50	51	0.76	7.6	13		
1475	0-45	39	15	46	0.18	45	0.11	0.3	1	A13	31
	45-90	41	10	49	0.24	48	0.10	0.7	1		
	90-150				0.63						
1476	0-45	29	15	56	0.20	51	0.10	0.3	-	A13	2
	45-90	26	13	61	0.30	51	0.13	2.7	4		
1477	0-45	26	13	61	0.30	48	0.12	1.9	3	A13	2
	45-90	26	15	59	0.48	53	0.19	8.2	14		
1478	0-45	24	12	64	0.28	59	0.15	3.0	< 5	A13	2
	45-90	24	15	61	0.46	47	0.12	7.1	12		
1479	0-45	26	15	59	0.34	53	0.20	4.2	7	A13	3a
	45-90	26	13	61	1.04	59	0.60	9.8	16		
	90-150				2.10						
1480	0-45	19	17	64	0.32	53	0.20	5.0	8	A13	2
	45-90	19	15	66	0.76	60	0.52	8.3	13		
1481	0-45	19	15	66	0.34	63	0.25	3.3	> 5	A13	3a
	45-90	16	18	66	1.50	55	0.51	14.7	22		
1482	0-45	31	13	56	0.22	53	0.10	1.1	2	A13	2
	45-90	26	15	59	0.65	52	0.33	5.3	9		
1483	0-45	24	17	59	0.30	50	0.13	2.7	< 5	A13	2
	45-90	21	15	64	0.80	52	0.40	8.4	13		
	90-150				2.20						
1484	0-45	34	10	56	0.14	52	0.10	0.3	1	A13	2
	45-90	29	10	61	0.24	69	0.17	1.0	2		
1485	0-45	21	15	64	0.34	50	0.13	4.3	7	A13	3a
	45-90	21	15	64	0.56	47	0.12	10.3	16		
1486	0-45	24	15	61	0.40	54	0.14	9.1	< 15	A13	3a
	45-90	24	12	64	0.62	41	0.26	13.3	21		
1487	0-45	26	10	64	0.34	51	0.19	5.8	9	A13	3a
	45-90	19	15	66	1.12	53	0.73	13.3	> 20		
	90-150				2.20						
1488	0-45	19	15	66	0.30	61	0.23	5.0	8	A13	3a
	45-90	19	15	66	1.32	51	0.39	11.2	17		
1489	0-45	19	15	66	0.38	59	0.15	5.8	9	A13	2
	45-90	21	13	66	0.75	63	0.48	6.7	> 10		
1490	0-45	21	15	64	0.32	57	0.14	3.1	< 5	A13	2
	45-90	19	10	71	1.0	60	0.60	10.6	< 15		
1491	0-45	34	12	54	0.75	55	0.42	6.8	13	A13	2
	45-90	31	13	56	1.40	55	0.84	8.0	14		
	90-150				3.20						
1492	0-45	24	15	61	0.40	57	0.15	6.6	11	A13	3a
	45-90	24	15	61	1.30	57	0.58	13.4	22		

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.							
1493	0-45	24	15	61	0.58	63	0.32	9.3	> 15	A14	4a
	45-90	19	15	66	2.70	55	1.95	16.4	< 25		
1494	0-45	22	13	65	0.26	53	0.13	4.7	7	A13	2
	45-90	22	13	65	0.56	51	0.26	9.3	14		
1495	0-45	17	13	70	0.44	65	0.16	9.4	13	A23	2
	45-90	19	16	65	0.52	59	0.22	9.0	14		
	90-150				0.66						
1496	0-45	14	16	70	0.59	67	0.33	9.7	14	A23	6a(2)
	45-90	14	14	72	2.40	73	1.94	18.5	26		
1497	0-45	14	16	70	0.52	68	0.35	10.4	< 15	A13	3a
	45-90	14	16	70	1.70	74	1.30	13.9	< 20		
1498	0-45	22	13	65	0.68	63	0.48	13.1	> 20	B24	6a
	45-90	17	16	67	2.55	67	1.74	19.9	< 30		
1499	0-45	12	18	70	0.68	63	0.32	11.7	17	B24	6a(4a)
	45-90	12	16	72	2.60	66	1.82	19.8	28		
	90-150				1.90						
1500	0-45	22	13	65	1.30	69	0.86	13.1	> 20	B24	6a
	45-90	42	18	40	4.30	61	2.70	8.9	22		
1501	0-45	22	16	62	0.90	57	0.42	12.4	> 20	B24	4a
	45-90	17	16	67	3.60	71	3.30	16.7	< 25		
1502	0-45	14	14	72	0.26	67	0.17	13.4	19	B14	4a
	45-90	19	14	67	2.20	66	1.70	14.7	22		
1503	0-45	19	24	57	0.26	64	0.16	12.2	22	B14	6a
	45-90	17	16	67	1.60	71	1.15	8.0	12		
	90-150				1.95						
1504	0-45	12	16	72	0.32	73	0.18	9.0	13	B13	2
	45-90	22	16	62	2.60	72	2.0	8.4	14		
1505	0-45	12	16	72	0.60	60	0.30	10.5	< 15	B13	6a(2)
	45-90	19	16	65	2.60	65	1.80	17.0	26		
1506	0-45	14	16	70	0.48	64	0.32	7.3	> 10	A13	2
	45-90	17	18	65	1.0	69	0.87	8.7	13		
1507	0-45	12	16	72	0.48	69	0.18	11.0	> 15	A14	4a
	45-90	12	13	75	1.60	65	1.0	15.8	21		
	90-150				2.70						
1508	0-45	14	11	75	0.55	69	0.35	13.6	18	A14	4a
	45-90	9	16	75	2.20	66	1.70	16.3	22		
1509	0-45	12	18	70	0.42	70	0.26	12.1	17	A14	4a
	45-90	14	16	70	1.05	71	0.80	11.2	16		
1510	0-45	14	16	70	0.44	62	0.16	15.0	21	A14	6a
	45-90	14	16	70	0.75	63	0.47	20.7	< 30		
1511	0-45	22	16	62	1.00	60	0.44	18.0	29	B14	6a
	45-90	27	13	60	2.50	63	1.80	10.2	17		
	90-150				2.20						

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.							
1512	0-45	12	18	70	0.32	64	0.16	7.8	11	B13	3a
	45-90	14	16	70	0.80	65	0.32	13.7	< 20		
1513	0-45	12	13	75	0.38	77	0.10	7.1	9	B23	2
	45-90	7	13	80	0.68	66	0.34	11.3	14		
1514	0-45	14	19	67	0.34	67	0.17	7.0	< 10	A13	2
	45-90	12	16	72	0.42	67	0.25	8.5	12		
1515	0-45	12	18	70	0.35	68	0.17	9.8	14	A13	3a
	45-90	17	16	67	1.40	62	0.77	13.6	> 20		
	90-150				1.40						
1516	0-45	17	13	70	0.56	63	0.32	12.5	18	B24	6a(4a)
	45-90	24	16	60	1.90	63	0.94	19.9	33		
1517	0-45	14	16	70	0.48	67	0.34	12.1	17	A14	4a
	45-90	12	18	70	0.96	61	0.46	15.9	23		
1518	0-45	17	16	67	1.40	60	0.76	18.8	28	A14	6a
	45-90	17	18	65	1.90	63	1.28	17.9	28		
1519	0-45	19	16	65	0.44	68	0.34	9.3	14	A13	6a(2)
	45-90	37	16	47	2.10	56	1.40	17.8	38		
	90-150				1.50						
1520	0-45	12	16	72	0.48	70	0.26	7.7	11	A11	2
	45-90	17	13	70	0.65	68	0.34	6.9	> 10		
1521	0-45	14	16	70	0.68	63	0.48	13.5	19	B24	6a(4a)
	45-90	12	13	75	1.00	68	0.34	19.3	26		
1522	0-45	22	13	65	5.20	72	4.70	30.9	47	A14	6a
	45-90	34	14	52	2.40	75	2.10	12.3	24		
1523	0-45	22	13	65	1.70	67	1.40	13.8	21	A14	6a
	45-90	17	13	70	1.50	64	0.97	16.6	24		
	90-150				0.84						
1524	0-45	22	13	65	1.90	72	1.60	16.8	26	A14	6a
	45-90	22	16	62	1.90	70	1.40	9.8	16		
1525	0-45	24	11	65	0.48	54	0.21	11.4	17	B14	4a
	45-90	12	18	70	2.80	81	2.40	10.4	< 15		
1526	0-45	14	16	70	0.40	67	0.25	11.7	17	A14	4a
	45-90	12	16	72	0.65	56	0.28	13.3	19		
1527	0-45	12	13	75	0.64	62	0.32	16.5	22	A14	6a
	45-90	12	16	72	1.90	60	1.20	21.6	30		
	90-150				2.10						
1528	0-45	12	13	75	0.40	68	0.18	15.0	20	A14	6a
	45-90	8	18	74	2.20	64	1.50	24.1	32		
1529	0-45	22	16	62	2.50	65	1.90	12.9	21	A14	6a
	45-90	29	14	57	2.40	67	1.90	10.9	19		

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.							
1530	0-45	14	16	70	0.40	69	0.18	9.4	13	A11	3a
	45-90	29	14	57	2.50	62	1.90	10.9	19		
1531	0-45	14	16	70	0.52	61	0.16	14.2	< 20	B14	6a
	45-90	19	16	65	1.70	72	1.26	15.9	< 25		
	90-150				2.30						
1532	0-45	12	16	72	1.90	69	1.40	13.0	18	A12	6a(4a)
	45-90	9	16	75	1.38	73	0.92	19.1	> 25		
1533	0-45	14	14	72	0.49	62	0.24	11.8	17	B14	4a
	45-90	24	16	60	1.80	78	1.50	10.5	17		
2726	0-45	26	16	58	0.76	61	0.46	14.3	< 25	A22	6a
	45-90	19	16	65	1.60	73	1.30	12.7	< 20		
	90-150				0.90						
2727	0-45	29	13	58	2.40	56	1.60	13.6	23	B24	6a
	45-90	26	14	60	2.10	64	1.60	13.6	23		
2728	0-45	21	16	63	1.70	61	1.20	18.8	< 30	B24	6a
	45-90	16	16	68	2.10	74	1.90	27.7	41		
2729	0-45	19	18	63	1.0	60	0.60	21.0	33	B22	6a
	45-90	16	16	68	2.40	62	1.70	19.9	29		
2730	0-45	24	16	60	2.30	62	1.60	14.4	24	B14	6a
	45-90	24	16	60	5.30	64	4.0	10.8	18		
2731	0-45	16	21	63	0.48	57	0.28	18.1	29	B14	6a
	45-90	26	11	63	5.20	63	4.30	29.3	46		
	90-150				0.98						
2732	0-45	24	13	63	0.92	59	0.58	21.8	< 35	B24	6a
	45-90	21	16	63	1.50	57	0.87	23.1	37		
2733	0-45	19	16	65	1.30	66	1.0	11.4	18	A24	4a
	45-90	16	16	68	1.32	68	0.93	12.7	19		
2734	0-45	24	13	63	4.20	60	3.0	21.0	33	A24	6a
	45-90	59	8	33	4.50	65	3.5	9.7	29		
2735	0-45	27	15	58	0.46	66	0.33	9.3	16	B22	6a(4a)
	45-90	22	13	65	5.40	62	3.80	17.8	27		
	90-150				0.84						
2736	0-45	30	12	58	2.60	60	1.80	12.6	22	B14	6a
	45-90	20	12	68	1.60	70	1.30	15.1	22		
2737	0-45	27	15	58	0.84	57	0.57	13.0	22	B14	6a
	45-90	22	13	65	1.60	57	0.85	14.7	23		
2738	0-45	15	10	75	0.44	68	0.3	6.9	9	B13	2
	45-90	20	10	70	1.30	68	1.0	8.6	12		
2739	0-45	22	18	60	0.55	65	0.41	10.4	17	B14	4a
	45-90	20	15	65	1.50	70	1.24	14.0	22		
	90-150				0.60						

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.							
2740	0-45	20	12	68	1.16	59	0.60	17.8	26	B23	6a
	45-90	20	12	68	0.55	64	0.32	9.3	14		
2741	0-45	17	13	70	0.48	63	0.24	11.0	16	B14	4a
	45-90	35	10	55	1.60	59	0.96	12.6	23		
2742	0-45	22	15	63	3.0	67	2.20	11.4	18	B24	6a(4a)
	45-90	30	12	58	2.40	58	1.60	18.4	32		
2743	0-45	12	15	73	0.64	69	0.52	14.3	< 20	A24	4a
	45-90	15	10	75	2.20	56	1.26	17.5	23		
	90-150				3.20						
2744	0-45	32	13	55	1.0	57	0.56	7.4	13	A23	3a
	45-90	32	10	58	1.30	60	0.90	11.1	19		
2745	0-45	15	10	75	0.48	61	0.31	14.9	< 20	A24	6a(4a)
	45-90	25	15	60	1.40	62	1.0	15.0	25		
2746	0-45	10	12	78	0.42	64	0.32	11.7	< 15	B23	3a
	45-90	20	12	68	0.96	68	0.68	12.9	19		
2747	0-45	17	13	70	0.75	60	0.45	11.1	16	A14	4a
	45-90	27	5	68	1.30	68	1.00	11.8	17		
	90-150				2.62						
2748	0-45	12	13	75	0.38	68	0.26	9.3	12	A13	3a
	45-90	17	8	75	1.30	61	0.75	16.8	22		
2749	0-45	20	15	65	1.40	62	1.10	14.1	22	B14	6a
	45-90	22	15	63	1.90	64	1.50	12.9	21		
2750	0-45	32	15	53	0.75	63	0.63	9.4	18	B14	4a
	45-90	35	12	53	5.20	63	3.60	9.2	17		
2751	0-45	22	10	68	0.44	66	0.4	9.2	14	A13	3a
	45-90	20	12	68	1.50	58	0.9	10.7	16		
	90-150				1.06						
2752	0-45	17	18	65	0.38	53	0.26	14.1	22	A14	6a
	45-90	17	13	70	2.10	65	1.60	18.0	26		
2753	0-45	40	10	50	0.55	65	0.49	5.9	12	B23	6a(2)
	45-90	27	10	63	1.80	68	1.40	16.6	26		
2754	0-45	25	7	68	0.80	70	0.70	10.5	> 15	A12	4a
	45-90	17	15	68	1.44	65	1.64	15.2	22		
2755	0-45	25	12	63	0.75	65	0.57	9.8	16	A14	6a(4a)
	45-90	20	50	30	4.0	76	3.40	19.0	63		
	90-150				1.00						
2756	0-45	22	48	30	0.44	63	0.61	10.2	34	A14	6a1
	45-90	30	10	60	0.55	70	0.53	3.5	6		
2757	0-45	25	7	68	0.54	61	0.69	12.5	18	B24	6a(4a)
	45-90	10	25	65	4.0	81	4.10	18.3	28		
2758	0-45	15	15	70	0.60	69	0.52	7.5	11	A21	2
	45-90	25	10	65	0.50	62	0.4	6.8	10		

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.							
2759	0-45	25	15	60	0.52	55	0.28	5.3	9	B21	3a
	45-90	30	10	60	1.30	62	0.93	9.5	16		
	90-150				0.52						
2760	0-45	30	2	68	0.40	67	0.34	8.5	13	B21	3a
	45-90	17	15	68	0.96	61	0.78	10.4	> 15		
2761	0-45	42	15	43	1.60	63	1.20	14.0	33	C24	6a1
	45-90	62	5	33	1.10	57	0.71	14.9	45		
	150-200	69	19	12							
2762	0-45	27	8	65	1.30	73	1.10	8.5	13	A11	3a
	45-90	32	3	65	1.10	65	0.81	12.0	19		
	150-200	44	37	19							
2763	0-45	47	13	40	0.50	53	0.26	6.1	> 15	C22	3a1
	45-90	42	13	45	0.80	53	0.52	9.1	> 20		
	90-150				6.40						
2764	0-45	57	10	33	0.65	43	0.33	6.5	< 20	C22	6a1
	45-90	40	17	43	0.85	59	0.59	11.0	26		
		52	flocculated								
2765	0-45	45	2	53	0.75	59	0.44	7.6	14	B21	3a
	45-90	47	5	48	0.54	50	0.39	9.6	20		
2766	0-45	45	7	48	0.55	56	0.42	2.0	4	A21	3a1
	45-90	57	3	40	0.65	49	0.37	9.2	23		
	150-200	74	17	9							
2767	0-45	45	2	53	1.70	62	1.40	11.4	22	A12	6a
	45-90	35	10	55	2.40	72	2.40	21.6	39		
	90-150				1.80						
	150-200	77	11	12							
2768	0-45	40	2	58	1.40	66	1.30	10.7	18	A11	4a
	45-90	45	2	53	1.10	60	0.90	9.5	18		
2769	0-45	57	8	35	0.38	40	0.20	0.2	1	C21	3l
	45-90	62	5	33	0.48	40	0.20	1.4	4		
2770	0-45	25	8	67	1.80	71	1.20	13.2	< 20	A14	4a
	45-90	25	13	62	1.20	60	0.82	10.8	17		
2771	0-45	35	5	60	1.62	52	1.17	17.2	29	A24	6a
	45-90	37	3	60	0.70	69	0.51	3.1	> 5		
	90-150				1.00						
2772	0-45	22	13	65	0.40	47	0.24	4.2	6	B11	3a
	45-90	32	8	60	0.72	59	0.44	10.4	17		
	150-200	34	27	39							
2773	0-45	40	10	50	0.44	59	0.29	8.5	17	A12	6a(4a)
	45-90	27	8	65	3.60	55	2.50	17.1	26		
	150-200										

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.							
2774	0-45	40	5	55	0.55	66	0.50	5.5	10	A11	2
	45-90	30	5	65	0.92	68	0.68	6.5	10		
	150-200	47	34	19							
2775	0-45	30	5	65	0.28	72	0.27	4.9	8	A11	2
	45-90	15	13	72	0.64	61	0.46	9.5	13		
	90-150				0.72						
2776	0-45	12	11	77	0.40	66	0.34	9.7	13	B13	3a
	45-90	15	13	72	0.40	61	0.32	10.9	> 15		
2777	0-45	22	23	55	0.52	78	0.49	5.9	11	A11	6a(2)
	45-90	22	13	65	2.20	62	1.54	20.1	31		
2778	0-45	13	23	64	2.20	73	2.20	19.0	< 30		6a
	45-90	58	6	36	2.0	56	2.00	7.6	21		
	90-150				2.30						
2779	0-45	15	21	64	0.34	67	0.34	16.1	> 25		6a
	45-90	33	13	54	0.78	62	0.78	12.8	24		6as
2780	0-45	18	13	69	10.0	60	10.00	6.0	9		6as
	45-90	20	19	61	2.60	79	2.60	15.4	> 25		
2781	0-45	13	13	74	0.72	72	0.72	24.1	33		6a
	45-90	15	16	69	1.85	83	1.85	21.3	31		
	90-150				3.44						
2782	0-45	43	13	44	4.30	65	4.30	14.1	32		6a1
	45-90	35	14	51	1.80	66	1.80	13.4	26		
2783	0-45	23	16	61	0.7	70	0.52	12.3	> 20		6a
	45-90	30	14	56	2.8	67	2.50	20.3	36		
	90-150				1.90						
2784	0-45	43	13	44	7.0	52	4.90	19.1	43		6as
	45-90	25	16	59	2.4	69	2.30	21.7	37		
	90-150				2.20						
2785	0-45	45	11	44	1.5	59	1.02	8.58	19		6a(4a)
	45-90	45	14	41	3.6	60	2.70	14.9	36		
2786	0-45	5	14	81	0.44	55	0.14	3.1	4		3a
	45-90	23	16	61	2.0	77	1.9	15.3	25		
2787	0-45	10	14	76	0.6	77	0.48	5.1	7		3a
	45-90	30	14	56	3.4	66	2.80	10.8	19		
	90-150				0.56						
	155-200	32	21	47							
2788	0-45	38	16	46	6.5	63	5.10	19.7	43		6as
	45-90	30	16	54	4.0	67	3.40	17.4	32		
	90-150				1.50						
2789	0-45	40	16	44	2.2	64	1.90	20.5	47		6a1
	45-90	43	13	44	6.0	62	4.80	18.4	42		

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.							
2790	0-45	35	16	49	2.4	62	2.0	20.4	42		6al
	45-90	35	14	51	2.0	62	1.60	19.2	38		
2791	0-45	35	16	49	4.5	55	3.0	14.6	30		6as
	45-90	45	14	41	8.0	57	5.70	19.9	49		
	90-150				2.20						
2792	0-45	35	14	51	3.7	65	2.90	10.7	21		6a
	45-90	43	8	49	2.0	71	1.80	11.8	24		
	90-150				1.60						
2793	0-45	28	16	56	0.46	73	0.37	3.6	6		6a(2)
	45-90	40	14	46	7.0	59	5.0	19.0	41		
	150-200	42	46	12							
2794	0-45	15	14	71	0.52	63	0.32	14.1	< 20	A14	6a(4a)
	45-90	25	14	61	4.50	65	3.60	18.4	30		
2795	0-45	15	14	71	0.46	83	0.41	12.0	17	A14	6a(4a)
	45-90	35	19	46	1.20	66	1.09	13.3	29		
	90-150				1.60						
3662	0-45	24	13	63	0.58	52	0.22	6.39	10	A13	2
	45-90	20	15	65	2.20	58	1.39	6.27	10		
3663	0-45	21	14	65	0.50	51	0.28	4.06	6	A11	2
	45-90	21	14	65	1.60	53	0.92	5.00	8		
3664	0-45	39	13	48	0.39	50	0.21	2.23	5	A11	3l
	45-90	44	13	43	0.94	52	0.81	3.19	7		
3665	0-45	24	16	60	0.38	54	0.28	1.98	3	A11	2
	45-90	24	16	60	0.70	56	0.58	3.25	5		
3666	0-45	21	14	65	1.05	54	0.58	3.95	6	A11	2
	45-90	21	14	65	3.20	58	2.08	4.71	7		
3667	0-45	21	16	63	0.54	53	0.55	3.79	6	A13	2
	45-90	24	13	63	3.00	59	1.98	5.16	8		
3668	0-45	20	14	66	1.20	73	0.73	4.9	7	B11	2
	45-90	27	14	59	1.30	64	0.96	7.0	12		
3669	0-45	37	14	49	0.32	64	0.16	0.2	-	B13	3al
	45-90	17	19	64	0.96	75	0.94	10.7	17		
	90-150				0.70						
3670	0-45	22	4	74	1.80	78	1.60	13.2	18	A12	4a
	45-90	45	11	44	0.30	63	0.20	7.8	18		
	90-150				1.15						
3671	0-45	37	17	46	0.75	54	0.48	8.3	18	A12	4al
	45-90	12	20	68	0.50	36	0.18	0.6	1		
3672	0-45	12	24	64	0.20	65	0.16	1.0	1	A11	6a(2)
	45-90	22	12	66	1.50	74	1.30	23.9	36		

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.							
3673	0-45	15	16	69	0.32	63	0.16	2.2	3	A11	2
	45-90	12	19	69	0.55	77	0.48	6.3	9		
	90-150				1.15						
3674	0-45	30	16	54	0.34	65	0.25	0.5	1	A11	3a
	45-90	27	14	59	0.48	55	0.28	13.3	23		
3675	0-45	22	14	64	0.30	68	0.17	3.0	< 5	A11	3a
	45-90	25	16	59	0.76	63	0.47	9.5	16		
	90-150				0.83						
3676	0-45	12	14	74	0.60	65	0.34	13.7	18	A12	4a
	45-90	15	11	74	1.10	66	0.66	15.3	21		
3677	0-45	15	16	69	0.98	67	0.68	13.7	< 20	A12	4a
	45-90	35	11	54	1.10	59	0.70	12.5	23		
	90-150				0.90						
3678	0-45	10	16	74	0.49	69	0.44	3.6	< 5	A11	2
	45-90	17	14	69	0.44	68	0.34	3.3	< 5		
3679	0-45	17	12	71	0.44	69	0.26	4.1	6	B13	2
	45-90	20	14	66	0.56	70	0.36	8.4	13		
	90-150				0.70						
3680	0-45	24	12	64	1.4	67	1.17	11.6	18	A12	4a
	45-90	18	16	66	2.4	75	2.40	15.2	23		
3681	0-45	23	11	66	1.2	72	0.98	9.0	14	A11	3a
	45-90	25	12	63	3.2	70	2.80	10.8	17		
	90-150				1.60						
3682	0-45	23	16	61	1.6	66	1.34	13.1	21	A24	6a
	45-90	30	9	61	1.5	66	1.15	8.8	14		
3683	0-45	15	14	71	0.6	65	0.49	9.9	14	A11	3a
	45-90	28	14	58	3.5	68	2.90	13.1	23		
	90-150				2.60						
3684	0-45	24	12	64	0.50	73	0.40	11.8	18	A12	4a
	45-90	16	15	69	1.30	54	0.90	13.5	< 20		
3685	0-45	28	9	63	1.5	70	1.20	14.0	22	B24	6a
	45-90	35	12	53	2.2	68	2.0	14.0	26		
	90-150				0.57						
3686	0-45	35	12	53	1.3	100	1.80	13.0	< 25	B24	6a
	45-90	18	19	63	2.6	54	1.90	13.3	21		
3687	0-45	20	19	61	2.0	75	1.90	8.5	14	B13	6a(2)
	45-90	17	19	64	1.7	84	1.90	18.1	28		
	90-150				1.55						
3688	0-45	17	19	64	2.6	85	2.90	18.7	29	A14	6a
	45-90	12	17	71	3.0	80	3.20	23.2	33		

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.							
4639	0-45	22	18	60	0.55	53	0.34	5.41	9	A11	2
	45-90	19	18	63	3.30	65	2.61	5.05	8		
4640	0-45	22	20	58	7.00	60	2.14	0.82	1	A13	6s
	45-90	17	18	65	8.50	55	3.62	2.30	4		
4641	0-45	19	18	63	0.4	50	0.21	4.66	7	A11	2
	45-90	22	13	65	1.6	59	1.09	5.01	8		
4642	0-45	24	13	63	0.76	47	0.49	4.04	6	A13	2
	45-90	24	13	63	2.30	55	1.37	5.77	9		
4643	0-45	29	11	60	3.60	48	1.46	4.28	7	A13	2
	45-90	27	13	60	0.56	56	0.58	7.43	12		
4644	0-45	9	17	74	0.51	73	0.37	8.8	12	B11	6a(2)
	45-90	19	15	66	1.50	62	1.10	17.3	26		
	185-200	35	33	32							
4645	0-45	47	14	39	0.65	55	0.40	6.8	17	C22	6a(4a1)
	45-90	44	15	41	1.30	56	0.84	12.8	31		
	155-200	73	15	12							
4646	0-45	22	17	61	1.2	64	0.96	7.8	13	B11	3a
	45-90	22	17	61	0.5	63	0.32	12.5	21		
4647	0-45	69	11	20	0.49	34	0.04	0.3	1	C21	4l
	45-90	43	11	35	0.6	38	0.95	0.6	2		
	90-150				2.40						
	175-200	70	18	12							
4648	0-45	39	17	44	1.2	50	0.63	10.2	23	C24	6a1
	45-90	missing									
	150-200	65	23	12							
4649	0-45	missing									
	45-90	29	17	54	0.44	64	0.32	11.7	22		
	150-200	58	25	17							
4650	0-45	34	15	51	0.46	60	0.30	4.5	9	B11	3a
	45-90	29	15	56	0.70	52	0.33	8.5	> 15		
	150-200	65	25	10							
4651	0-45	27	22	51	0.94	63	0.50	7.9	> 15	B12	4a
	45-90	34	12	54	0.73	61	0.45	9.5	18		
	150-200	63	20	17							
4652	0-45	27	14	59	0.97	59	0.59	9.0	16	B12	4a
	45-90	22	17	61	1.50	73	1.30	11.9	< 20		
	90-150				0.97						
	150-200	70	20	10							
4653	0-45	39	15	46	0.48	60	0.30	5.7	12	C23	3a1
	45-90	37	9	54	2.0	58	0.15	10.2	19		
	150-200	68	20	12							

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.							
4654	0-45	34	17	49	0.75	61	0.46	3.5	7	B21	3a1
	45-90	44	15	41	2.40	61	1.80	7.4	18		
4655	0-45	24	20	56	0.44	62	0.31	3.7	7	B13	3a
	45-90	24	15	61	0.86	54	0.54	9.5	16		
4656	0-45	14	15	71	0.55	69	0.35	7.2	> 10	A11	2
	45-90	9	15	76	2.0	61	1.40	10.6	14		
	90-150				3.00						
4657	0-45	19	22	59	0.55	62	0.31	2.9	< 5	A11	3a
	45-90	24	12	64	0.95	62	0.61	13.4	21		
	150-200	43	27	30							
4658	0-45	47	12	41	0.73	48	0.46	2.3	6	C23	3a1
	45-90	34	15	51	0.8	54	0.53	8.3	16		
	150-200	48	20	32							
4659	0-45	37	14	49	0.46	55	0.28	2.5	< 5	B13	31
	45-90	42	12	46	1.35	59	0.89	4.7	> 10		
4660	0-45	24	12	64	2.6	51	1.50	10.5	16	A14	4a
	45-90	27	5	68	0.56	65	0.41	9.2	14		
	90-150				3.30						
4661	0-45	19	13	68	1.2	61	0.91	15.9	23	B14	6a
	45-90	22	15	63	1.9	65	1.46	12.1	19		
4662	0-45	19	13	68	1.38	59	1.00	13.4	< 20	B14	4a
	45-90	22	15	63	1.80	67	1.50	14.5	23		
4663	0-45	14	18	68	0.9	63	0.80	7.2	11	B11	2
	45-90	12	17	71	1.35	70	1.05	7.3	> 10		
4664	0-45	14	18	68	0.85	70	0.59	10.6	16	B14	4a
	45-90	24	15	61	1.70	63	1.40	14.6	24		
	90-150				1.70						
5763	0-45	19	15	66	0.59	62	0.47	8.7	13	B13	3a
	45-90	19	15	66	2.60	76	2.60	11.0	17		
5764	0-45	19	17	64	0.50	67	0.50	9.9	> 15	B14	4a
	45-90	29	12	59	1.30	55	0.95	11.0	19		
5765	0-45	32	12	56	0.46	64	0.32	4.9	9	B13	3a
	45-90	34	12	54	0.36	58	0.29	10.1	19		
	90-150				0.50						
	160-200										
5766	0-45	19	15	66	0.9	60	0.75	8.8	13	B13	3a
	45-90	19	12	69	1.6	65	1.47	13.7	< 20		
5767	0-45	19	15	66	0.52	69	0.52	11.1	17	B14	4a
	45-90	24	12	64	2.80	65	2.30	12.1	19		

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.							
5768	0-45	24	17	59	0.64	59	0.58	14.6	< 25	A14	6a
	45-90	29	12	59	2.0	57	1.40	10.6	18		
5769	0-45	14	15	71	0.5	59	0.37	9.2	13	B13	3a
	45-90	38	16	46	2.0	50	1.25	11.5	< 25		
	90-150				1.66						
5770	0-45	15	16	69	0.4	63	0.32	6.5	9	B13	3a
	45-90	28	16	56	1.2	58	1.00	10.2	18		
5771	0-45	23	3	74	0.7	64	0.56	7.4	10	A13	3a
	45-90	32	12	56	1.6	54	1.10	9.3	17		
5772	0-45	22	14	64	0.34	64	0.32	4.5	7	A13	2
	45-90	30	16	54	0.50	67	0.33	6.9	13		
	100-200										
5773	0-45	9	15	76	0.45	61	0.30	8.9	12	A13	3a
	45-90	12	17	71	1.80	66	1.50	12.9	18		
	90-150				1.70						
5774	0-45	19	15	66	0.70	64	0.32	2.9	4	B11	2
	45-90	19	15	66	1.02	56	0.56	7.0	11		
5775	0-45	12	14	74	0.55	78	0.39	3.2	4	A11	2
	45-90	10	11	79	1.20	77	1.34	9.9	13		
5776	0-45	23	18	59	0.44	84	0.52	6.7	11	B13	3a
	45-90	15	14	71	1.50	82	1.63	12.0	17		
	100-200										
5777	0-45	20	16	64	0.52	81	0.81	15.6	24	B14	6a
	45-90	13	16	71	0.84	72	0.72	19.3	27		
5778	0-45	20	16	64	0.88	67	0.68	8.9	14	B13	3a
	45-90	25	16	59	1.80	77	1.80	13.0	22		
	90-150				0.54						
5779	0-45	10	14	76	0.50	82	0.62	10.6	14	B13	3a
	45-90	30	14	56	0.86	73	0.73	10.5	19		
5780	0-45	13	13	74	0.50	87	0.54	13.1	18	B14	4a
	45-90	28	13	59	0.74	71	0.71	10.5	18		
5781	0-45	8	21	71	0.50	96	0.72	9.7	14	B23	3a
	45-90	33	13	54	1.50	74	1.30	9.5	18		
5782	0-45	23	21	56	0.36	73	0.28	2.9	> 5	A21	2
	45-90	24	17	59	0.43	67	0.34	6.9	12		
	90-200	69	12	19							
5783	0-45	49	12	39	0.72	52	0.52	8.7	22	C22	6a1
	45-90	42	19	39	0.76	56	0.42	14.0	36		
	90-150				0.48						
5784	0-45	22	19	59	0.46	72	0.39	6.8	12	B13	2
	45-90	49	12	39	0.90	51	0.51	5.1	13		
	130-200	69	10	21							

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.							
5785	0-45	12	19	69	0.56	70	0.36	7.2	> 10	A13	2
	45-90	7	19	74	0.60	80	0.70	10.5	14		
	110-200	44	15	41							
5786	0-45	17	19	64	0.39	86	0.43	6.8	11	B11	3a
	45-90	29	12	59	0.85	69	0.69	10.1	17		
5787	0-45	9	20	71	0.41	76	0.38	6.8	< 10	B11	2
	45-90	38	8	54	0.42	62	0.23	4.2	8		
	90-150				0.37						
5788	0-45	7	12	81	0.42	80	0.30	6.1	8	B13	3a
	45-90	17	14	69	0.95	82	0.93	11.9	17		
5789	0-45	14	17	69	0.36	76	0.28	6.9	10	B13	3a
	45-90	22	12	66	1.30	69	1.04	12.96	< 20		
5790	0-45	9	12	79	0.50	72	0.45	17.1	22	B14	6a
	45-90	19	15	66	1.10	66	0.83	16.8	> 25		
5791	0-45	19	17	64	0.45	70	0.35	12.4	19	B14	6a(4a)
	45-90	19	15	66	0.74	65	0.65	18.5	28		
	90-150				0.48						
5792	0-45	22	12	66	1.10	70	1.06	14.1	21	B14	4a
	45-90	32	12	56	0.72	60	0.60	10.6	19		
5793	0-45	22	17	61	0.40	67	0.33	6.5	11	B13	2
	45-90	19	40	41	0.70	58	0.43	3.6	9		
	120-200	81	3	16							
5794	0-45	24	12	64	0.70	63	0.48	5.9	9	B13	6a(2)
	45-90	24	12	64	0.76	64	0.55	22.6	36		
	135-200	64	10	26							
5795	0-45	22	17	61	0.46	66	0.34	9.3	> 15	B12	4a
	45-90	24	12	64	0.71	71	0.53	7.9	12		
	90-150				0.62						
	135-200	69	5	26							
5796	0-45	32	17	51	0.40	63	0.16	4.6	9	B21	3a
	45-90	32	12	56	0.80	59	0.45	11.1	< 20		
	140-200	56	10	34							
5797	0-45	24	12	64	0.65	68	0.42	10.8	17	B14	6a(4a)
	45-90	42	12	46	2.20	78	3.10	26.1	57		
	135-200	46	10	44							
5798	0-45	32	12	56	4.50	79	4.70	27.3	49	B14	6a
	45-90	29	15	56	2.10	63	1.60	12.0	21		
5799	0-45	17	14	69	1.40	67	1.10	14.5	21	B12	6a
	45-90	19	15	66	1.10	79	1.00	19.8	30		
	90-150				0.80						
5800	0-45	22	22	56	1.2	70	0.87	14.3	26	A14	6a
	45-90	19	20	61	1.5	75	1.10	18.9	31		
	90-200	61	10	29							

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.							
5801	0-45	22	19	59	0.55	65	0.25	2.9	< 5	A11	6a(2)
	45-90	24	20	56	1.30	64	1.10	17.3	31		
5802	0-45	37	12	51	0.94	71	0.90	10.7	>20	B24	6a
	45-90	24	15	61	0.95	63	0.78	10.4	17		
5803	0-45	19	15	66	0.53	71	0.53	9.9	<15	B11	3a
	45-90	14	13	73	0.64	65	0.50	13.1	18		
	90-150				0.92						
5804	0-45	34	15	51	0.46	58	0.29	8.9	17	B14	6a(4a)
	45-90	27	12	61	3.80	62	2.80	16.4	27		
	105-200	74	12	14							
5805	0-45	22	15	63	0.42	50	0.25	10.5	17	B14	4a
	45-90	19	15	66	0.46	65	0.49	13.1	<20		
	120-200	66	8	26							
5806	0-45	17	15	68	0.48	65	0.33	7.7	11	B13	3a
	45-90	12	17	71	0.74	72	0.54	11.9	17		
5807	0-45	34	13	53	1.0	59	0.74	15.3	29	B14	6a
	45-90	24	13	63	2.4	63	1.88	13.3	21		
	90-150				0.72						
5808	0-45	17	15	68	0.46	62	0.31	6.9	>10	B23	2
	45-90	17	15	68	0.76	63	0.47	7.9	12		
5809	0-45	47	37	16	1.80	51	1.15	11.6	73	C22	6a1
	45-90	52	37	11	2.0	50	1.40	21.8	100		
	90-200										
5810	0-45	27	15	58	0.70	61	0.46	5.9	>10	B11	2
	45-90	22	15	63	0.75	70	0.53	7.9	13		
5811	0-45	24	18	58	0.56	53	0.26	9.7	17	B24	4a
	45-90	17	22	61	0.56	56	0.42	12.8	21		
	110-200	46	18	36							
5812	0-45	19	18	63	0.88	66	0.74	21.3	34	B14	6a
	45-90	17	17	66	2.40	70	2.30	20.9	33		
5813	0-45	18	15	67	0.55	70	0.52	9.1	14	B23	2
	45-90	28	10	62	2.10	69	1.84	5.4	9		
5814	0-45	20	16	64	0.65	65	0.49	5.9	9	B13	2
	45-90	15	16	69	0.88	71	0.72	6.5	9		
	150-200	64	20	16							
5815	0-45	30	16	54	0.44	65	0.32	4.5	8	B13	2
	45-90	28	10	62	0.90	61	0.61	8.2	13		
	90-150				0.60						
	140-200	54	27	19							
5816	0-45	15	13	72	0.50	67	0.42	3.6	5	B23	2
	45-90	23	13	64	1.40	73	1.20	4.4	7		
	145-200	29	27	44							

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.							
5817	0-45	43	13	44	0.46	67	0.42	1.2	3	C23	31
	45-90	40	13	47	0.95	60	0.75	2.0	4		
	150-200										
5818	0-45	23	13	64	1.30	66	1.00	4.2	7	B11	2
	45-90	13	15	72	0.95	71	0.90	5.1	7		
5819	0-45	5	11	84	0.42	69	0.43	5.2	6	B11	3a
	45-90	20	11	69	1.60	69	1.40	17.0	< 25		
	90-150				1.14						
5820	0-45	20	11	69	0.50	72	0.36	11.6	17	B14	4a
	45-90	15	13	72	0.92	59	0.44	14.0	19		
5821	0-45	20	16	64	0.36	51	1.92	3.3	< 5	B21	2
	45-90	20	13	67	0.52	68	0.34	8.1	12		
5822	0-45	18	13	69	0.50	67	0.50	10.7	> 15	B14	4a
	45-90	15	13	72	1.40	63	0.96	13.0	18		
	150-200	34	20	46							
5823	0-45	28	10	62	1.0	71	0.90	11.1	18	B14	4a
	45-90	23	13	64	1.1	71	0.90	12.3	19		
	105-200	46	20	34							
5824	0-45	18	13	69	0.48	62	0.39			B14	6a
	45-90	18	13	69	0.90	60	0.45	17.9	26		
	90-150				0.70						
5825	0-45	15	16	69	0.44	74	0.37	6.8	< 10	B14	3a
	45-90	10	16	74	0.60	66	0.41	11.6	16		
5826	0-45	13	18	69	0.55	66	0.33	14.1	> 20	B12	6a
	45-90	10	18	72	0.80	68	0.68	16.5	23		
5827	0-45	40	11	49	0.40	56	0.28	7.7	16	B24	4a1
	45-90	38	13	49	0.52	59	0.30	10.9	22		
	90-150				0.60						
	130-200	56	10	34							
5828	0-45	8	15	77	0.40	80	0.30	7.7	10	B11	2
	45-90	8	13	79	0.48	75	0.38	10.4	13		
5829	0-45	29	11	60	0.48	63	0.32	9.3	> 15	B14	6a
	45-90	18	15	67	0.65	65	0.65	24.9	37		
	150-200	21	25	54							
5830	0-45	18	18	64	0.80	65	0.64	13.0	> 20	B12	6a
	45-90	18	15	67	0.90	71	0.71	16.1	24		
	150-200	59	20	21							
5831	0-45	8	15	77	0.50	67	0.34	12.9	17	B14	6a(4a)
	45-90	20	13	67	1.60	71	1.50	23.3	< 35		
	90-150				0.80						
	150-200	41	8	51							

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.							
5832	0-45	25	13	62	0.55	64	0.32	8.5	14	B11	3a
	45-90	25	13	62	0.86	64	0.56	12.6	>20		
5833	0-45	33	13	54	0.43	62	0.23	7.8	14	B23	3a
	45-90	30	13	57	0.90	57	0.57	13.8	24		
	150-200	54	15	31							
5834	0-45	18	15	67	0.50	68	0.34	10.4	>15	B14	4a
	45-90	15	16	69	0.55	66	0.50	15.5	22		
	125-200	31	25	44							
5835	0-45	15	16	69	0.4	72	0.18	14.2	21	B14	6a
	45-90	missing									
	90-150				0.55						
5836	0-45	33	10	57	1.30	66	1.00	12.6	22	B14	6a
	45-90	28	13	59	0.43	66	0.33	11.7	<20		
5837	0-45	30	13	57	0.43	84	0.42	6.0	11	B21	6a(2)
	45-90	28	13	59	1.30	70	1.25	18.7	32		
5838	0-45	10	16	74	1.20	73	1.00	23.0	31	B14	6a
	45-90	45	11	44	1.10	67	0.84	8.0	18		
	90-150				0.65						
5839	0-45	25	13	62	0.95	67	0.67	9.7	16	B24	4a
	45-90	23	13	64	1.4	63	1.00	13.4	21		
	140-200	46	18	36							
5840	0-45	20	33	47	1.10	63	0.87	9.5	>20	C24	6a1
	45-90	53	5	42	0.90	54	0.54	13.1	31		
	150-200	64	10	26							
5841	0-45	23	10	67	1.20	65	0.82	12.8	19	B12	4a
	45-90	25	13	62	1.60	69	1.30	13.9	22		
5842	0-45	25	11	64	1.0	63	0.80	16.0	25	B14	6a
	45-90	48	10	42	0.92	47	0.52	13.9	33		
	90-150				0.70						
5843	0-45	30	11	59	2.0	66	1.64	5.6	9	B11	2
	45-90	30	11	59	0.51	53	0.27	6.9	12		
	135-200	46	23	31							
5844	0-45	25	13	62	0.48	64	0.26	9.3	<15	B11	2
	45-90	25	11	64	0.70	61	0.38	7.6	12		
	145-200	46	15	39							
5845	0-45	43	10	47	0.95	56	0.57	7.4	16	C24	6a(4a1)
	45-90	63	8	29	1.10	50	0.63	13.0	45		
	130-200	61	13	26							
5846	0-45	30	11	59	2.0	62	1.60	14.4	24	B14	6a
	45-90	30	11	59	0.50	62	0.31	7.7	13		
	90-150				0.60						
	125-200	59	17	24							

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.							
5847	0-45	13	13	74	0.90	62	0.70	12.1	16	B12	4a
	45-90										
5848	0-45	10	13	77	0.36	59	0.15	8.6	11	B13	3a
	45-90	13	13	74	0.53	73	0.37	13.2	18		
5849	0-45	10	11	79	0.85	64	0.64	24.2	31	B14	6a
	45-90	20	11	69	1.90	44	1.04	14.96	22		
5850	0-45	8	13	79	0.48	57	0.29	16.9	21	A14	6a
	45-90	18	10	72	1.70	69	1.40	13.0	18		
6360	0-45	20	17	63	0.3	69	0.26	6.9	11	B11	3a
	45-90	20	17	63	1.7	76	1.70	11.9	19		
	90-150				0.46						
6361	0-45	38	14	48	1.5	56	1.04	5.56	12	B11	3a1
	45-90	43	11	46	0.54	60	0.45	10.3	22		
6362	0-45	15	17	68	0.5	68	0.5	14.3	21	B11	6a
	45-90	23	21	56	1.8	69	1.54	18.1	32		
6363	0-45	23	16	61	0.5	71	0.44	9.2	>15	A12	6a(4a)
	45-90	20	19	61	3.6	62	2.86	19.5	32		
6364	0-45	15	17	68	0.36	67	0.33	11.7	17	A12	4a
	45-90	18	14	68	1.40	65	1.14	14.1	21		
	90-150				1.24						
6365	0-45	13	19	68	0.38	68	0.34	9.7	14	B11	6a(2)
	45-90	23	16	61	3.40	70	3.1	18.1	<30		
6366	0-45	15	17	68	1.20	76	0.94	11.1	16	B14	6a(4a)
	45-90	10	14	76	1.30	82	1.40	23.0	>30		
6367	0-45	18	19	63	1.60	72	1.25	13.5	21	B12	6a
	45-90	30	17	53	3.80	65	3.40	22.6	43		
6368	0-45	33	16	51	3.0	63	2.43	14.0	27	B12	6a
	45-90	33	16	51	0.75	62	0.61	7.4	14		
	90-150				0.66						
6369	0-45	30	17	53	0.28	65	0.22	2.2	4	A11	3a
	45-90	18	16	66	0.68	68	0.51	12.3	19		
	150-200	76	13	11							
6370	0-45	33	16	51	0.38	54	0.20	3.8	7	B11	3a
	45-90	25	17	58	0.60	66	0.49	11.1	19		
	150-200	49	22	29							
6371	0-45	30	19	51	0.32	61	0.15	3.4	7	B13	3a
	45-90	28	14	58	0.55	64	0.40	9.2	16		
6372	0-45	25	17	58	1.70	58	1.12	19.3	33	B14	6a
	45-90	28	14	58	4.0	70	3.40	15.8	27		
	90-150				1.75						

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.							
6373	0-45	25	14	61	0.65	64	0.56	19.0	31	B14	6a
	45-90	18	19	63	0.95	62	0.85	23.1	37		
6374	0-45	20	17	63	0.8	60	0.60	21.0	33	B14	6a
	45-90	18	19	63	1.6	61	1.22	20.8	33		
6375	0-45	18	24	58	0.56	65	0.48	15.1	26	B14	6a
	45-90	23	16	61	2.10	63	1.72	21.5	> 35		
6376	0-45	30	17	53	0.70	59	0.29	19.3	36	B22	6a
	45-90	45	14	41	7.0	53	4.15	10.2	< 25		
	90-150										
6377	0-45	15	17	68	0.50	64	0.4	18.0	26	B14	6a
	45-90	18	16	66	6.0	72	5.2	20.4	31		
	90-150				0.50						
6378	0-45	18	16	66	0.65	65	0.49	19.5	< 30	B14	6a
	45-90	15	17	68	1.70	66	1.33	19.1	28		
6379	0-45	18	16	66	0.70	64	0.48	18.7	28	B14	6a
	45-90	18	16	66	1.50	68	1.50	27.7	42		
6380	0-45	20	22	58	0.70	62	0.47	21.1	36	B14	6a
	45-90	18	16	66	1.20	64	0.96	26.6	40		
	90-150				1.52						
6381	0-45	20	17	63	1.70	69	1.55	18.4	29	B14	6a
	45-90	13	16	71	1.10	78	1.17	24.0	34		
6382	0-45	18	11	71	0.52	67	0.33	15.7	22	B14	6a
	45-90	13	21	66	4.50	74	3.66	21.1	32		
6383	0-45	13	16	71	0.44	71	0.35	11.6	16	B14	4a
	45-90	13	19	68	0.8	70	0.7	13.3	< 20		
6384	0-45	18	16	66	0.36	70	0.26	5.7	9	B13	3a
	45-90	20	12	68	0.48	76	0.38	11.6	17		
	90-150				0.75						
6385	0-45	20	22	58	0.77	67	0.67	17.6	> 30	B14	6a
	45-90	28	11	61	1.70	73	1.47	15.7	26		
6386	0-45	28	16	56	0.88	54	0.54	16.3	29	B14	6a
	45-90	28	16	56	3.60	72	3.57	32.4	58		
6387	0-45	20	14	66	0.52	60	0.38	15.6	24	B14	6a
	45-90	33	14	53	0.61	62	0.40	13.6	26		
6388	0-45	10	19	71	0.65	70	0.52	17.1	24	B14	6a
	45-90	10	19	71	1.80	69	1.47	16.9	24		
6389	0-45	15	19	66	0.85	68	0.68	11.3	17	B14	4a
	45-90	18	16	66	1.30	73	1.09	15.7	24		
	90-150				1.70						

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.							
6390	0-45	15	22	63	0.50	68	0.33	8.1	13	B13	2
	45-90	15	14	71	0.50	70	0.35	9.2	13		
6391	0-45	13	14	73	0.44	76	0.56	11.4	16	B12	6a(4a)
	45-90	8	14	78	1.20	83	1.25	21.9	28		
6392	0-45	33	11	56	1.60	66	1.40	13.0	23	B14	6a
	45-90	23	14	63	1.20	68	1.02	10.98	17		
6393	0-45	13	14	73	0.55	74	0.46	21.9	< 30	B14	6a
	45-90	35	12	53	5.10	64	4.15	10.6	< 20		
	90-150				3.00						
6394	0-45	10	14	76	0.48	72	0.44	13.6	18	B12	4a
	45-90	13	14	73	1.20	78	1.17	14.8	> 20		
6395	0-45	18	16	66	0.76	61	0.60	22.2	34	B24	6a
	45-90	20	14	66	2.10	77	1.93	13.3	< 20		
6396	0-45	8	19	73	0.68	74	0.56	16.6	23	B14	6a
	45-90	25	12	60	2.40	72	2.14	14.7	< 25		
6397	0-45	15	14	71	0.55	69	0.43	10.8	> 15	B14	6a(4a)
	45-90	15	14	71	1.20	78	1.18	20.4	29		
	90-150				0.86						
6398	0-45	10	19	71	0.7	70	0.53	19.5	27	B14	6a
	45-90	13	16	71	2.2	77	2.10	21.1	< 30		
6399	0-45	15	19	66	0.56	70	0.52	19.5	< 30	B14	6a
	45-90	15	14	71	2.0	74	1.94	23.3	33		
6400	0-45	25	19	58	1.12	67	1.0	23.0	40	B24	6a
	45-90	18	16	66	1.10	83	1.38	29.8	45		
6401	0-45	15	17	68	0.78	79	0.69	11.7	17	B14	4a
	45-90	18	16	66	2.0	77	1.93	12.5	19		
	90-150				1.70						
6402	0-45	10	14	76	0.38	70	0.26	4.5	6	B11	2
	45-90	38	14	48	1.32	55	0.82	5.2	11		
6403	0-45	20	19	61	0.65	67	0.50	7.5	12	B13	6a(2)
	45-90	20	19	61	2.50	76	2.36	21.6	> 35		
6404	0-45	45	12	43	3.40	69	0.35	22.8	53	C24	6a1
	45-90	20	14	66	1.70	78	1.41	28.6	43		
6405	0-45	13	19	63	0.44	69	0.38	13.2	19	B14	6a(4a)
	45-90	30	14	56	1.90	64	0.32	15.7	28		
	90-150				2.20						
6406	0-45	23	14	63	0.38	76	0.44	5.2	8	B13	2
	45-90	35	14	48	0.46	64	3.26	0.7	1		
6407	0-45	13	14	73	0.55	71	0.44	9.6	13	B13	6a(2)
	45-90	25	14	61	3.60	65	2.22	17.4	28		

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.							
6408	0-45	13	16	71	0.48	71	0.44	13.2	19	B14	6a(4a)
	45-90	18	14	68	2.40	74	2.22	18.6	27		
6409	0-45	15	17	68	0.50	69	0.42	8.8	13	B13	3a
	45-90	20	17	63	2.20	67	1.68	11.1	17		
6410	0-45	23	16	61	0.44	67	0.41	6.0	< 10	B13	6a(2)
	45-90	38	14	48	2.20	58	1.73	12.3	26		
6411	0-45	35	15	50	2.60	64	2.26	15.7	31	B14	6a
	45-90	13	16	71	1.10	72	0.98	17.4	< 25		
6412	0-45	10	17	73	0.55	63	0.40	8.8	12	B13	3a
	45-90	10	17	73	0.88	71	0.71	15.3	21		
6413	0-45	13	16	71	0.44	70	0.42	8.0	11	B13	3a
	45-90	23	16	61	1.70	69	1.55	11.2	18		
	90-150				1.90						
6414	0-45	28	14	58	1.60	58	1.16	13.2	23	B24	6a
	45-90	30	17	53	1.60	64	1.28	12.3	23		
6415	0-45	38	14	48	0.48	68	0.41	0.4	1	B23	31
	45-90	38	11	51	0.68	64	0.48	5.5	11		
6416	0-45	40	17	43	0.68	61	0.53	3.1	7	C23	6a(31)
	45-90	35	17	48	2.10	62	1.68	12.7	26		
6417	0-45	23	14	63	0.55	72	0.45	4.3	7	B13	3a
	45-90	23	14	63	0.70	69	0.60	12.2	19		
	90-150				1.10						
6418	0-45	25	14	61	1.70	69	1.54	15.3	> 25	B14	6a
	45-90	28	14	58	6.50	72	5.16	10.8	19		
6419	0-45	23	14	63	1.50	68	1.47	12.1	19	B14	4a
	45-90	25	12	63	1.0	74	0.93	13.5	21		
6420	0-45	18	19	63	0.75	67	0.67	17.7	28	B14	6a
	45-90	25	14	61	2.40	73	2.16	15.4	> 25		
6421	0-45	21	39	40	1.60	67	1.33	12.3	30	C24	6a1
	45-90	39	9	52	2.40	63	1.90	9.3	18		
	90-150				1.90						