

THE REPUBLIC OF THE SUDAN
MINISTRY OF AGRICULTURE

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ROSEIRES SOIL SURVEY

REPORT No. 2

BLUE NILE EAST BANK, GUNEID TO KHARTOUM
SOILS AND ENGINEERING RECONNAISSANCE

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

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

SEPTEMBER 1963

THE REPUBLIC OF THE SUDAN
MINISTRY OF AGRICULTURE

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28th September, 1963.

H.E. Minister of Agriculture,
Ministry of Agriculture,
Khartoum,
SUDAN.

Your Excellency,

ROSEIRES SOIL SURVEY REPORT NO. 2.

We have pleasure in submitting our Report No. 2 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.

The Report is in one volume and contains the results of the soils and engineering reconnaissance carried out on the east banks of the Blue and Main Niles from Rufaa in the south to Qubba in the north. This includes all the lands referred to as Area 3d in the Contract together with a small part of Area 4 to the north of Khartoum. The eastern boundary of these lands is the 20 metre isopotamon as defined by the engineering survey. The reconnaissance plans accompanying this Report are in a pocket on the cover.

The Report defines the lands which we are recommending for semi detailed soil survey and land classification, the total area of which is 172,000 feddans.

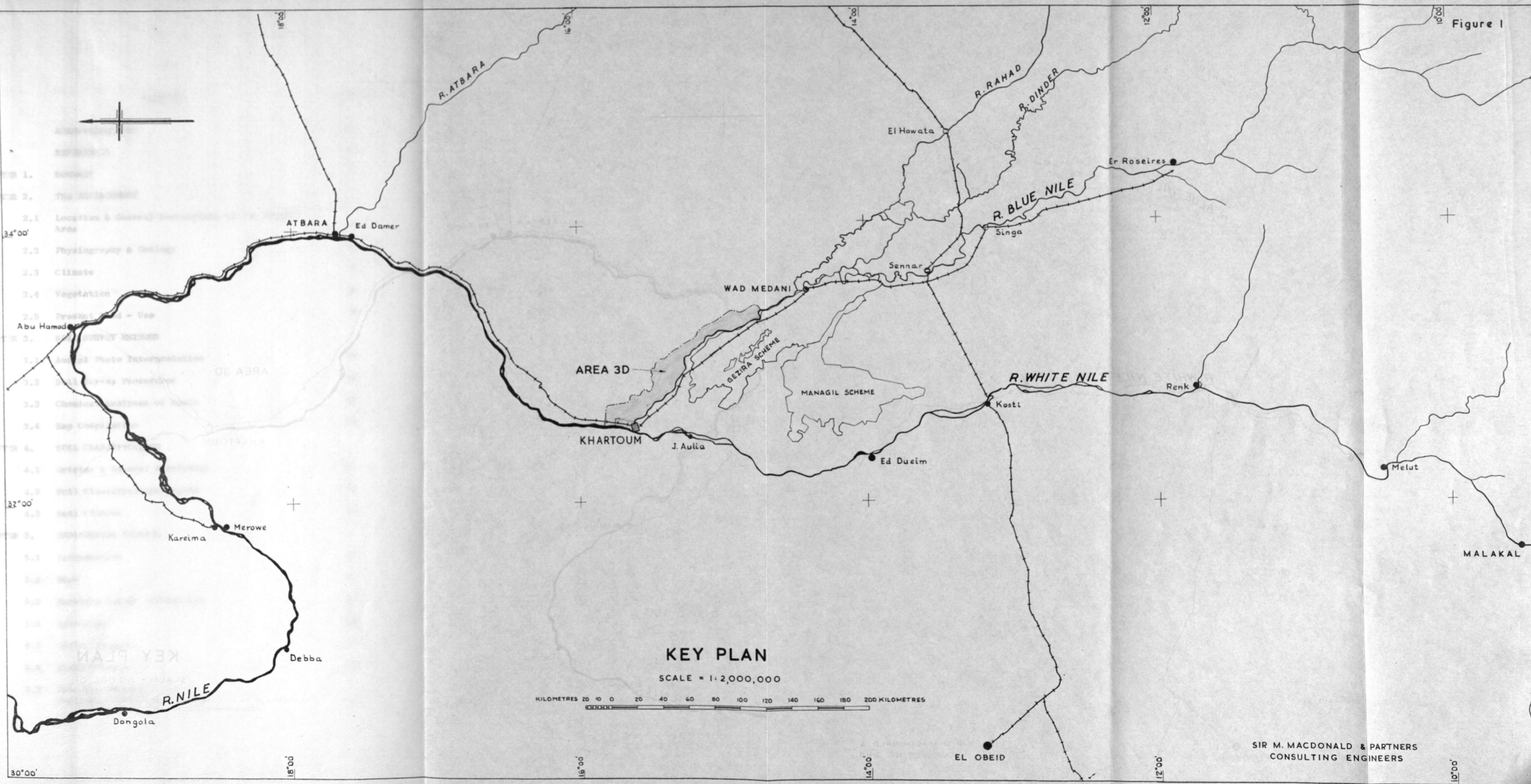
The agricultural and soil studies were undertaken on our behalf by Messrs. Hunting Technical Services Ltd., under the direction of Dr. Robert Smith, Consultant in charge of the soil surveys.

We are, Excellency,

Your obedient servants,

R. H. Macdonald

SIR M. MACDONALD & PARTNERS.



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KEY PLAN

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KHARTOUM PROVINCE

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PLATES

The compilation of a report of this kind cannot be complete without the help of many individuals, both in the Sudan and the United Kingdom, who have assisted us either by providing information or by their personal help. Many who have assisted in this way are mentioned in the following. Thanks are due.

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

University of Khartoum

Professor D. Drover, Head of the Department of Agricultural Chemistry and Pedology, and Mr. E.L. Strickland of this Department, for their help with the laboratory analyses. Professor E.R.G. Macleay, Head of the Botany Department, for identifying our plant specimens.

REFERENCES

GENERAL REFERENCES

ENIGHT, E.L. & BOYNS, B.M. - Agricultural Science in the Sudan in the Sudan. A Bibliography with abstracts. 1960, Dundee, Arbuthnot, Scotland.

REPUBLIC OF THE SUDAN, DEPARTMENT OF AGRICULTURE - Annual Reports, REPUBLIC OF THE SUDAN, DEPARTMENT OF AGRICULTURE, ADMINISTATIVE COMMITTEE ON AGRICULTURAL RESEARCH IN THE SUDAN - Annual Reports of the Research Division.

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REPUBLIC OF THE SUDAN, MINISTRY OF IRRIGATION AND HYDRO-ELECTRIC POWER - Sudan Irrigation. 1957, Survey Department, Khartoum.

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

University of Khartoum

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MIDDLETON, K.R. Various Methods for Chemical Examination of Soils. Government of the Sudan, Ministry of Agriculture Miscellaneous Paper No. 70. 1955.

SMITH, J. - Distribution of Tree Species in the Sudan in Relation to Rainfall and Soil Texture. 1948, Sudan Government, Ministry of Agriculture, Bulletin No. 4.

TORRILL, J.D. - The Origin of the Gezira Plain. Sudan Notes and Records, Volume 27, Pages 157-163. 1946.

U.S. DEPARTMENT OF AGRICULTURE - Soil Survey Manual. Handbook No. 18, 1951, Government Printing Office, Washington D.C.

U.S. DEPARTMENT OF AGRICULTURE - The Diagnosis and Improvement of Saline and Alkali Soils, Handbook No. 60. 1953, Government Printing Office, Washington D.C.

REFERENCES

GENERAL REFERENCES

- KNIGHT, R.L. & BOYNS, B.M. - Agricultural Science in the Sudan. A Bibliography with abstracts. 1960, Buncle, Arbroath, Scotland.
- REPUBLIC OF THE SUDAN, DEPARTMENT OF AGRICULTURE - Annual Reports.
- REPUBLIC OF THE SUDAN, DEPARTMENT OF AGRICULTURE, ADVISORY COMMITTEE ON AGRICULTURAL RESEARCH IN THE SUDAN - Annual Reports of the Research Division.
- REPUBLIC OF THE SUDAN, MINISTRY OF IRRIGATION AND HYDRO-ELECTRIC POWER - Sudan Irrigation. 1957, Survey Department, Khartoum.
- TOTHILL, J.D. (Editor) - Agriculture in the Sudan, By Numerous Authors. 1952, Oxford University Press, London.

OTHER REFERENCES

- ANDREWS, F.W. - The Flowering Plants of the Anglo-Egyptian Sudan. 3 volumes. 1950, 1952 and 1956, Buncle, Arbroath, Scotland.
- BARBOUR K.M. - The Republic of the Sudan University of London Press.
- FINCK, A. - Classification of Gezira Clay Soil. Soil Science, Volume 92, Pages 263-267. 1961.
- FINCK, A. & OCHTMAN, L.H.J. - Problems of Soil Evaluation in the Sudan. Journal of Soil Science, Volume 12, Pages 87-95. 1961.
- GREENE, H. - Soil Permeability in the Eastern Gezira. Journal of Agricultural Science, Volume 18, Pages 531-542. 1928.
- HUNST, H.E. - The Nile Basin Vol.viii, 1950 Government Press Cairo.
- JESSUP, R.W. - The Stony Tableland Soils of the South-Eastern Portion of the Australian Arid Zone and their Evolutionary History. Journal of Soil Science, Volume 11, Pages 188-196. 1960.
- JEWITT, T.N. - Gezira Soil. Sudan Government Album Agricultural Bulletin No. 12. 1955.
- MIDDLETON, K.R. Various Methods for Chemical Examination of Soils. Government of the Sudan, Ministry of Agriculture Miscellaneous Paper No. 70. 1955.
- SMITH, J. - Distribution of Tree Species in the Sudan in Relation to Rainfall and Soil Texture. 1949, Sudan Government, Ministry of Agriculture, Bulletin No.4.
- TOTHILL, J.D. - The Origin of the Gezira Plain. Sudan Notes and Records, Volume 27, Pages 127-163. 1946.
- U.S. DEPARTMENT OF AGRICULTURE - Soil Survey Manual. Handbook No. 18, 1951, Government Printing Office, Washington D.C.
- U.S. DEPARTMENT OF AGRICULTURE - The Diagnosis and Improvement of Saline and Alkali Soils. Handbook No. 60. 1953, Government Printing Office, Washington D.C.

U.S. DEPARTMENT OF AGRICULTURE - Soil Classification, a Comprehensive System, 7th Approximation. 1960, Government Printing Office, Washington D.C.

U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION - Irrigated Land Use, Volume 5. 1961, Government Printing Office, Washington D.C.

WORRALL, G.A. - Features of Some Semi-Arid Soils in the District of Khartoum. (I) The High Level Dark Clays. Journal of Soil Science, Volume 8 (2), Pages 193-202. 1958.

The reconnaissance soil survey covers a total area of 390,000 feddans of land at a density of one site for each 2,500 feddans. Areas covered by the soil survey include Gharbia lands along the Blue Nile, registered lands along the Main Nile, the Gezira Pump Project lands and an area of 91,500 feddans of hard-growing rainlands to the north of Khartoum extending on either side of the Gezira pump project lands. This latter area was, however, examined by the engineering survey and found to be worthy of further study.

The project lands are a gently sloping plain from 4 to 30 kilometres wide which extends beside the Blue and Main Niles for a distance of about 60 kilometres. In the south east, around Gezira, these lands are part of the southern clay plain but further north, where the clay lands are confined to the immediate vicinity of the rivers, the plain has a loamy or sandy surface and is bordered to the east by low ridges of Rubian sandstone out of shallow valleys. In the extreme north the plain abuts the low granitic escarpment of the Jebel Simatit and the well defined basins of the Wadi el Barana and the Wadi el Bahari which extend to the registered lands beside the Main Nile.

The climate is very hot and very dry with an average annual rainfall of 50 to 300 mm., mostly falling between June and September. The original vegetation over most of the area, now much modified by human interference, is a *Prosopis juliflora* - *Acacia senegal* desert scrub type. In the south there is a smaller area of semi-desert grassland on clay.

The total population is about 350,000 and the greatest density is found around the urban and industrial parts of Khartoum North and in the registered lands along the Main Nile. The remainder of the population, who live in scattered small villages up to 15 kilometres from the river, are mainly engaged in livestock, supplemented in the south by rain grown cereals and at a few places along the river by small flood or pump irrigated crops.

The soil survey reveals that the lands of Area 3d have a much wider range in topographic and soils conditions than the Gezira and Gharbia lands. As well as Gezira type clays (Vertisols) and Gharbia Province type silts (Entisols) there are older soils with well defined illuvial horizons known as Aridisols.

The Vertisols are subdivided into those with a self-slicking surface (Gumusterts) and those with a crusty surface (Mauusterts). The Entisols are all loamy soils (Orthusterts). The Aridisols belong to three distinct groups: - Naptargids have an illuvial clay horizon; Murgids have a gravelly hard pan underlying the illuvial clay horizon; and Sargids have high alkalinity (E.S.P. exceeds 15) in the illuvial clay horizon.

CHAPTER 1

SUMMARY

1.1 The reconnaissance soils and engineering survey of Area 3d is concerned with a gross area of 580,000 feddans on the east banks of the Blue and Main Niles extending from Rufaa in the south east to Qubba in the north. The eastern boundary of these lands is the 20 metre isopotamon as defined by the engineering survey.

1.2 The reconnaissance soil survey covers a total area of 395,000 feddans of land at a density of one site for each 2,500 feddans. Areas not covered by the soil survey include kerrib lands along the Blue Nile, registered lands along the Main Nile, the Guneid Pump Project lands and an area of 91,600 feddans of dura-growing rainlands to the north of Rufaa and extending on either side of the Guneid pump project lands. This latter area was, however, examined by the engineering survey and found to be worthy of further study.

1.3 The project lands are a gently sloping plain from 4 to 20 kilometres wide which extends beside the Blue and Main Niles for a distance of about 150 kilometres. In the south east, around Guneid, these lands are part of the southern clay plain but further north, where the clay lands are confined to the immediate vicinity of the rivers, the plain has a loamy or sandy surface and is bordered to the east by low ridges of Nubian sandstone cut by shallow wadies. In the extreme north the plain abuts the low granite outcrops of the Jebel Sileitat and the well defined channels of the Wadi el Garwaqa and the Khor Kabbashi which extend to the registered lands beside the Main Nile.

1.4 The climate is very hot and very dry with an average annual rainfall of 150 to 300 mm., mostly falling between June and September. The original vegetation over most of the area, now much modified by human interference, was Acacia tortilis - Maerva crassifolia desert scrub type. In the south there is a smaller area of semi-desert grassland on clay.

1.5 The total population is about 250,000 and the greatest density is in and around the urban and industrial parts of Khartoum North and in the registered lands along the Main Nile. The remainder of the population, who live in scattered small villages up to 15 kilometres from the river, depend mainly on livestock, supplemented in the south by rain grown dura and at a few places along the river by small flood or pump irrigated schemes.

1.6 The soil survey reveals that the lands of Area 3d have a much wider range in topographic and soils conditions than the Gezira and Gezira Extension lands. As well as Gezira type clays (Vertisols) and Northern Province type silts (Entisols) there are older soils with well defined illuvial horizons known as Aridisols.

The Vertisols are subdivided into those with a selfmulching surface (Grumusterts) and those with a crusty surface (Mazusterts). The Entisols are all loamy soils (Orthustents). The Aridisols belong to three distinct groups: - Haplargids have an illuvial clay horizon; Durargids have a gravelly hard pan under-lying the illuvial clay horizon; Natrargids have high alkalinity (E.S.P. exceeds 15) in the illuvial clay horizon.

The Vertisols and Orthustents are moderately calcareous, are richly supplied with phosphate and potash but are low in organic matter and nitrogen. The Durargids and Haplargids have no carbonate horizon and the pH is neutral to weakly alkaline; they are non-saline, non-alkali soils but the fertility level is low. The Natrargids have a leached surface horizon overlying a calcareous sub-soil which is invariably highly alkaline, with E.S.P. exceeding 15, and weakly saline.

1.7 The engineering surveys were concerned primarily with establishing the 20 metre isopotamon. Between Soba and Guneid this was accomplished by office study of the contour maps at scale 1:50,000 with reference to the minimum ten-day mean water levels at Soba, El Kamlin and Wad Medani gauges. From Soba on the Blue Nile to Khogalab on the Main Nile the position of the 20 metre isopotamon was established by extension of the Survey Department section lines and some additional field work by the Consultants.

In addition to the establishment of the 20 metre isopotamon, the engineering investigation studied the possible method and layout for irrigating the area. A preliminary layout plan showing pump station sites and main canal lines was prepared for the full project area (See Figure 10) After the completion of the reconnaissance soil survey the engineering proposals were revised to irrigate only those lands recommended for semi-detailed soil survey. The final results are shown on Plate 6.

1.8 The land suitability classification was concerned with agricultural, engineering and land tenure considerations. Agricultural aspects of land selection were concerned chiefly with the physical bases of potential agricultural production. As in Area 1, impeded drainage was rarely a limiting factor. Topographic limitations were encountered in the kerrib (gullied) lands adjacent to the Blue Nile and at higher levels where stoniness, shallow wadis and sand hummocks are encountered near the 20 metre isopotamon. Soils limitations were mostly due to alkalinity (E.S.P. exceeds 15); other soils limitations were slight salinity or low clay percentage of Vertisols and low fertility status of Aridisols.

Consideration of engineering aspects enabled the elimination of lands with marginal soils which required high pump lifts and or a long supply canal through difficult terrain.

Considerations of land tenure led to the elimination of small strips and pockets of Government lands on the east side of the registered lands on the Main Nile and adjacent to the urban and industrial areas at Khartoum North.

1.9 The lands recommended for semi-detailed soil survey and land suitability classification in Area 3d are as follows: -

<u>Locality</u>	<u>Area</u> (Feddans)
Umm Dubban	6,250
Eilafun	14,600
Wad Rawa - Guneid	<u>151,000</u>
Total	<u>171,850</u>

1.10 Irrigation Projects.

A preliminary layout for irrigation of these lands has been prepared and is shown on Plate 6. Subject to the result of the semi-detailed land classification and close levelling surveys there should be the following irrigation pump projects in the Area 3d: -

	<u>Gross Area</u> (Feddans)	<u>Static Lift</u> (Metres)
Wad Rawa	103,000	18.0
		and 20.8
Eilafun	9,000	12.5
Umm Dom	5,000	12.0
Total area	<u>117,000</u>	

The Wad Rawa Project is essentially an extension to the existing Guneid Scheme - 45,000 feddans will require a second lift of about 2.8 metres. The Eilafun Project is a new development on lands which have not previously been irrigated. The Umm Dom Project is the rehabilitation of existing and derelict pump schemes in the vicinity of Umm Dom and Karkoj.

CHAPTER 2

THE ENVIRONMENT

2.1 LOCATION & GENERAL DESCRIPTION OF THE PROJECT AREA

The project area is defined in the Contract as the east bank of the Blue Nile between El Guneid and Khartoum up to a height which is 20 metres above the lowest river level, except where a major topographic obstacle is encountered between the river and the 20 metre isotopamon.

After the start of the 1962-63 field season the Client and the Consultant agreed that, for the purpose of selecting further possible project areas and pump station sites, Area 3d should be extended northwards by 30 kilometres along the east bank of the Main Nile to include those lands between the river and the 20 metre isotopamon from Khartoum to Qubba.

At the southern end of the project area the boundary of the project lands remained undefined until the northern limit of the lands of Area 3c had been defined. Unfortunately this occurred after the reconnaissance soil surveyor had completed field operations and moved to Northern Province. As a result, 91,600 feddans of land to the north of Rufaa and extending on either side of the Guneid pump project, between the river and the 20 metre isotopamon, were not covered by the reconnaissance soil survey although examined by the engineering survey.

The project lands extend beside the Blue and Main Niles for a distance of about 150 kilometres, from Rufaa in the south to Qubba in the north. The width of this belt varies from 4 kilometres at Soba Sharq to 20 kilometres across the Eilafun - Umm Dubban plain. Approximately two thirds of the project lands lie in Blue Nile Province and the remaining third in Khartoum Province although a few square kilometres, at latitude 15° 35', lie in Kassala Province.

Although it is not possible to give any precise figures for the population of the project area the total number of people must approach 250,000, of whom about 140,000 are administered by Khartoum Rural Council, 40,000 by Khartoum North Municipal Council and 90,000 by Shukriya Rufaa Rural Council (Blue Nile Province). The most important concentrations of population lie in and around Khartoum North and along the riverain lands of the Main Nile where proximity to the metropolis provides an obvious economic attraction. The remainder of the population live in scattered small villages at distances up to ten kilometres from the river. The three largest villages, which have populations of 2000 or more, are Eilafun, Umm Dubban and Wad Rawa.

The total area of land lying between the 20 metre isotopamon and the Blue and Main Niles is 570,000 feddans. Of this, the Guneid Pump Project lands account for 53,000 feddans. The gross area examined by the reconnaissance soil survey, from the northern end of Guneid Pump Project to Qubba, is 425,000 feddans. In this total is included kerrib lands along the Blue Nile and registered lands along the White Nile; the net area is about 395,000 feddans examined on the ground with sites at a density of one to each 2,500 feddans.

Access is very easy throughout the area. Location on the 1:50,000 base maps on the Blue Nile is facilitated by the 10-kilometre grid of

26 ft. concrete posts, though none of the other information on the maps can be regarded as accurate. On the 1:100,000 base maps north of Khartoum, features such as the railway and various tombs, water towers, and chimneys have been mapped accurately.

2.2 PHYSIOGRAPHY AND GEOLOGY

2.21 Physiography

The area South of Khartoum is divided into three distinct regions, which can be seen on the accompanying sketch map (Fig.2)

- A. A flat clay plain covers the whole area just north of Guneid, and extends northwards as a narrow belt of land next to the river. This plain slopes gently and uniformly to the west, and falls about 1 metre per 2 kilometres. It is dissected by a few broad wadis in the south, near Wad Rawa.
- B. Along the eastern edge of the above plain, merging into it, is a slightly less even plain with a general westward slope of 2 or 3 metres per kilometre. The terrain is generally flat, with occasional low sandy ridges, and the soil surface over most of the area appears sandy.
- C. To the north and east of the second plain above is an area of low sandstone ridges and shallow wadis. The lower boundary of this zone corresponds roughly with the 20 metre Isopotamon.

To the north of Khartoum these features continue to opposite Abu Halima, where a clay plain (D) replaces the sandy plain B. It is somewhat higher, with an even slope to the west of about 2 metres per kilometre. There is a number of small granite outcrops in this plain including the Jebel Sileitat, and there are many stones and a few patches of boulders on the surface.

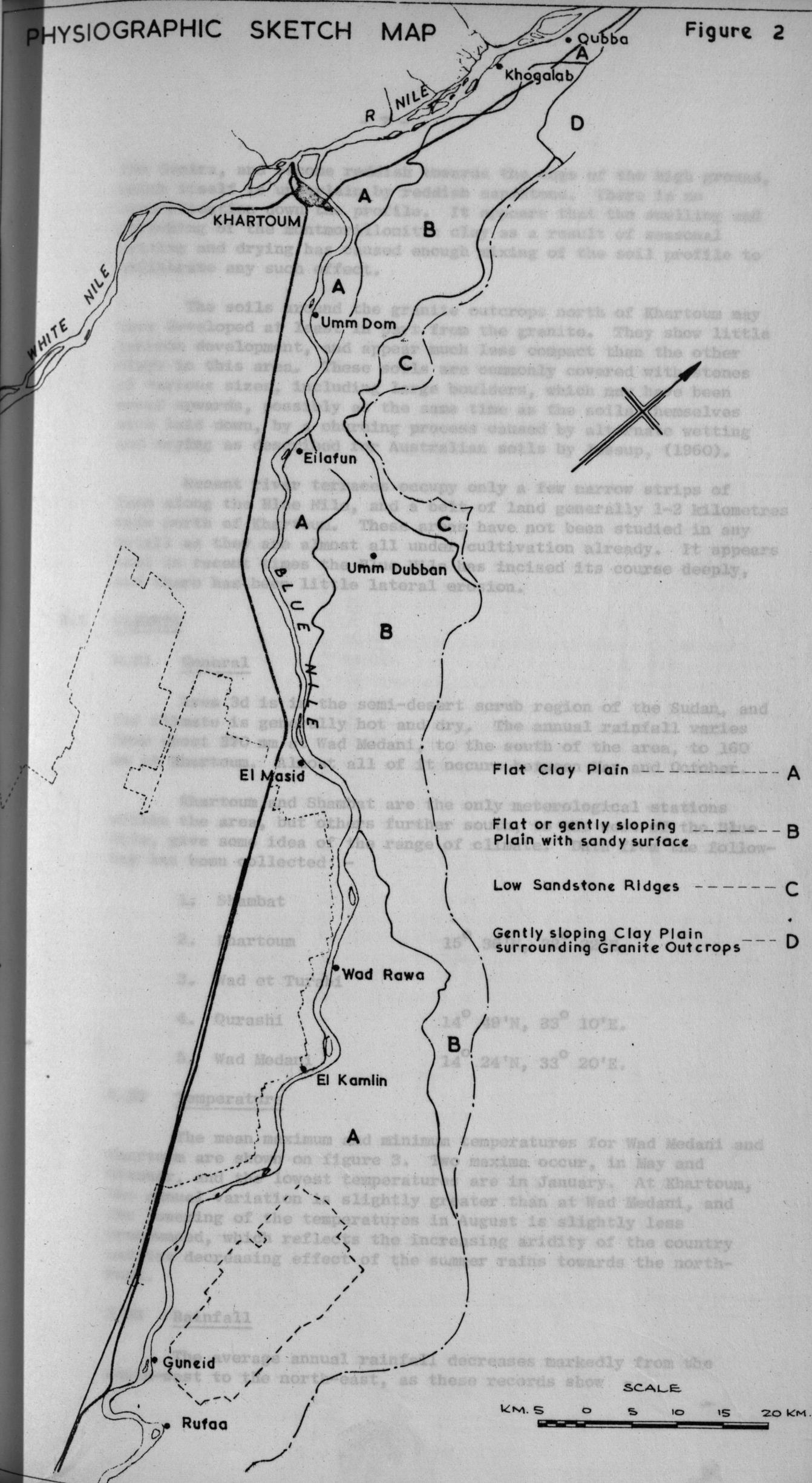
2.22 Geology

Almost all of the area is underlain by Nubian sandstones, which outcrop to form the high ground in the east. Small outcrops of iron-stained and cemented conglomerates belonging to the Nubian series are found near Eilafun, and some sandstones are exposed along the banks of the Blue Nile between Eilafun and Khartoum. It is possible that some of the sandy soils in Region B of the sketch map, especially south-east of Umm Dubban, may have developed in situ on Nubian sandstones.

Some 25 km North of Khartoum, a small outcrop of igneous rocks - Soda Granite and Rhyolite - is exposed as a number of low jebels, the Jebel Sileitat, rising abruptly from the plain.

Overlying the Nubian sandstones in the regions marked A and B on the sketch map are materials that appear to have been deposited in a seasonal lake or swamp on a flood plain. The clays of the south (Region A) are of the kind known as Gezira clay, and are considered by some to have been laid down between 50,000 and 10,000 years ago by a river carrying only fine materials. This river was probably the Rahad, with some contribution from the Blue Nile. The source of the clay is the young volcanic rocks of the Ethiopian Highlands.

The land to the north-east of the Gezira soil (Region B) is a mixture of Gezira-type clay with reddish sand, often coarse, and some gravel. It appears that here there was an additional contribution of colluvium from the high ground nearby. The soils are browner than



- Flat Clay Plain ----- A
- Flat or gently sloping Plain with sandy surface ----- B
- Low Sandstone Ridges ----- C
- Gently sloping Clay Plain surrounding Granite Outcrops ----- D

SCALE
 KM. 5 0 5 10 15 20 KM.

the Gezira, and become reddish towards the edge of the high ground, which itself is underlain by reddish sandstone. There is no stratification down the profile. It appears that the swelling and shrinking of the montmorillonitic clay as a result of seasonal wetting and drying has caused enough mixing of the soil profile to obliterate any such effect.

The soils around the granite outcrops north of Khartoum may have developed at least in part from the granite. They show little horizon development, and appear much less compact than the other clays in this area. These soils are commonly covered with stones of various sizes, including large boulders, which may have been moved upwards, possibly at the same time as the soils themselves were laid down, by a churning process caused by alternate wetting and drying as described for Australian soils by Jessup, (1960).

Recent river terraces occupy only a few narrow strips of land along the Blue Nile, and a belt of land generally 1-2 kilometres wide north of Khartoum. These areas have not been studied in any detail as they are almost all under cultivation already. It appears that in recent times the Blue Nile has incised its course deeply, and there has been little lateral erosion.

2.3 CLIMATE

2.31 General

Area 3d is in the semi-desert scrub region of the Sudan, and the climate is generally hot and dry. The annual rainfall varies from about 370 mm at Wad Medani, to the south of the area, to 160 mm at Khartoum. Almost all of it occurs between May and October.

Khartoum and Shambat are the only meteorological stations within the area, but others further south, to the west of the Blue Nile, give some idea of the range of climate. Data from the following has been collected: -

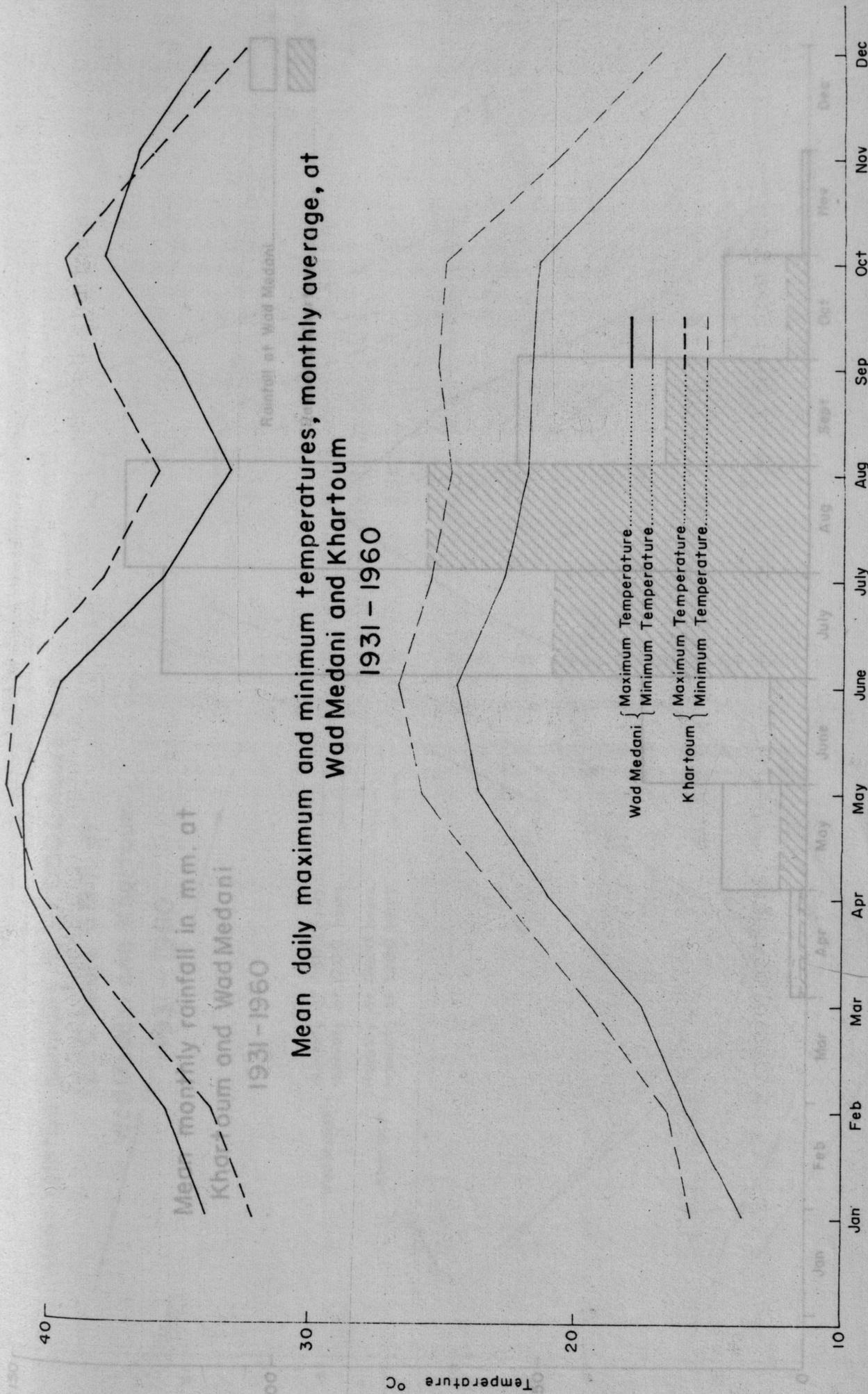
1. Shambat
2. Khartoum 15° 36'N, 32° 32'E.
3. Wad et Turabi
4. Qurashi 14° 49'N, 33° 10'E.
5. Wad Medani 14° 24'N, 33° 20'E.

2.32 Temperature

The mean maximum and minimum temperatures for Wad Medani and Khartoum are shown on figure 3. Two maxima occur, in May and October, and the lowest temperatures are in January. At Khartoum, the annual variation is slightly greater than at Wad Medani, and the lowering of the temperatures in August is slightly less pronounced, which reflects the increasing aridity of the country and the decreasing effect of the summer rains towards the north-west.

2.33 Rainfall

The average annual rainfall decreases markedly from the south-west to the north-east, as these records show: -



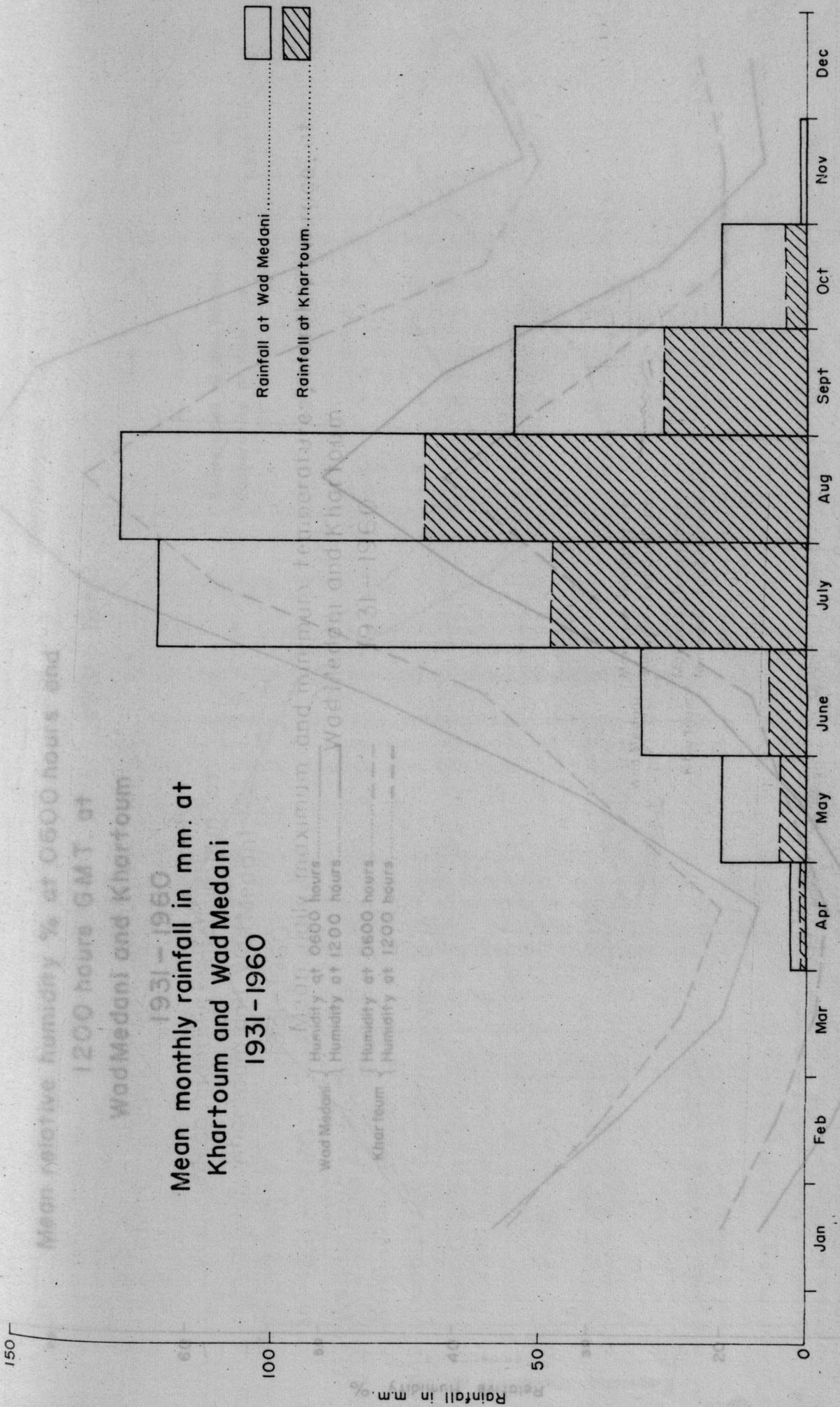
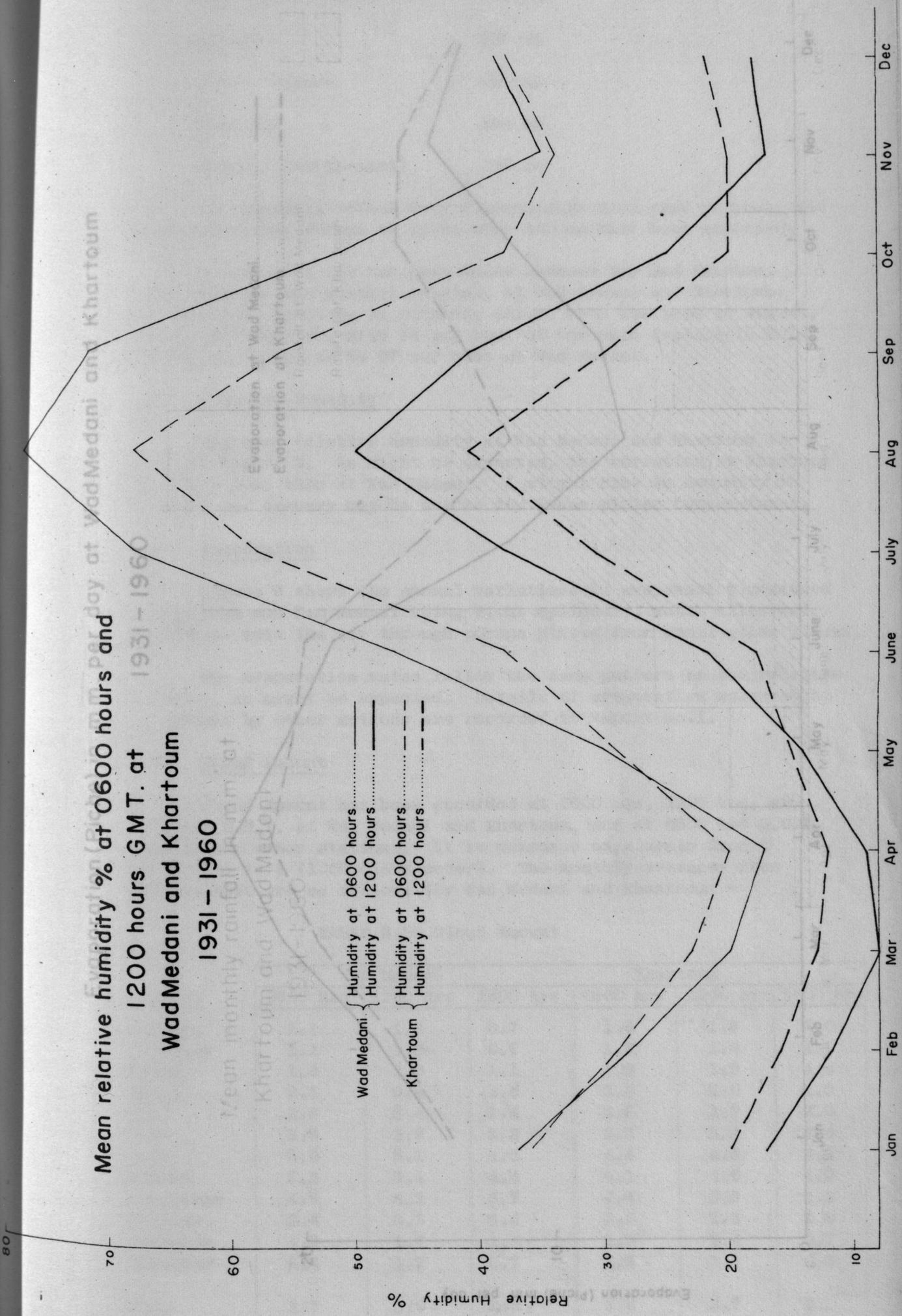


Figure 5

Mean relative humidity % at 0600 hours and
1200 hours GMT. at
WadMedani and Khartoum
1931 - 1960

Wad Medani { Humidity at 0600 hours
 { Humidity at 1200 hours
Khartoum { Humidity at 0600 hours
 { Humidity at 1200 hours



Evaporation (Piche) in m.m. per day at WadMedani and Khartoum

1931 - 1960

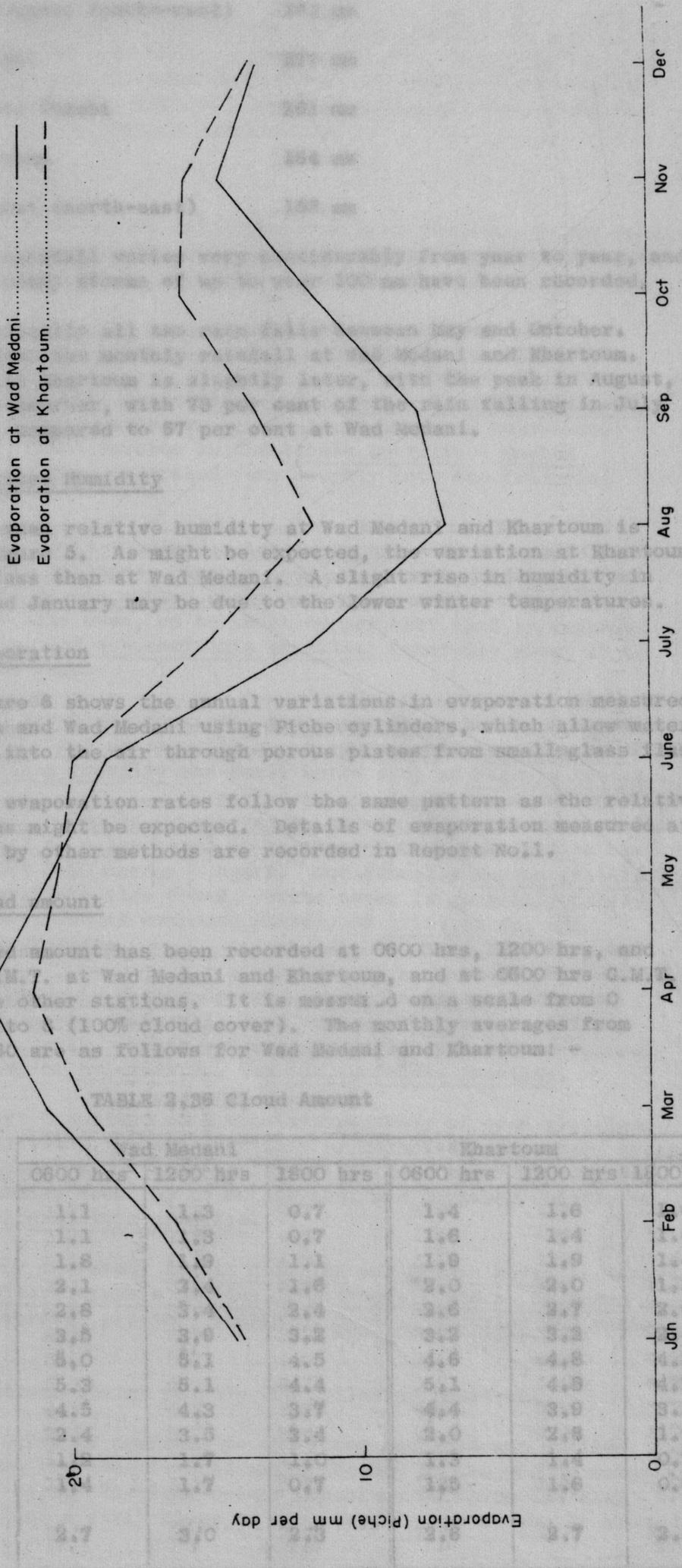


TABLE 2,35 Cloud Amount

	Wad Medani			Khartoum		
	0600 hrs	1200 hrs	1800 hrs	0600 hrs	1200 hrs	1800 hrs
Jan	4.5	4.3	3.7	4.4	3.9	3.3
Feb	4.5	4.3	3.7	4.4	3.9	3.3
Mar	4.5	4.3	3.7	4.4	3.9	3.3
Apr	4.5	4.3	3.7	4.4	3.9	3.3
May	4.5	4.3	3.7	4.4	3.9	3.3
June	4.5	4.3	3.7	4.4	3.9	3.3
July	4.5	4.3	3.7	4.4	3.9	3.3
Aug	4.5	4.3	3.7	4.4	3.9	3.3
Sep	4.5	4.3	3.7	4.4	3.9	3.3
Oct	4.5	4.3	3.7	4.4	3.9	3.3
Nov	4.5	4.3	3.7	4.4	3.9	3.3
Dec	4.5	4.3	3.7	4.4	3.9	3.3

Wad Medani (south-west)	373 mm
Qurashi	277 mm
Wad et Turabi	261 mm
Khartoum	164 mm
Shambat (north-east)	158 mm

The rainfall varies very considerably from year to year, and occasional heavy storms of up to over 100 mm have been recorded.

Practically all the rain falls between May and October. Figure 4 shows the monthly rainfall at Wad Medani and Khartoum. The season at Khartoum is slightly later, with the peak in August, and is also shorter, with 73 per cent of the rain falling in July and August, compared to 67 per cent at Wad Medani.

2.34 Relative Humidity

The mean relative humidity at Wad Medani and Khartoum is shown on figure 5. As might be expected, the variation at Khartoum is rather less than at Wad Medani. A slight rise in humidity in December and January may be due to the lower winter temperatures.

2.35 Evaporation

Figure 6 shows the annual variations in evaporation measured at Khartoum and Wad Medani using Piche cylinders, which allow water to diffuse into the air through porous plates from small glass flasks.

The evaporation rates follow the same pattern as the relative humidity, as might be expected. Details of evaporation measured at Wad Medani by other methods are recorded in Report No.1.

2.36 Cloud amount

Cloud amount has been recorded at 0600 hrs, 1200 hrs, and 1800 hrs G.M.T. at Wad Medani and Khartoum, and at 0600 hrs G.M.T. only at the other stations. It is measured on a scale from 0 (no cloud) to 8 (100% cloud cover). The monthly averages from 1931 to 1960 are as follows for Wad Medani and Khartoum: -

TABLE 2.36 Cloud Amount

Month	Wad Medani			Khartoum		
	0600 hrs	1200 hrs	1800 hrs	0600 hrs	1200 hrs	1800 hrs
January	1.1	1.3	0.7	1.4	1.6	1.0
February	1.1	1.3	0.7	1.6	1.4	1.0
March	1.8	1.9	1.1	1.9	1.9	1.4
April	2.1	2.4	1.6	2.0	2.0	1.3
May	2.8	3.4	2.4	2.6	2.7	2.0
June	3.5	3.9	3.2	3.2	3.2	2.4
July	5.0	5.1	4.5	4.6	4.8	4.2
August	5.3	5.1	4.4	5.1	4.8	4.2
September	4.5	4.3	3.7	4.4	3.9	3.3
October	2.4	3.5	3.4	2.0	2.8	1.9
November	1.2	1.7	1.0	1.3	1.4	0.7
December	1.4	1.7	0.7	1.5	1.6	0.9
Year	2.7	3.0	2.5	2.6	2.7	2.0

Khartoum is seen to have slightly less cloud than Wad Medani. The average cloud cover at both places is over 50 per cent in July and August, falling to under 20 per cent in January and February. Except in August and September, there is generally more cloud at mid-day than in the morning and evening.

2.37 Other Data

No information was available from most stations on the amount of sunshine, solar radiation, or wind direction and speed. Information on these from Wad Medani is presented in Report No.1.

2.4 VEGETATION

Most of the area lies in the Acacia tortilis - Maerua crassifolia Desert Scrub zone, but the southern end is in the zone of Semi-Desert Grassland on clay. Plant species in the Acacia tortilis - Maerua crassifolia zone have been separated very roughly into the following associations: -

- A. Open Acacia tortilis woodland. Acacia tortilis trees, up to about 7metres high, are dominant. Acacia seyal is common, and Balanites Aegyptiaca and Acacia nubica are occasionally found. The grass cover is generally even, up to about 50 per cent, and is composed of Aristida sp. and Schoenefeldia gracilis, generally about 10 to 40 centimetres high.
- B. Acacia nubica scrubland consists of Acacia nubica bushes generally no more than 2metres apart, with a patchy cover of Aristida sp. and Schoenefeldia gracilis and small herbs such as Fagonia cretica.
- C. Acacia tortilis - Acacia erhenbergiana scrub. These two species are co-dominant as a low scrub up to about 3 metres high with bushes generally about 2-10 metres apart. Occasionally Maerua crassifolia and Acacia seyal are also found. Grass cover is generally sparse, about 5 per cent and is composed chiefly of Aristida sp. and Schoenefeldia gracilis.
- D. Acacia sp. - Capparis decidua scrub. Acacia tortilis or Acacia erhenbergiana may be dominant; less commonly Capparis. Acacia seyal may also occur. Grass cover is generally patchy and sparse, and is composed of Aristida sp. and Schoenefeldia gracilis.

The Semi-Desert Grassland zone consists entirely of open grassland, where it is not cultivated. Acacia tortilis or Balanites aegyptiaca trees, up to 7metres high, may occur at intervals of 0.5 kilometre or more. The grass cover is generally even, up to 50 per cent and composed chiefly of Aristida sp. and Schoenefeldia gracilis.

Along the river terraces, Acacia nilotica and Acacia seyal are found with Salvadora persica, Capparis decidua, Calotropis procera, Zizyphus spina-christi, and various grasses, including Cynodon dactylon and various coarse grasses.

These associations occupy roughly the following positions: -

The Riverain Scrub is confined to the river terraces and gullies near the river, where the land is seasonally flooded or the ground water table is seasonally high. The Semi-Desert Grassland occupies the clay soils in the South, and a strip close to the river in the north. It also

covers the clay plain surrounding the Granite outcrops of Jebel Sileitat in the north. The Acacia tortilis woodland occupies most of the sandy clay plains (Region B on the sketch map). The Acacia nubica scrubland occurs in a narrow strip between the Acacia tortilis woodland and the Semi-Desert Grassland in the south, and in scattered patches along the edges of the clay plains in the north. The Acacia tortilis - Acacia erhenbergiana scrubland generally replaces Acacia tortilis woodland to the North and East of Region B, and in Region C of the sketch map. It appears to occupy land from which water is lost by run-off, and the lower rainfall areas to the north, whereas Acacia tortilis woodland occupies the higher rainfall areas in the south and land where run-off water accumulates. Acacia sp. - Capparis decidua scrub occurs in Region B of the sketch map, mostly north of Khartoum and in scattered patches between Khartoum and Umm Dubban. It appears to consist of the inclusion of Capparis in Acacia tortilis - Acacia erhenbergiana scrubland. The factors influencing its distribution are not apparent from this survey. The distribution of the associations found at sites on this survey are shown in Table 2.40

Table 2.40 Frequency Distribution of Vegetation Association at Soil Sites

Vegetation Association	SOIL TYPES					
	Grumustert	Mazustert	Natrargid	Haplargid	Durargid	Orthustert
Semi-Desert Grassland	26	13	18	-	-	3
Acacia tortilis Woodland	-	-	31	-	4	3
Acacia nubica Scrubland	1	-	3	1	-	1
Acacia tortilis - Acacia erhenbergiana Scrubland	1	1	23	2	1	2
Acacia sp.- Capparis decidua Scrubland	2	1	10	1	-	3
Riverain Scrub	2	1	-	-	-	1

This table is based on rather limited information. However, it shows the very marked dominance of open grassland on the cracking clays of Region A on the sketch map.

The boundary between the Semi-Desert Grassland and the Acacia tortilis scrubland is somewhat north and east of the soil boundary between the Vertisols and the Aridisols on the soil map. Acacia tortilis appears to prefer a sandy topsoil, with rapid infiltration, and little or no loss of water by run-off.

2.5 PRESENT LAND USE

The population of the project area is concentrated on a strip of land lying close to the Blue Nile. Many of the towns and villages are located on the river bank whilst others, such as Umm Dubban which is about 25 km from the river, have a plentiful supply of groundwater obtained from shallow wells.

Livestock provide an important source of income to the resident population. Cattle, sheep and goats graze fairly close to the river and usually cross over to the Gezira between May and September when grazing is scarce on the east bank. On the other hand the camels of the Shukriya tribe range far into the Butana grasslands during the rainy season and return to the vicinity of the river in the dry season.

The whole of the project area lies outside the zone receiving more than 400 mm of rainfall per year which is considered necessary for the production of successful raincrops. The 400 mm isohyet runs roughly through a line from Kosti to Wad el Haddad - Wad Medani and then swings due east to the Atbara. The 300 mm isohyet has a similar shape and passes between Qurashi and Rufaa as it crosses the Blue Nile to the south of the project area. In spite of the fact that all the project lands receive less than 300 mm of rainfall per year, however, there are considerable areas in the vicinity of Guneid, Wad Rawa and Eilafun that are used for the production of dura (Sorghum vulgare). These cultivated lands are invariably located on cracking clays (Vertisols) where run-off from higher lands is concentrated behind low earth banks called 'Terus'. As in the Managil rainlands, quick maturing types of dura are grown, the most favoured varieties being Feterita and Gassabi. No rotation is practised; the same land is cropped to dura year after year with enforced resting periods only resulting from failure of the rains. Crop yields have not been measured but they are undoubtedly low in years of average rainfall. It is a system of catch cropping designed to supplement income from livestock and other sources and so provide homegrown grain for the local inhabitants. Only in years of above average rainfall would a surplus be produced for sale outside the district.

CHAPTER 3

SOIL SURVEY METHODS

3.1 AERIAL PHOTO INTERPRETATION

On a reconnaissance survey, in order to be able to base a reasonably accurate soil map on the limited number of sites that can be investigated, it is essential to correlate as completely as possible the information obtained from field soil descriptions with the various features that can be seen on the aerial photographs.

The method used on this survey was to site the bores or pits, within the framework of a 10.5 square kilometre grid, on as wide a variety of visible surface patterns as possible, and to attempt to correlate the data obtained with these patterns. As only a limited number of sites was sampled, this correlation has been based on the soil characteristics observed in the field. It was found that the Soil Groups, and in many cases the Sub-groups, could be separated by interpretation of the features visible on the aerial photos.

Final mapping was carried out with the aid of stereoscopic examination; although, in this area, variations of relief are so slight that most boundaries, except those of sloping gullied land or of the sandstone ridge in the east, are not clarified by the use of a stereoscope.

The following is a brief description of the physiographic units in this area, with associated soil types, as they are seen on the aerial photographs: -

Along the river, the recent alluvial terraces are dark grey, generally with a pattern of small rectangular pump-irrigated fields. These border sharply onto the higher ground to the east. Generally for about a kilometre from the river this is light grey, with a dendritic pattern indicating land gullied by run-off water, sloping down towards the river. There is generally a sharp boundary between this and somewhat darker grey even-coloured land, which is generally divided into small irregular or rectangular blocks of different shades. These are the cracking clays of region A on the sketch map. They are mostly under rain-fed sorghum cultivation. The darker patches indicate recent sorghum stubble, while the lighter patches indicate land not cultivated for some time, now under grass. Occasional black dots indicate Acacia tortilis or Balanites aegyptiaca trees.

On flat land, the fields are irregularly shaped, but where there is a slight slope they are elongated and rectangular, the long sides pointing up the slope. The uphill ends are open, in order to catch run-off water from the uncultivated grassland nearby. This grassland appears light grey on the aerial photographs, generally with a pattern of whitish lines (animal tracks) and fewer dark lines (main animal tracks or motor tracks), and villages surrounded by areas of dark bare ground. Here the soils have a poorly structured surface, often with some sand and gravel. The boundary between the Vertisols and the Aridisols is along the edge of this grassland and the cultivated land.

Merging into the open grassland are areas, similarly light grey in colour, with very many small whitish dots. This is the Acacia nubica scrubland. The Acacia tortilis scrubland shows up as a light grey surface with black dots up to 0.5 mm across and a few mm apart. The Acacia tortilis - Acacia erhenbergiana scrubland shows up as many very small

black dots with occasional larger ones up to 0.5 mm across. In this type of country the background colour may sometimes consist of mottled dark and light grey shades, which indicates uneven land, the low ground of which may be seasonally flooded. North-east of Khartoum, there is a pattern of light coloured low sandy ridges, covered with Acacia tortilis trees, running north - south, with a darker grey, somewhat mottled surface indicating lower lying seasonally waterlogged, sparsely vegetated land between them.

Region C of the sketch map, the area of low sandstone ridges, can be distinguished by its dendritic pattern of shallow gullies, often visible as lines of small black dots - Acacia erhenbergiana bushes.

Region D of the sketch map appears as typical grassland - light grey - with a few tracks crossing it. Some dark patches of rainfed sorghum cultivation are visible between the granite outcrops. The outcrops themselves appear as much broken dark patches, surrounded by a piedmont somewhat lighter in colour than the surrounding grassland. There is a sharp boundary between the piedmont and the grassland, suggesting that the products of weathering of the granite form a superficial layer over the deposits forming the level plain.

On many photos there are large black or very dark grey patches, bordering abruptly on the normal colours of the land. Their edges often coincide with tracks or roads. These are areas where the grass has been burned off. The more recent the fire, the darker the colour.

3.2 SOIL SURVEY PROCEDURES

Aerial Photographs of Area 3d were flown by the Sudan Survey Department in 1961-62 at a scale of 1:25,000, and were compiled into mosaics at a scale of 1:50,000 by Hunting Surveys Ltd. in 1963.

As the mosaics were not available for the survey, the Sudan Survey 1/50,000 maps dated 1954 of the Blue Nile, and the 1/100,000 maps dated 1952, of the Main Nile, were used as field base maps.

The Reconnaissance Survey was commenced in November 1962. A preliminary study was made of the maps and the aerial photographs, together with a field trip by the Consultant in charge and the Soil Surveyor, to establish some idea of the terrain.

In order to ensure the required intensity of investigation of one auger hole or pit per 2,500 feddans, a 10.5 square kilometre grid was marked out on the base maps, one site to be investigated within each square of the grid. This grid was transferred to the aerial photographs as the survey progressed and the photographs could be located accurately by means of the 26 ft survey posts. The sites were then selected within the grid to cover as wide a range as possible of the landforms that could be differentiated on the photographs. The following investigations were then carried out: -

1. Bores were dug to a depth of 2 metres, and the profile described. These were not sampled.
2. Pits were dug to a depth of 2 metres at selected sites, representative of the different soil types found in the area. These were sampled at the rate of one sample per horizon described.

A total of 130 bores and 26 pits was investigated, and 143 samples were taken for the following laboratory analyses: -

Mechanical analysis (international fractions).

Incorporated Carbonate.

p H on soil paste and 1:5 Suspension.

Salinity test (E.C. on saturation extract).

Soluble sodium in saturation extract.

Exchangeable sodium content.

The exchangeable sodium percentage (E S P) is calculated from the exchangeable sodium content and the percentage of clay in the soil.

3.21 Field Permeability Studies

Field permeability tests were carried out at 5 pit sites. Two tests were made at 1 of these sites so a total of 6 tests was made.

The method was adapted from the type 'A' test described in the Earth Manual, United States Bureau of Reclamation, 1951, as used by Hunting Technical Services Ltd. in their Kirkuk (Iraq) and Pangani (Tanganyika) projects.

Apparatus:

Land Rover	Clean gravel
2 x 40 gallon drums	Mirror
2" Jarret auger	50 c.c. graduated cylinder
10 m rubber tubing	250 cc. graduated cylinder
2 screw clamps	Stopwatch
2 m measuring tape	Thermometer
	1 Surveyors Umbrella (optional)

Procedure:

The tests were carried out in or beside the 2 metre pits dug during the soil survey, whose textural layers had previously been defined and described. Horizons more than 25 cm. had to be used as the method is unreliable where the length of the test section is less than five times the diameter of the bore. The top of the horizon was cut back as a step in the pit and a hole bored in it vertically with the Jarret auger. The bore was examined with a mirror and was only used if no cracks were visible. Despite this caution many tests proved abortive through water escaping down concealed cracks after the test was started. Such escape nullifies the value of many results in the clay soil because it destroys the conditions on which the theoretical calculations depend.

If the inflowing water is colder than the soil, dissolved air comes out of solution as it enters the soil and the bubbles produced block the soil pores and reduce the soil permeability. As the water was if anything slightly warmer than the soil, however, it was considered that possible errors from this source could be neglected.

After boring, the depth of the hole is measured in centimetres. A few handfuls of gravel are then put in and a 1 metre length of auger tubing inserted. The hole is then filled with gravel. The top of the gravel is considered to be the top of the test section. Its depth below the top of the hole is measured and subtracted from the total hole depth to give h, the height of the test section. The gravel is needed to prevent the hole collapsing when wetted and the auger tubing is needed to facilitate the introduction of the water.

The hole is then filled to the mark with water from the drum through the rubber hose. The screw clamp on the hose is used to maintain the water surface at the level of the top of the gravel. The rate of inflow is measured at 5 minute intervals by catching the flow in a graduated cylinder for a time period. This rate steadily decreases at first but becomes more uniform after 20 minutes, and the final reading of the rate of flow is taken when the readings have become reasonably constant - generally 30-45 minutes after the commencement of the test.

From the final reading the permeability is deduced from the formula given below:

$$K = \frac{864Q}{C\sqrt{rh}}$$

where K = coefficient of permeability in m/day/unit hydraulic gradient

Q = rate of steady inflow in ml/sec.

r = radius of bore in cm.

h = height of water column in cm.

Cu = coefficient of conductivity obtained from Table 3.210

Table 3.210 - Coefficient of Conductivity

h/r	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5
Cu	32.0	32.9	33.7	34.5	35.3	36.1	36.9	37.8

h/r	14.0	14.5	15.0	16.0	17.0	18.0	19.0	20.0
Cu	38.6	39.4	40.2	41.9	43.5	45.2	46.8	48.5

The following sources of inaccuracy became apparent during the tests: -

1. When the permeability is low, the variations in water level caused by altering the rate are very slow and so the percentage error is likely to be high..
2. The height of the tap above the ground must be kept constant. If the water is poured into the cylinder from a higher level than into the auger hole, the "head" of water is reduced and the flow becomes slower.

3. Any changes in the position of the rubber water pipe may cause it to be pinched at some point and so cut off the flow.

The following results were obtained: -

Table 3.211 Field Permeability Measurements

Pit No.	Depth	Soil Particles %			Field Texture	Hydraulic Conductivity m/day/unit gradient
		Sand	Silt	Clay		
DR 125 (1)	4 - 48 cm	70	7	23	Sandy Clay Loam	0.023
		85	2	13		
(2)	63 - 106 cm	80	5	15	" " "	0.011
		75	5	20		
R 021	49 - 91 cm	72	5	23	Coarse Sandy Clay	0.032
		55	5	40		
R 025	47 - 91	67	8	25	Coarse Sandy Clay	0.015
		65	5	30		
R 017	52 - 97	42	10	48	Sandy Clay Clay Loam	0.039
		45	10	45		
R 012	46 - 89	55	7	38	Gravlyly Clay Loam Clay Loam	0.007

No tests were carried out on Vertisol profiles, as a number of such profile have been tested elsewhere (see Report No.1). The results on these Sandy Clay profiles are surprisingly low - lower than most results from the clays.

3.3 CHEMICAL ANALYSES OF SOILS

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

3.31 Mechanical Analysis: Bouyoucos Hydrometer Method

40 grams soil soaked with 25 ml. water and 11 ml. of 10 per cent sodium hexametaphosphate solution overnight; next morning dispersed in electric stirrer for 10 minutes, transferred to 1 litre measuring cylinder, shaken and readings taken after 4 minutes, 2 hours and 7 hours. With every reading the temperature is recorded and corrections made for temperature and dispersing agent content. The readings are also corrected for moisture content, when required, by performing separate moisture determination.

3.32 pH

Potentiometric determination using glass electrode on saturation extract, soil paste or 1:5 extract as required.

3.33 Electrical Conductivity

By using Solubridge on saturation extract or soil paste, as required.

3.34 Carbonate as Incorporated Calcium Carbonate

Gasiometrical determination in Collins calcimeter (ref. Collins S.H. 1906, J.Soc. Chem. Ind. 25: 518). The volume of CO₂ 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.

3.35 Soluble Sodium in Saturation Extract

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

3.36 Exchangeable Sodium

12.5g, of soil are soaked in 50 ml. of normal ammonium chloride, left for one hour and 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 flamephotometer against 10 ppm. sodium standard containing the same amount of ammonium chloride. Zero is set with 0.05 N. ammonium chloride. From these readings the sum of soluble plus exchangeable sodium is calculated. By subtracting the soluble sodium from saturation extract data the net figure for exchangeable sodium is obtained.

3.4 MAP COMPILATION

3.41 The Base Map

The Base Map was compiled from the following maps: -

1/50,000 Sudan Survey Maps dated 1954, covering the Blue Nile Right Bank from Guneid to Soba Sharq.

1/100,000 series dated 1952, Sheets 1 & 2 Survey of Irrigable Area

Additional information was transferred from the current 1/250,000 series maps covering the area.

The base map was produced by Sir M. Macdonald and Partners at a scale of 1/100,000.

The investigated sites were marked on the base map as follows: -

o 2 - metre bores. Not Sampled.

△ 2 - metre pits. Sampled.

The numbers 0 to 99 are preceded by the letter R. The numbers 100 to 156 are preceded by the letters DR to avoid confusion with soil descriptions from other surveys.

3.42 The Soil Map

The classification of the individual sites have not been marked on the soil maps. The soil boundaries were determined stereoscopically on the aerial photographs, and then transferred freehand onto the map. The soil classification used is explained fully in Chapter 4.

3.43 The Land Suitability Map

The areas recommended for semi-detailed investigation were transferred directly from the soil map.

4.11 Vertisols

The soils of Region A of the sketch map consist of clays, probably of Ethiopian origin, transported by the Blue Nile and the Rahad, with little or no addition from local sources. The profile of these soils is similar to that found in the Gezira. The texture is uniform throughout the profile, though the surface horizon is generally somewhat coarser than the underlying soil. The colour is uniformly very dark grey or greyish brown to a depth of about 150 cm, at which level there is normally a marked break to a paler reddish brown clay. The surface may consist of a loose mulch of small hard aggregates, with a polygonal pattern of wide, partly infilled cracks, or it may be level with a soft, poorly structured surface horizon, and generally a faint pattern of old infilled cracks. The type of surface of these soils appears to be linked with the land use. Of 32 profiles with a mulch surface, 28 had been under cultivated surplus within the last few years, and 5 were uncultivated. Of 17 profiles with a crusty or poorly structured surface, 14 were uncultivated, and only 3 showed signs of sorghum cultivation. This connection could be due to the fact that cultivation only takes place where the water accumulation is greatest, either due to higher rainfall or to run-off from other areas. In these areas the effect of wetting and drying of the clay would be marked, with the consequent appearance of these self-mulching characteristics at the surface. Also, the effect of periodic cultivation may be to destroy the poorly structured surface horizon, and so improve infiltration.

The surface of the soil is commonly covered with dark coloured calcic carbonate concretions. These occur to a depth of half a metre or more in the profile, when they are replaced by light-coloured concretions which become larger with depth. Verrill (1951) found that the dark colour in these concretions was due largely to manganese salts, which form an outer 'rim' on the dark concretions, and occur as dark patches or 'condrites' inside the light-coloured concretions.

He suggests that the concretions all form as light coloured ones, and that some have subsequently been moved towards the surface of the soil, when the manganese salts have migrated to the outside. The accumulation of concretions on the surface may be due to removal of the finer material by wind, or to the periodic rainstorms washing the more easily transported clay down the cracks in the soil.

CHAPTER 4

SOIL CLASSIFICATION

4.1 ORIGINS AND GENERAL MORPHOLOGY

As has been recorded in Chapter 2.2, the soils over most of the area within the 20 metre Isopotamon are clays deposited from the Blue Nile and the Rahad under seasonally flooded conditions, mixed in places with colluvium from the high ground immediately to the East. These soils, covering regions A and B of the accompanying sketch map Fig.2 are generally alkaline, with a pH between 8 and 9.5, and high percentage of exchangeable sodium in the clay complex.

4.11 Vertisols

The soils of Region A of the sketch map consist of clays, probably of Ethiopian origin, transported by the Blue Nile and the Rahad, with little or no addition from local sources. The profile of these soils is similar to that found in the Gezira. The texture is uniform throughout the profile, though the surface horizon is generally somewhat coarser than the underlying soil. The colour is uniformly very dark grey or greyish brown to a depth of about 150 cm, at which level there is normally a marked break to a paler mottled brown clay. The surface may consist of a loose mulch of small hard aggregates, with a polygonal pattern of wide, partly infilled cracks, or it may be level with a soft, poorly structured surface horizon, and generally a faint pattern of old infilled cracks. The type of surface of these soils appears to be linked with the land use. Of 32 profiles with a mulch surface, 26 had been under rain-fed sorghum within the last few years, and 6 were uncultivated. Of 17 profiles with a crusty or poorly structured surface, 14 were uncultivated, and only 3 showed signs of sorghum cultivation. This connection could be due to the fact that cultivation only takes place where the water accumulation is greatest, either due to higher rainfall or to run-off from other areas. In these areas the effect of wetting and drying of the clay would be marked, with the consequent appearance of these self-mulching characteristics at the surface. Also, the effect of periodic cultivation may be to destroy the poorly structured surface horizon, and so improve infiltration.

The surface of the soil is commonly covered with dark coloured calcium carbonate concretions. These occur to a depth of half a metre or more in the profile, when they are replaced by light-coloured concretions which become larger with depth. Worrall (1961) found that the dark colour in these concretions was due largely to manganese salts, which form an outer 'rim' on the dark concretions, and occur as dark patches or 'dendrites' inside the light-coloured concretions.

He suggests that the concretions all form as light coloured ones, and that some have subsequently been moved towards the surface of the soil, when the manganese salts have migrated to the outside. The accumulation of concretions on the surface may be due to removal of the finer material by wind, or to the periodic rainstorms washing the more easily transported clay down the cracks in the soil.

Gypsum is commonly present at various depths, especially between 100 and 150 cm. It has been found at this depth by Worrall (1961) as fibrous crystals in old wide curved oblique cracks. These structures appear to be caused by differential movement of the soil due to a self-mulching process - contraction and deep cracking of the clay in dry weather, and the breaking up of the surface horizon into small aggregates which fall down the cracks, then expansion on wetting, with considerable stresses resulting in the subsoil. He suggests that since this fibrous gypsum is very slow to form, the self-mulching processes which produced these structures have long since ceased. In any case, the present rainfall is insufficient to account for such violent expansion and contraction.

The structure of these soils was generally found to be moderate or strong prismatic to a depth of 30 or 40 cm, and structureless or weak prismatic or blocky below. Some old cracks, infilled with material from above, were found to a depth of a metre or more. It appears that these soils were once self-mulching to a depth of about 150 cm, which is the lower limit of the dark colour. In area 3c, it was found that vertical cracks in the soil extended to the base of the dark coloured horizon, and that the percentage of carbon in the soil was uniform to this depth, below which it fell off sharply. This suggests that there the self-mulching process may be continuing.

The sequence of events in the formation of these soils appears to have been as follows -

1. Deposition of clay under seasonally flooded conditions.
2. Mixing of about the top $1\frac{1}{2}$ metres of the profile by self-mulching, under either seasonally flooded conditions or a somewhat wetter climate than that of the present day.
3. With a change to drier conditions, the self-mulching process appears to have become confined to the top 30 to 40 cm of the soil, and some reduction in the clay content has resulted either from downward washing or from removal of the clay fraction by wind.

The soils are generally somewhat saline, with the Electrical Conductivity and the soluble sodium percentage reaching a maximum at a depth of about 50 cm to 1 metre, and falling off lower down. The Exchangeable Sodium Percentage (E.S.P.) of the sorption complex of the clay is low in the surface horizons, and is generally constant at a higher level from 30 or 40 cm downwards. This suggests that there is some leaching of these soils going on, with accumulation of sodium salts, and probably clay, lower in the profile.

4.12 Natrargids and Haplargids

Region B of the sketch map consists of clays of Ethiopian origin mixed with colluvium from the high ground along the eastern edge of the area. The soils vary from sandy loams near the high ground to clays and clay loams near the lower edge of this plain. The profile is commonly as follows: -

The surface horizon is a sandy or gravelly loam, 10 to 15 cm thick, brown or reddish brown in colour, with a weak or moderate subangular blocky structure, and much quartz sand or gravel. At this level there is a sharp break to a darker brown or greyish brown colour, and the soil is finer in texture, generally with a

moderate or strong prismatic structure to about 30 or 40 cm, and massive below. Old cracks are found to a depth of about a metre, infilled with sandy material, and sometimes polished clay surfaces - slickensides - are found in the subsoil. Generally, at a depth of 1 to 1½ metres, there is a break to a paler coloured, mottled clay.

The analyses of the samples of these profiles generally show a sharp increase in clay content from the first to the second horizon, and a more or less constant clay content in the lower horizons, at least to 100 or 150 cm. Below this level, the clay content is higher in some profiles (e.g. R025), and a good deal lower in others (eg R012, R095).

The surface of these soils is generally level and firm, with no visible cracking, other than a finely cracked 'rain cap'. It is generally covered with a good deal of sand and gravel, mostly quartz, and in many places with dark coloured calcium carbonate concretions. Generally, the surface is pitted with 'sink' holes up to six inches deep, a few yards apart. These are where the sandy surface material has been washed down cracks in the subsoil by rain water. During the course of some permeability studies, it was found that water poured onto the surface did not penetrate readily, but if some of the topsoil was removed, the water ran away rapidly down the cracks in the second horizon, carrying the loose topsoil with it. The presence of 'sink' holes does not appear to be connected with the clay content of the soil, and it may be that they are concentrated in the somewhat lower land, where run-off water accumulates. The appearance of calcium carbonate concretions on the surface seems to be restricted to sites near the lower edge of this plain, but is not clearly related to any features in the profile. Only four sampled sites on this type of soil have calcium carbonate concretions at the surface. They do not show any particular trend either in clay content or the amount of free carbonate in the samples.

Other forms of calcium carbonate found in the profile include: -

1. Soft white vertical streaks down the profile, especially between about 10 cm and 50 cm. (The sides of pits exposed in this soil look rather like cliffs inhabited by sea-gulls).
2. Soft and hard light coloured concretions, generally appearing at 50 to 100 cm and increasing in number and size further down the profile. These are found in profiles both with and without dark coloured concretions at the surface.
3. The dark concretions, where they are found at the surface, occur in decreasing numbers to a depth of 50 cm or 1 metre, and are generally associated with light coloured concretions at greater depths.

Gypsum is found at many sites, occurring at various depths in the profile, normally below 50 cm and above 150 cm. The different crystal forms of gypsum were not recorded on this survey, but Worrall (1961) records fibrous crystals deep in the profile and small lenticular plates at higher levels in his High Level Dark Clays, which appear to be comparable to the soils described here.

The Electrical Conductivity and percentage of soluble Sodium ions in the saturation extract of the soil samples are very low in the surface horizons they rise to a maximum, generally of 8 mmhos or more, between 50 and 150 cm, and fall off below this level. The Exchangeable Sodium Percentage of the sorption complex is also very low in the topsoil, but is constant at a high level below about 30 cm. Almost all the soils are alkali, and generally somewhat saline, but some non-alkali and non-saline soils appear to occupy sloping land or low sandy ridges:

The history of the formation of these soils appears to be roughly as follows: -

1. Deposition of clay from the Blue Nile and the Rahad mixed with colluvium from the nearby high ground, under seasonally waterlogged conditions.
2. In areas where a high percentage of clay has been deposited, there has been some churning of the soil to a depth of 1 to $1\frac{1}{2}$ metres, which ceased with the onset of drier conditions, leaving the soil with wide cracks.
3. Subsequently, sandy material has been washed or blown over the land surface from the nearby high ground, filling in the old cracks and covering the old soil to a depth of a few cm.
4. Under present conditions, the rainfall is sufficient to thoroughly leach the topsoil of salts which accumulate further down the profile, probably together with some clay. Some leaching of carbonates is also evident, from the vertical streaks down the profile. The resultant profile is solonetzic in appearance, with a poorly structured surface horizon, and a prismatic horizon beneath, with some evidence of downward clay movement in the form of clay skins.

It appears that the present rainfall is only sufficient to produce structure in the soil to a depth of 30 to 40 cm.

4.13 Durargids

Region C of the sketch map (Fig.2) is the edge of the high ground which has contributed to the formation of the soils of Region B. This is an old erosion surface, consisting of outcrops of sandstone, and iron-cemented sand and conglomerates, with red sandy clay soils and ironstone gravel on the lower land. The soils are non-saline, non-alkaline, and have a pH between 7 and 8. Two profiles of this type of soil were sampled, RO20 and DR143. In both, the soil was reddish brown, the texture becoming finer with depth to about 1 metre, when there was a sharp break to a brown iron-stained gravel. At RO20, the gravel appeared to consist of small iron concretions about 0.5 to 1 cm across - 'Pea Ironstone Gravel', but at DR143 it was found to be small iron-stained quartz grains, all 0.2 to 0.5 cm in diameter. At RO20, some hard, horizontal discontinuous iron pans were found in the gravel, apparently formed in situ;

The soils are poorly structured but friable, porous and rapidly water absorbent. The low salinity and alkalinity, together with the increasing clay content of the profile with depth, suggest that the soils have been fairly strongly leached in the past, but this may be due partly to the leached sandy parent material from which the soils have been derived.

4.14 Entisols

The soils of Region D of the sketch map (Fig.2) appear to be somewhat different from those found elsewhere. The surface is covered with stones larger than those found on any other soils, but there is little or no sand. There are no 'sink' holes, nor is there any cracking or mulching. The soil is uniformly coloured throughout the profile. Structure is not normally strong anywhere, but some structure is found to a considerable depth (DR156). The soils are generally friable, and the subsoil is very much less compact than that of any other clay in the area. Some calcium carbonate concretions - only light coloured - are found in the profile, and gypsum at some sites. No data is available on the mineralogy of these soils, but the differences in their physical appearance, and the fact that they occur at a higher level than the riverain deposits of regions A and B of the sketch map, suggest that these soils are of a different origin. It is difficult to see how such soils could have originated as a result of weathering of the granite outcrops which they surround. The only remaining alternative is that their origin is connected with the few large gullies which form another feature of this area. The soils immediately below this plain, in the outwash from these gullies, are found to have similar weak horizon development, and may consist of Gezira type clay modified by material from the gullies.

4.2 SOIL CLASSIFICATION SYSTEM

The soils of the project area have been classified according to the specifications of the U.S. Department of Agriculture (1960), the Seventh Approximation. See Table 4.3 and the soil map. The soil orders, sub-orders, great groups and subgroups are defined as follows: -

Vertisols are clayey mineral soils containing more than 35 per cent of an expanding lattice type clay and having more than 30 milliequivalents exchange capacity per 100 grams of soil in all horizons below the surface 5 cm. When not irrigated they exhibit cracks 1-25 cm. wide extending from the surface to the middle of the solum.

They are characterized by one or more of the following: -

- (1) Gilgai (microrelief of basins and mounds).
- (2) Slickensides close enough to intersect or,
- (3) At some depth between 25-100 cm wedge shaped or parallelepiped structural aggregates with their long axis tilted 10-60 degrees from the horizontal.

Vertisols are found throughout the world in the subhumid to arid regions. The central concept is one of soils that crack widely and that often remoisten from water that runs into the cracks rather than from water that percolates through the soil. If the surface mulches during the dry season there may be a significant amount of surface material that sloughs into the cracks. The moistening and swelling of a layer, with dry soil above and below, causes shearing within the soil and produces slickensides and wedge shaped or parallelepiped structures.

Usterts are generally restricted to the drier climatic range of the vertisols. Soil colours show chromas of more than 1.5 throughout the upper 30 cm and lack distinct or prominent mottling within the surface 75 cm. The hues are often redder than 10 YR.

Grumusterts have, when dry, a loose, porous mulch of discrete, very hard aggregates, dominantly less than 3 mm in diameter; they do not have a platy or massive surface crust containing uncoated silt and sand grains that persists after drying.

Orthic Grumusterts have, throughout each pedon (soil unit), moist colour values of 3.5 or less and dry values of 5 or less to a depth of 30 cm. They have less than 15 per cent extractable sodium in all parts of the upper 30 cm.

Natrargidic Grumusterts have more than 15 per cent extractable sodium in some part of the upper 30 cm.

Mazusterts have a platy or massive surface crust, the upper surface of which has a light coloured matrix of uncoated silt and sand thick enough to be visible in cross section without magnification, or that have fragments of such a crust in the plough layer.

Orthic Mazusterts have a surface horizon 30 cm or more thick and colours throughout that are as dark or darker than 3.5 when moist and 5 when dry. They have less than 15 per cent extractable sodium throughout the upper 30 cm.

Natrargidic Mazusterts have 15 per cent or more extractable sodium in some part of the upper 30 cm. They are usually dry throughout the soil.

Entisols are soils either without natural genetic horizons or with only the beginnings of horizons. The horizons present are so weakly expressed that they fail to meet the requirements of any of the diagnostic horizons, except the albic (white) horizon and those that are produced through cultivation by man. At one extreme in age an Entisol might consist of very recent alluvium; at the other extreme in age it may include quartz sands that have been in place for many thousands of years. These soils are found throughout a wide range of climates. The central concept includes soils in deep regolith or earth with no horizons except a plough layer. Colour is not of significance in defining the Entisols.

Ustents are Entisols that, unless irrigated, are dry soils. They include many of the soils of arid and semi-arid regions of the world that have been called Lithosols, Regosols and Alluvial soils. The Ustents have ochric epipedons (light coloured surface horizons). They lack other diagnostic horizons, although they may have discernible secondary carbonates or accumulations of salts. They may even show slight cementation in some horizons, enough to give few to many hard or very hard disconnected nodules. Unless the soil is irrigated, moisture is held at tensions of more than 15 atmospheres throughout the soil for more than half the year. If irrigated, the soil soon becomes dry when irrigation ceases.

Orthustents include dry, loamy soils with textures finer than loamy fine sand extending to 50 cm. or more. They have an ochric epipedon that may or may not be slightly darker than the underlying horizons or layers. Weak cementation that is not destroyed by soaking in acid is permitted in the lower horizons if only cemented nodules are present. Accumulations of secondary lime, gypsum or salts may be seen as efflorescences or mycelia. Distinct CS and SA horizons may be present but not gypsic or

salic horizons (accumulations of gypsum exceeding 5 per cent or soluble salts exceeding 2 per cent). Redistribution of carbonates sufficient to give a CA horizon underlying a horizon that has lost its carbonates is not permitted, for the leached horizon comes within the definition of a cambic horizon (a changed or altered horizon). These soils are found on flood plains, fans and uplands throughout the arid and semi-arid regions of the world. Vegetation, if undisturbed, consists of annuals and zerophytic perennials.

Orthic Orthustents are loamy soils extending to 30 cm or more, having less than 40 per cent expanding lattice clay and in lower horizons lacking cementation into small nodules that will not soften in acid. Secondary accumulations of gypsum and salts that do not constitute gypsic or salic horizons are permitted but not required. Visible secondary lime is also permitted but leached surface horizons lying on CA horizons are excluded.

Vertic Orthustents have more than 40 per cent expanding lattice clay but lack the cracks, slickensides, gilgai or structure diagnostic for Vertisols. In other parts of the world these soils are generally shallow over basic rock. In the project area, however, they consist of isolated mounds of wind blown material aggregated to fine sand size.

Lithic Orthustents have hard rock (usually ferruginous sandstones) at shallow depths in the profile. Rock outcrops in each pedon are common but are not required in the subgroup. Textures are variable; they are sometimes gravelly or stony but they do not include clays that have 40 per cent or more expanding lattice clay. The soils in this subgroup have previously been called Lithosols for the most part.

Natrargidic Orthustents have 15 per cent or more extractable sodium in some part of the upper 50 cm. These soils are an intergrade towards the Natrargid great group of the Order of Aridisols; they do not, however, show indications of clay migration or the formation of an argillic horizon.

Aridisols are primarily soils of dry places. They have an ochric epipedon (light coloured surface horizon) and one or more additional diagnostic horizons. These are cambic, argillic, natric, calcic, gypsic and salic horizons and duripans. The Aridisols do not have a spodic or oxic horizon, nor do they have a mollic or umbric epipedon. Included in the Order of Aridisols are most soils that previously were called Desert Soils, Red Desert Soils, Sierozems, Reddish Brown Soils and Solonchaks. Some of the Regosols and Lithosols of dry climates and some Brown Soils and Solonetz are also included.

Argids are the Aridisols that have an ochric epipedon and a subsurface argillic or natric horizon. They are dry most of the time unless irrigated. They may also have a calcic, gypsic or salic horizon or duripan. In the arid regions of the world where these soils are found the associated vegetation commonly consists of scattered, zerophytic, woody or succulent plants, and annual grasses and herbs. Towards the margins of the desert, grasses become dominant but as a rule do not form a sod; rather they seem to have been scattered perennial or annual plants. Some of the Argids are on old land surfaces, perhaps early Pleistocene; others, particularly those with a natric horizon, are found on much younger surfaces. Bedrock may be deep or shallow; where shallow, raptic intergrades with the Entisols or "not-soil" are common.

Haplargids are the Argids that have an ochric epipedon and an argillic horizon. They do not have a natric horizon or a duripan. They often have a Ca horizon below or in the base of the argillic horizon. Where

they have been mapped in other parts of the world the Haplargids are associated with old land surfaces (older than the last glacial substage) and at some stage in their development have been under a more humid climate than the present. In the U.S. the Haplargids are found on the rocky slopes above the desert fans and on the oldest parts of the fans.

Durargids are the Argids that have an ochric epipedon, an argillic horizon and an underlying duripan. Like the Haplargids they are found on old land surfaces and have formed under a more humid climate than the present.

Natrargids are the Argids that have an ochric epipedon and a natric horizon (E.S.P. exceeds 15 in a subsurface argillic horizon). Unlike the Haplargids they may be usually moist but conductivity of the saturation extract must exceed one millimho at some depth. In the U.S. the Natrargids are often found on the lower slopes of fans of late Wisconsin age or possibly even more recent; in this topographic position they receive run-off from higher areas.

4.3 SOIL CLASSES

The soils described in Section 4.1 have been classified as follows (see Table 4.3): -

The clay soils of Region A of the Sketch Map, and the more recent river terraces, have been classified as Vertisols. They have been separated into Grumusterts and Mazusterts according to the structure of the surface horizon. Separation of these into the Orthic and Natrargidic subgroups depends upon the soil analyses. From the limited amount of information available it appears that the soils of the recent river terraces are Orthic Grumusterts, while those of the rest of Region A include some Natrargidic Grumusterts and Natrargidic Mazusterts.

The soils of Region B are Aridisols, with an ochric epipedon and a subsurface natric and argillic horizon. Those have been separated into Haplargids, with an argillic horizon but no natric horizon, and Natrargids, with a natric horizon with over 15 per cent exchangeable sodium, and an argillic horizon.

The soils of Region C have been classified as Durargids. They have an argillic horizon, and generally an underlying Duripan, composed of discontinuous iron pans or "pea ironstone" gravel - small round iron concretions.

The soils of Region D are orthustents, showing little horizon development. Along the lower edge of this plain are Natrargidic Orthustents, with over 15 per cent Exchangeable Sodium in some part of the upper 50 cm. The area mapped as Lithic Orthustents is in fact a complex of Lithic Orthustents, with hard rock within 30 cm and Orthic Orthustents up to over 2 metres deep, though the surface may be covered with boulders.

TABLE 4.30

Order	1. Entisol	2. Vertisol	3. Aridisol

SOIL CLASSIFICATION CHART

U.S.D.A. 1960 SYSTEM

TABLE 4.30

Order	Sub Order	Great group	Sub Group
1. Entisol	1.3 Ustent	1.32 Orthustent	Orthic Orthustent Lithic Orthustent Natragidic Orthustent
2. Vertisol	2.2 Ustert	2.21 Grumustert 2.22 Mazustert	Orthic Grumustert Natragidic Grumustert Orthic Mazustert Natragidic Mazustert
4. Aridisol	4.2 Argid	4.21 Haplargid 4.22 Durargid 4.23 Natrargid	

CHAPTER 5

ENGINEERING STUDIES

5.1 INTRODUCTION

The Terms of Reference for engineering studies to be included in the reconnaissance surveys are stated in the contract for the Soil Survey of Irrigable Lands in the Sudan as follows: -

"An engineering survey to establish the 20 metre isopotamon using data on river levels supplied by the Ministry of Irrigation, excluding lands where a major topographical obstacle is encountered between the 20 metre isopotamon level and the river. Adequate field survey shall be carried out to establish these levels and define the irrigable areas".

The term isopotamon was first used by the Sudan Survey Department in their 1951/52 Survey of Irrigable Lands in Northern Province and was defined as: -

"A line formed by the intersection of the ground and a surface parallel to the surface of the river at mean low water level".

The reconnaissance engineering studies began in Khartoum on 16th November 1962 with the collection and examination of existing maps and survey data. Fieldwork for the portion of Area 3d between Soba and Guneid was carried out during December 1962 the remaining field work for the Soba Sharq - Khogalab area was carried out during the second half of April 1963. The Project area covered by the survey totals 570,000 feddans.

5.2 MAPS

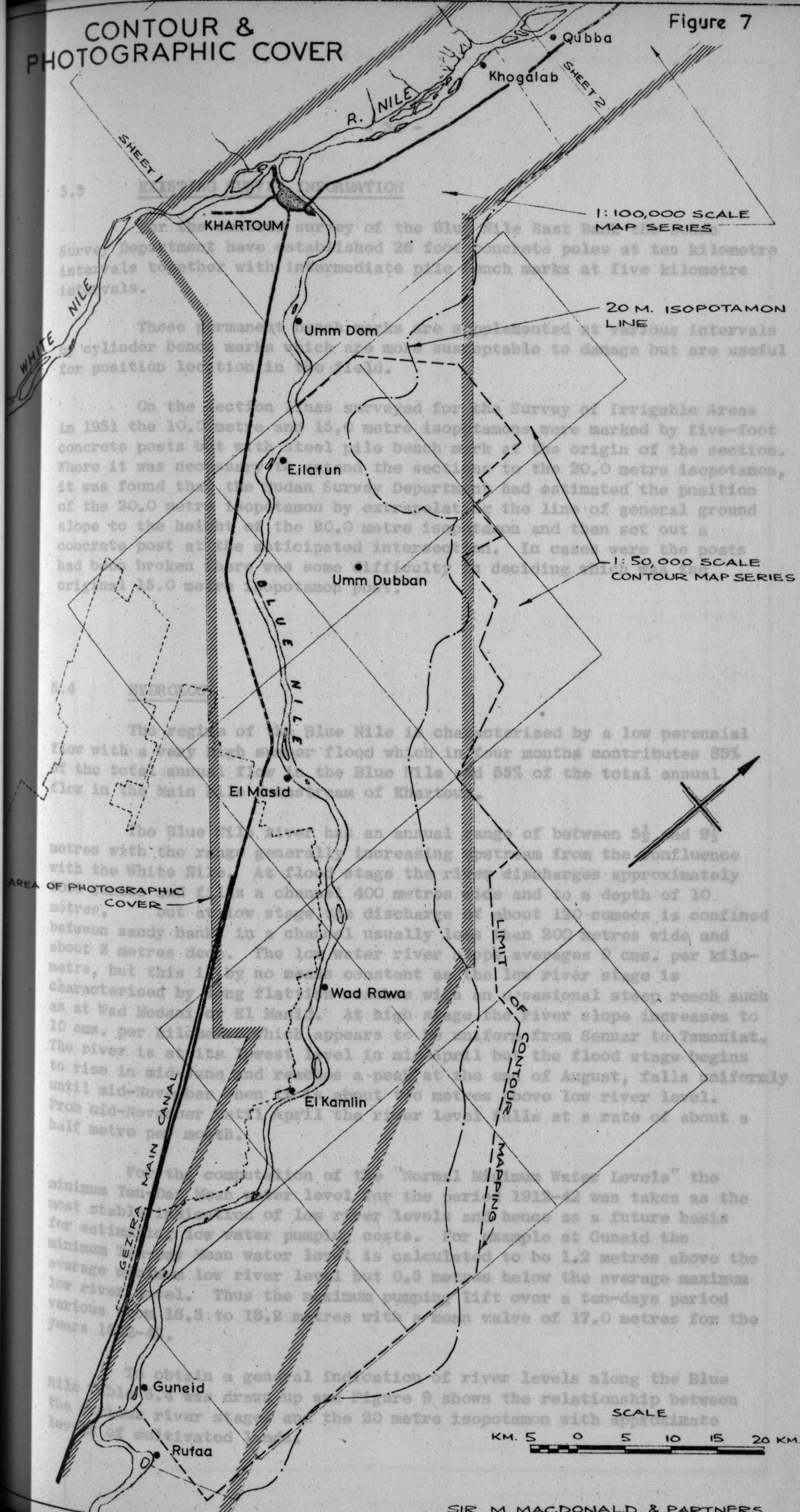
The mapping available for the project area is included in three series of map sheets published by the Sudan Survey Department. The most general series is the 1:250,000 scale Topographical maps, published in 1940, of which sheet Nos. 55-B 55-C 55-O provide complete cover for the project area.

The northern portion of the project area is covered by Sheet No. 1 of a 1:100,000 scale Topographical series covering the Main Nile, from Khartoum to the Third Cataract, which were prepared for the Survey of Irrigable Areas in 1951. This series marks the position of all registered lands along the Main Nile and also indicates the position of surveyed sections, at four kilometre intervals, between the river and the 15.0 metre isopotamon.

On the Blue Nile East Bank from Soba to Guneid contouring at half-metre intervals between the river and the 20.0 metre isopotamon is available at 1:50,000 scale. An index to these map sheets is shown in Figure 7. By extending to the 20.0 metre isopotamon section lines shown on sheet 1 of the 1:100,000 series it was possible to draw reconnaissance contours for that section of the project area from Khartoum North to Khogalab, but some 40 kilometres of additional section lines were required between section No. 1 and the edge of the Blue Nile East Bank contour mapping, so that complete contour cover was obtained. The positions of the section lines are shown on Plate 6.

CONTOUR & PHOTOGRAPHIC COVER

Figure 7



1: 100,000 SCALE
MAP SERIES

20 M. ISOPOTAMON
LINE

1: 50,000 SCALE
CONTOUR MAP SERIES

SCALE
KM. 5 0 5 10 15 20 KM.

5.3 EXISTING SURVEY INFORMATION

For the contour survey of the Blue Nile East Bank the Sudan Survey Department have established 26 foot concrete poles at ten kilometre intervals together with intermediate pile bench marks at five kilometre intervals.

These permanent bench marks are supplemented at various intervals by cylinder bench marks which are more susceptible to damage but are useful for position location in the field.

On the section lines surveyed for the Survey of Irrigable Areas in 1951 the 10.0 metre and 15.0 metre isopotamons were marked by five-foot concrete posts but with steel pile bench mark at the origin of the section. Where it was necessary to extend the sections to the 20.0 metre isopotamon, it was found that the Sudan Survey Department had estimated the position of the 20.0 metre isopotamon by extrapolating the line of general ground slope to the height of the 20.0 metre isopotamon and then set out a concrete post at the anticipated intersection. In cases where the posts had been broken there was some difficulty in deciding which was the original 15.0 metre isopotamon post.

5.4 HYDROLOGY

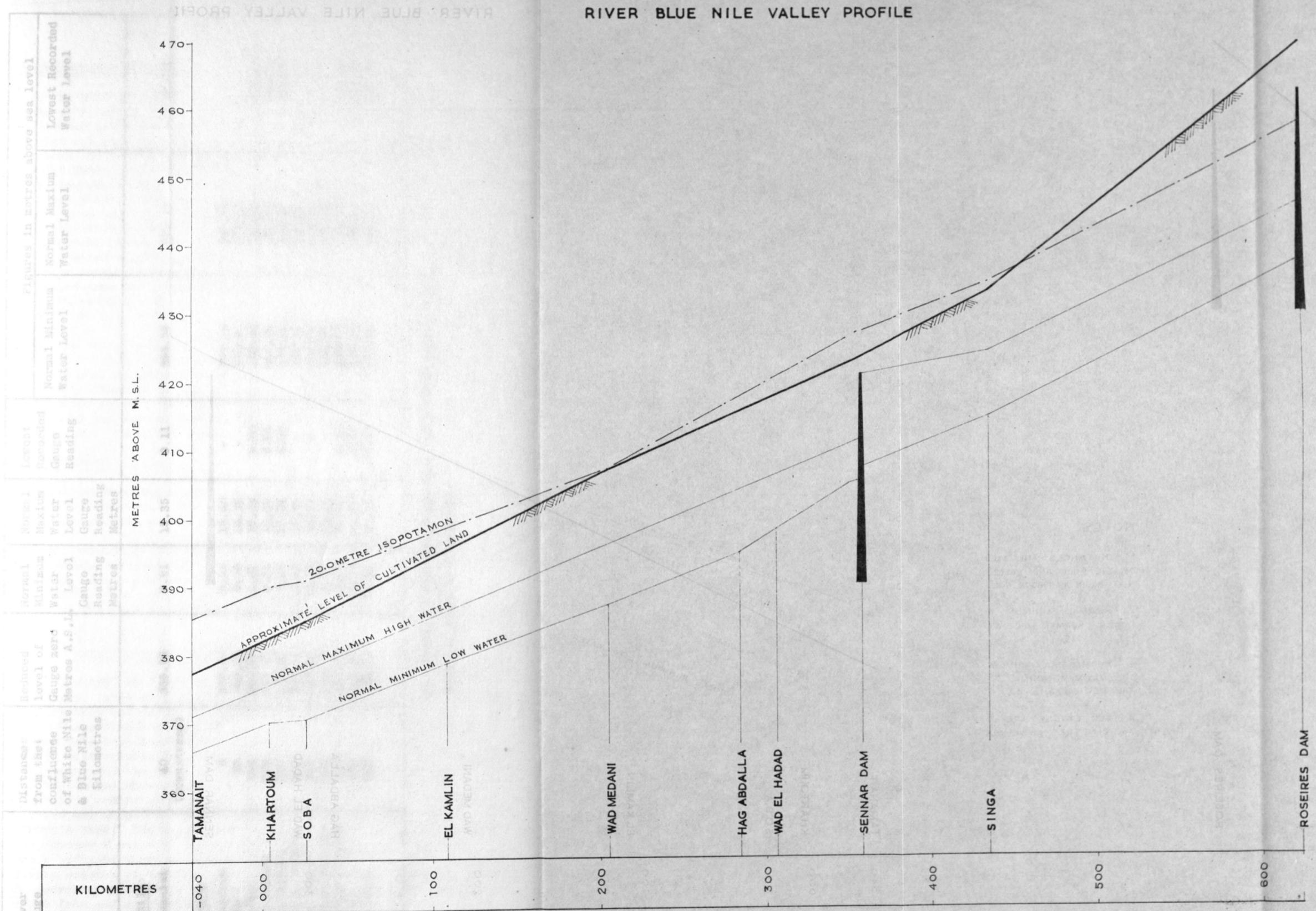
The regime of the Blue Nile is characterised by a low perennial flow with a very high summer flood which in four months contributes 85% of the total annual flow in the Blue Nile and 55% of the total annual flow in the Main Nile downstream of Khartoum.

The Blue Nile river has an annual range of between $5\frac{1}{2}$ and $9\frac{1}{2}$ metres with the range generally increasing upstream from the confluence with the White Nile. At flood stage the river discharges approximately 6000 cumecs and fills a channel 400 metres wide and to a depth of 10 metres, but at low stage the discharge of about 120 cumecs is confined between sandy banks in a channel usually less than 200 metres wide and about 2 metres deep. The low water river slope averages 9 cms. per kilometre, but this is by no means constant as the low river stage is characterised by long flattish reaches with an occasional steep reach such as at Wad Medani or El Masid. At high stage the river slope increases to 10 cms. per kilometre which appears to be uniform from Sennar to Tamaniat. The river is at its lowest level in mid-April but the flood stage begins to rise in mid-June and reaches a peak at the end of August, falls uniformly until mid-November when it is about two metres above low river level. From mid-November until April the river level falls at a rate of about a half metre per month.

For the computation of the "Normal Minimum Water Levels" the minimum Ten-Day Mean water level for the period 1912-42 was taken as the most stable indication of low river levels and hence as a future basis for estimating low water pumping costs. For example at Guneid the minimum Ten-Day Mean water level is calculated to be 1.2 metres above the average minimum low river level but 0.5 metres below the average maximum low river level. Thus the maximum pumping lift over a ten-days period varies from 16.5 to 18.2 metres with a mean value of 17.0 metres for the years 1912-42.

To obtain a general indication of river levels along the Blue Nile Table 5.4 was drawn up and Figure 9 shows the relationship between the various river stages and the 20 metre isopotamon with approximate levels of cultivated lands.

RIVER BLUE NILE VALLEY PROFILE



NOTES.

1. DISTANCES ARE MEASURED FROM THE CONFLUENCE OF THE BLUE AND WHITE NILE AND ARE TAKEN FROM THE NILE BASIN HANDBOOK VOL. III
2. NORMAL MINIMUM WATER LEVEL IS TAKEN AS THE LOWEST NORMAL TEN DAY GAUGE READING FOR THE PERIOD 1912 - 42.
3. NORMAL MAXIMUM WATER LEVEL IS TAKEN AS THE MAXIMUM NORMAL TEN DAY GAUGE READING FOR THE PERIOD 1912 - 42.
4. ALL LEVELS ARE TO KHARTOUM GAUGE ZERO 360.0 METRES ABOVE MEAN SEA LEVEL ALEXANDRIA.

Table 5.40 DATA ON RIVER LEVELS IN BLUE NILE AND MAIN NILE

River Gauge	Distance from the confluence of White Nile & Blue Nile & Kilometres	Reduced level of Gauge zero Metres A.S.L.	Normal Minimum Water Level Gauge Reading Metres	Normal Maximum Water Level Gauge Reading Metres	Lowest Recorded Gauge Reading	Figures in metres above sea level		
						Normal Minimum Water Level	Normal Maximum Water Level	Lowest Recorded Water Level
<u>Main Nile:</u>								
Tamaniat	40 (downstream)	355.76	9.81	15.35	9.11	365.57	371.11	364.87
<u>Blue Nile:</u>								
Khartoum	4	360.00	9.99	15.60	-	369.99	375.59	-
Soba	25	360.92	9.58	16.38	-	370.50	377.30	-
Kamlin	109	368.61	9.87	17.43	9.00	378.48	386.04	377.61
Wad Medani	206	377.09	9.86	18.59	8.61	386.95	395.68	385.70
Hag Abdulla	285	387.22	7.47	17.07	6.56	394.69	404.29	393.78
Wad el Haddad	307	389.17	8.99	17.13	-	398.16	406.30	-
Old Sennar	351	394.67	10.17	16.71	-	404.84	411.38	-
Sennar D.S. Dam	356	400.00	4.86	12.01	-	404.86	412.01	-
Sennar U.S. Dam	358	400.00	6.30	20.70	4.36	406.80	420.70	404.36
Singa	436	402.23	12.33	20.60	9.50	414.56	422.83	411.73
Roseires	624	426.21	11.37	19.25	10.53	437.58	445.46	436.74

All levels to Khartoum Gauge Zero Datum 360.0 metres above mean sea level at Alexandria.

5.5

OFFICE STUDIES

With the Blue Nile East Bank contour mapping from Soba to Guneid it was possible to plot the position of the 20.0 metre isopotamon from the minimum ten day mean water levels at Soba, El Kamlin and Wad Medani gauges. A continuous plot was made from the Contour information from Soba to Rufaa (the boundary of Area 3c) except for a length of ten kilometres to the north-east of Guneid scheme where the contours extend to only about 19 metres above low water level. The position of the 20.0 metre isopotamon along this gap was plotted from the estimated ground slope adjacent to contour limits. From Soba on the Blue Nile to Khogalab on the Main Nile, the position of the 20.0 metre isopotamon was located by additional survey in the field to extend the Survey Department Section lines made in 1952/3. The existing 15.0 metre isopotamon points on the Main Nile differ slightly from the Blue Nile definition in that they are tied to the lowest recorded water levels at Omdurman and Tamaniat and not the minimum Ten-day mean water levels at Khartoum and Tamaniat. The difference varies from 0.54 metres at Section No. 1 to 0.80 metres at the Tamaniat gauge.

It was possible from the office studies to choose three areas which appeared likely as feasible projects and for which field work was necessary. The most southerly area is downstream of Guneid Scheme and to the east of Wad Rawa. Nearer to Khartoum is the Eilafun-Umm Dubban plain which lies in a triangle between Jebel Direr, Eilafun and Kurtang while a third area lies parallel and to the east of the Khartoum-Atbara railway from the Blue Nile to Khogalab. These are shown in Figure 8.

5.6

FIELD STUDIES

The field studies began with a reconnaissance of the existing irrigation schemes in the area. The extent and state of these schemes is described in Section 5.61 of this chapter.

The main purpose of the field studies was to carry out an inspection of feasible irrigable areas and eliminate with the aid of aerial photography lands having unsuitable features such as eroded surfaces or stony soils. Pump station sites and alignments for main canals were also located. The results of these studies are described in section 5.62.

5.61 Existing Irrigation Schemes

Unlike the Blue Nile towards upstream the Dinder confluence, large scale irrigation development has not taken place in Area 3d, nor is the traditional sagia to be found as on the White Nile and Main Nile. Although several small private schemes have been constructed on the flood plains the high lift to cultivatable lands has generally discouraged large scale development and the large annual range of water levels in the Blue Nile makes the operation of a sagia unsuitable. On the Blue Nile a number of small private schemes have been built but most are now derelict with the exception of Umm Dom Farm and Kifouri's Farm. The most common cause of failure of private pump schemes appears to be damage to pump stations by high river levels and subsidence of foundations. The largest derelict private schemes at Basharqa and Kurtang were of the order of 400 feddans. The extent of a larger scheme at Soba Sharq was traced from aerial photography and appeared to have an area of about 1000 feddans.

	Construction)	Private Schemes
Kifouri's Farm	400	
Total Area	25,500	11,400

On the Main Nile from Khartoum to Khogalab there is a total irrigated area of 10,000 feddans. Table 5.61 gives details of existing irrigated areas on the Blue Nile, but in view of the numerous schemes on the White Nile no attempt has been made to tabulate the individual areas.

The principal government scheme in Area 3d is at Guneid where the gross area of the scheme is now 53,000 feddans. The scheme was built in 1955 with an irrigable area of 30,000 feddans on a cotton rotation. In 1962-63 a sugar factory was built and the scheme extended at the same time to grow sugar cane. The original pumping units at Guneid were 4 diesel driven 48" pumps which each had a capacity of 3 1/3 cumecs against a maximum static lift of 19 metres delivered through an 1100 metres rising main. In 1963 an electrically driven pumping station of the same capacity was added to irrigate the new extension and provide additional water for the sugar cane crop.

The other government scheme in the project area is the new American Aid Dairy Farm Project in Khartoum North. This scheme has a gross area of 2800 feddans and is primarily for the growing of forage for dairy cattle.

Table 5.61 Existing Irrigation Schemes

Blue Nile East Bank
Guneid - Khartoum

Scheme	Gross Area - (Feddans)		Remarks
	Government	Private	
Guneid	53,000		Scheme built 1955, and extended in 1961/2
Wad Rawa		165	Small Flood Basin
Bashaqra		400	Very low flood Plain
Bashaqra Sharq		235	Derelict Scheme
Kurtang		400	ditto
Umm Takali		325	Low Flood Plain
Eilafum		200	Garden and Orchard Areas
Soba		(1000)	Derelict Scheme
Soba Sharq		400	Garden and Orchard Areas
Umm Dom		3500	Private Scheme
Karkoj		740	Derelict Scheme
Dairy Farm	2,300		Experimental Pasture Scheme (Under Construction)
Kifouri's Farm		4000	Private Scheme
Total Areas	55,800	11,465	

5.62 Preliminary Selection of Irrigable Areas

As a result of the office studies it was clear that there were three main areas for examination in the field. During the field inspection and engineering surveys the irrigable areas could be defined. The results are summarised in Table 5.62 and a description of each irrigable area follows. (See Figure 8)

Table 5.62 Irrigable Areas selected in Engineering Reconnaissance

Location	Gross area Feddans	Pump Stations	
		Number of sites located	Static Lift (Metres)
Wad Rawa - Guneid	103,000	3	15.5-20.8
Eilafun-Umm Dubban	62,000	2	14.3-17.0
Khartoum North - Khogalab	41,000	1	14.2

5.621 Wad Rawa - Guneid Area

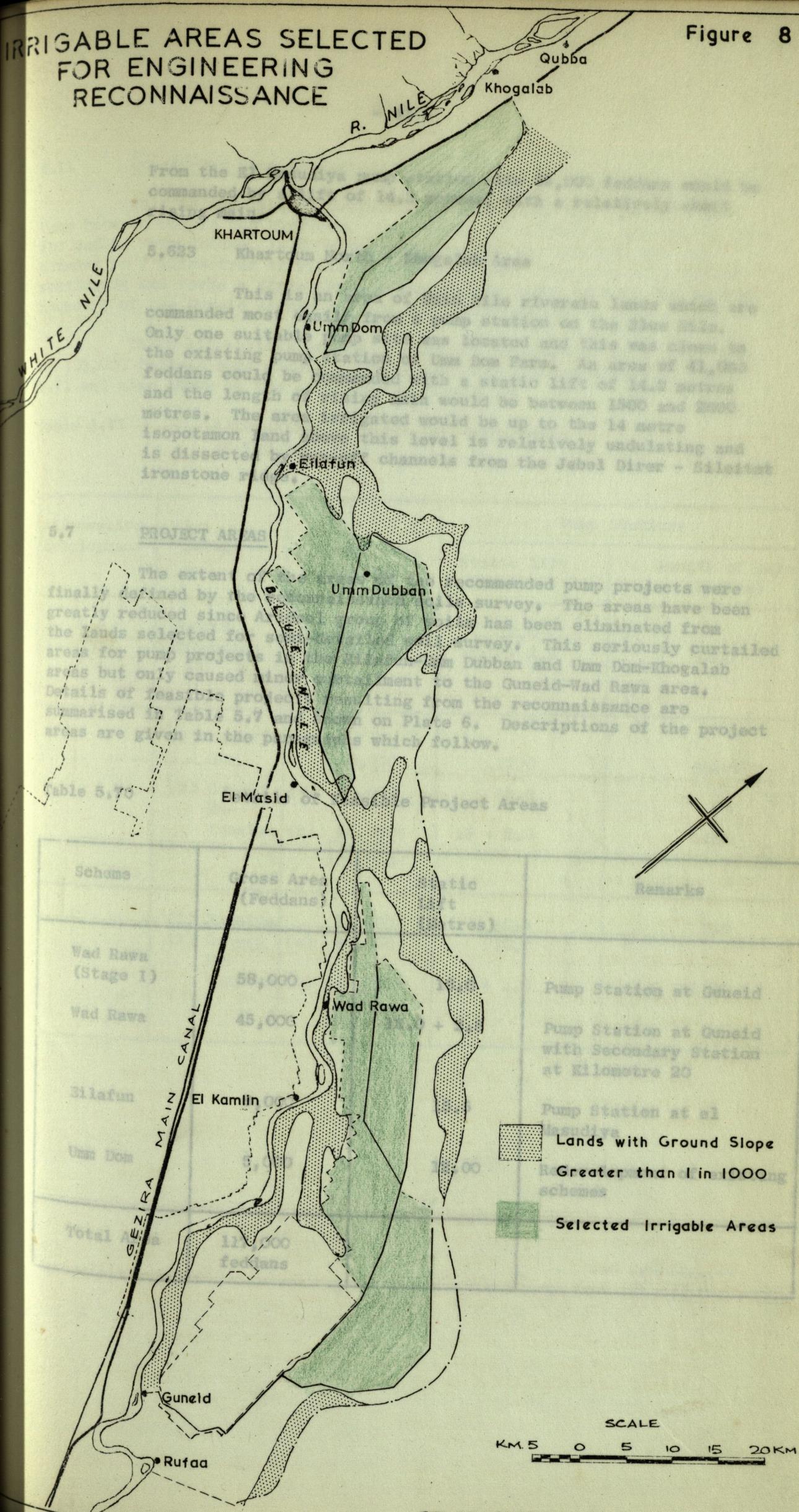
This area of a little over 100,000 feddans is the largest available for development in Area 3d. The area is the remaining area of a plain of cracking clay soil, on which Guneid Scheme is already sited, and which follows the Blue Nile from just south of Rufaa to about 13 kilometres downstream of Wad Rawa. The plain is generally 12-15 kilometres in width but is 25 kilometres wide near the tail of Guneid Scheme. The plain is 15-20 metres above low water river levels and so the lift is high to all areas.

There are no pump station sites on the area which are capable of commanding to the 20 metre isopotamon by means of a single lift but from the Guneid site it is possible to irrigate to a level within two metres of the 20.0 metres isopotamon. Two other pump station sites were located as alternatives to Guneid. A suitable alignment for the supply canal headreach from one of these sites was surveyed. The whole of this area has been recommended for semi detailed soil survey as a result of the soils reconnaissance and alternative projects for development are described fully in Section 5.71.

5.622 Eilafun - Umm Dubban Plain

This area of 62,000 feddans is relatively easy to canalise in that the plain has a gentle slope northwards away from the river. Two pump station sites were located, one three kilometres upstream of Kurtang and the second near El Masudiya, twelve kilometres downstream of Kurtang. From the first pump station some 34,000 feddans on the upper part of the plain would be commanded with a lift of 17.0 metres while the lower 28,000 feddans would be commanded with a lower lift of 14.1 metres. The rising main would require to be 5-600 metres in length.

IRRIGABLE AREAS SELECTED FOR ENGINEERING RECONNAISSANCE



From the reconnaissance... commanded most... This... river... lands... are... station on the Blue Nile. Only one suitable... located and this was given to the existing... Umm Dom Falls. An area of 42,000 feddans could be... a static lift of 14.5 metres and the length... would be between 1500 and 2500 metres. The... would be up to the 14 metre isopotamon... this level is relatively undulating and is dissected by... channels from the Jebel Direr - Siletat ironstone...

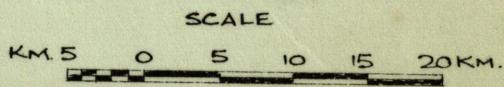
5.7 PROJECT AREAS

The extent... commanded pump projects were finally... greatly reduced since... has been eliminated from the lands selected for... survey. This seriously curtailed areas but only caused... Dubban and Umm Dom-Khogalab areas. Details of... to the Guneid-Wad Rawa area, summarised in Table 5.7... on Plate 6. Descriptions of the project areas are given in the pages which follow.

Table 5.7 Project Areas

Scheme	Gross Area (Feddans)	Remarks
Wad Rawa (Stage 1)	58,000	Pump Station at Guneid
Wad Rawa	45,000	Pump Station at Guneid with Secondary Station at Kilonetre 20
Silafun	11,000	Pump Station at el...
Umm Dom	5,000	
Total Area	119,000 feddans	

-  Lands with Ground Slope Greater than 1 in 1000
-  Selected Irrigable Areas



From the El Masudiya pump station site 25,000 feddans would be commanded by a lift of 14.3 metres, with a relatively short rising main.

5,623 Khartoum North - Khogalab Area

This is an area of Main Nile riverain lands which are commanded most easily from a pump station on the Blue Nile. Only one suitable pump site was located and this was close to the existing pump station of Umm Dom Farm. An area of 41,000 feddans could be commanded with a static lift of 14.2 metres and the length of rising main would be between 1500 and 2000 metres. The area irrigated would be up to the 14 metre isopotamon land above this level is relatively undulating and is dissected by run-off channels from the Jebel Direr - Sileitat ironstone ridge.

5.7 PROJECT AREAS

The extent of the areas of the recommended pump projects were finally defined by the reconnaissance soils survey. The areas have been greatly reduced since Aridsol group of soils has been eliminated from the lands selected for semi-detailed soil survey. This seriously curtailed areas for pump projects in the Eilafun-Umm Dubban and Umm Dom-Khogalab areas but only caused minor curtailment to the Guneid-Wad Rawa area. Details of feasible projects resulting from the reconnaissance are summarised in Table 5.7 and shown on Plate 6. Descriptions of the project areas are given in the paragraphs which follow.

Table 5.70 Details of Feasible Project Areas

Scheme	Gross Area (Feddans)	Static Lift (Metres)	Remarks
Wad Rawa (Stage I)	58,000	13.0	Pump Station at Guneid
Wad Rawa	45,000	18.0 + 2.8	Pump Station at Guneid with Secondary Station at Kilometre 20
Eilafun	9,000	15.5	Pump Station at el Masudiya
Umm Dom	5,000	12.00	Redevelopment of existing schemes
Total Area	117,000 feddans		

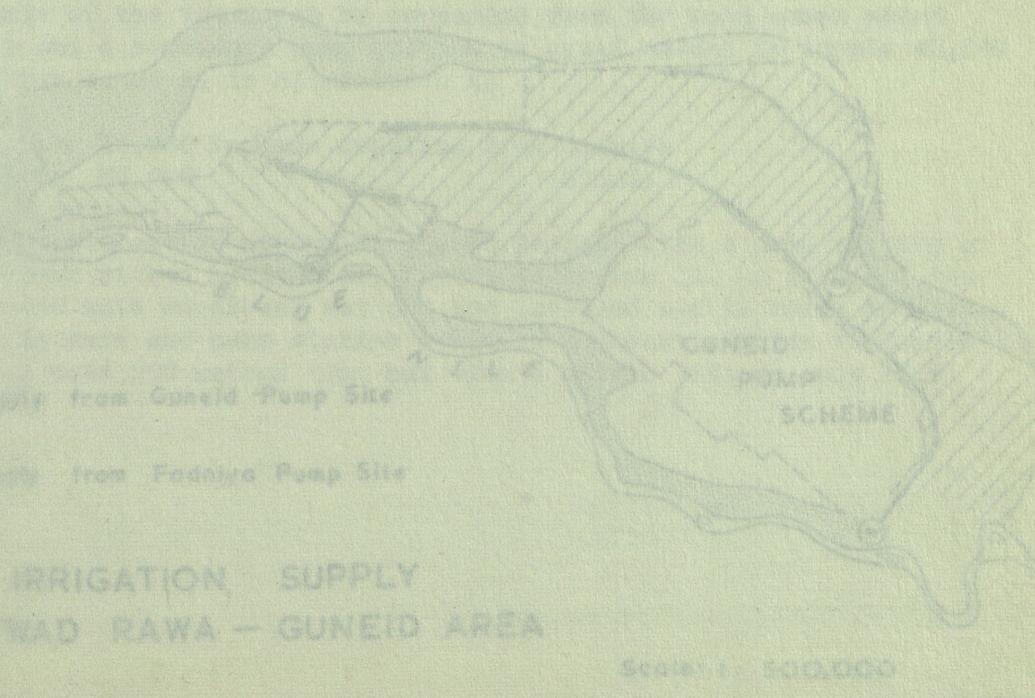
5.71 Guneid-Wad Rawa Project Area

This is the largest project area located on the Blue Nile east bank between Guneid and Khartoum. It extends 40 kilometres northwards from the Guneid Pump Scheme, is 20 kilometres wide at the southern end and narrows to 2 kilometres in width at the north end. The area also extends southwards and forms a strip three kilometres in width between the eastern boundary of the Guneid scheme and the 400 metre contour.

Three alternative schemes to provide development of a gross area of 103,000 feddans were studied. These projects are summarised in Table 5.71 and also shown on the accompanying Figure 10.

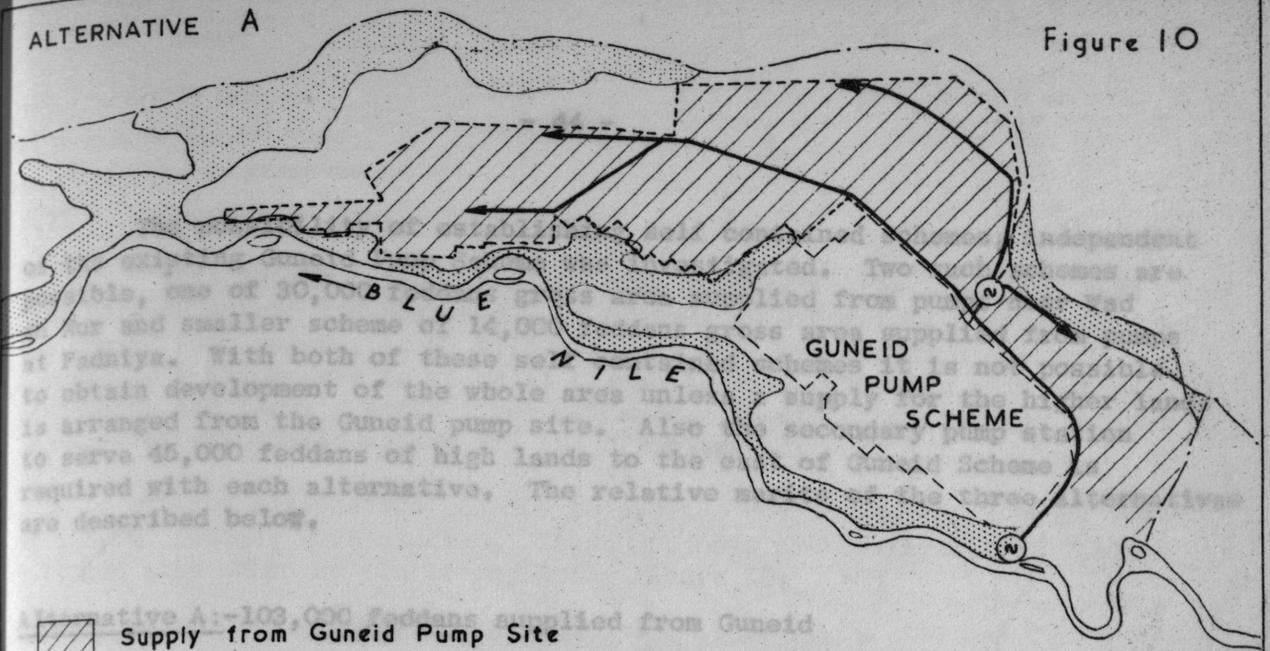
Table 5.71 Alternative Projects for development of Wad Rawa Area

Alternative Development	Scheme	Gross Area (Feddans)	Pump Stations	
			Static Lift (Metres)	Length of Main (Metres)
A	Guneid Extension	(a) 52,000 (b) <u>45,000</u> 103,000	18.0 18.0 + 2.8	1100
B	(1) Wad El Nur (2) Guneid Ex-tension	30,000 (a) 28,000 (b) <u>45,000</u> 103,000	17.0 18.0) 18 + 2.8)	Short 1100
C	(1) Fadniya (2) Guneid Ex-tension	14,000 (a) 44,000 (b) <u>45,000</u> 103,000	15.5 18.0) 18 + 2.8)	800 1100



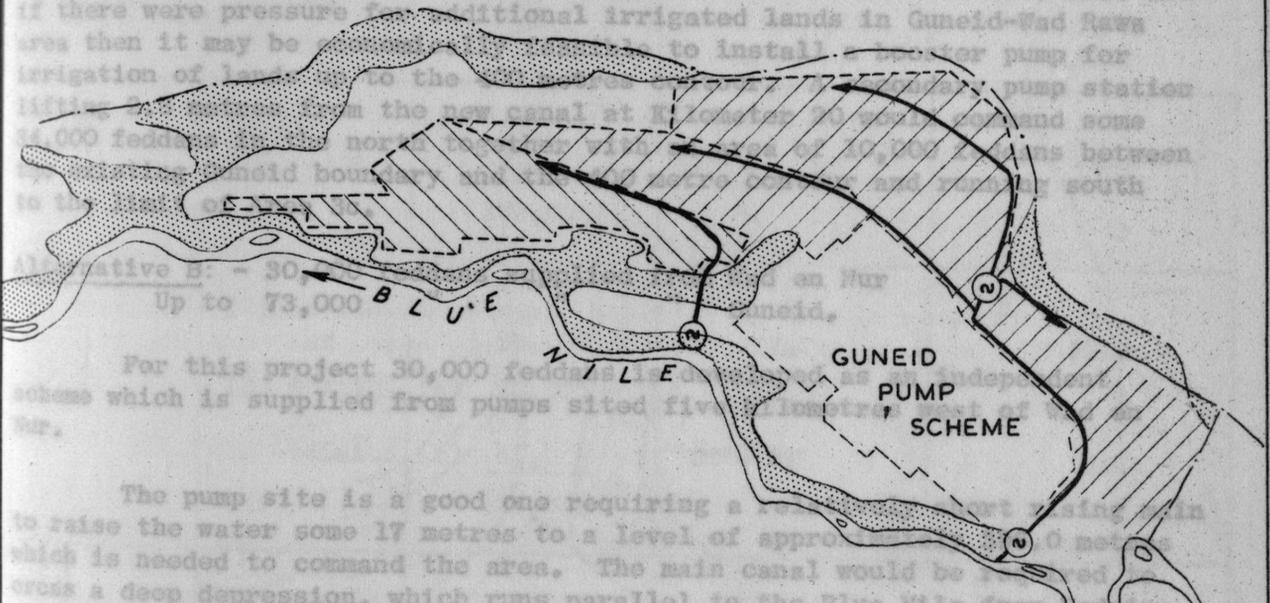
ALTERNATIVE A

Figure 10



Supply from Guneid Pump Site

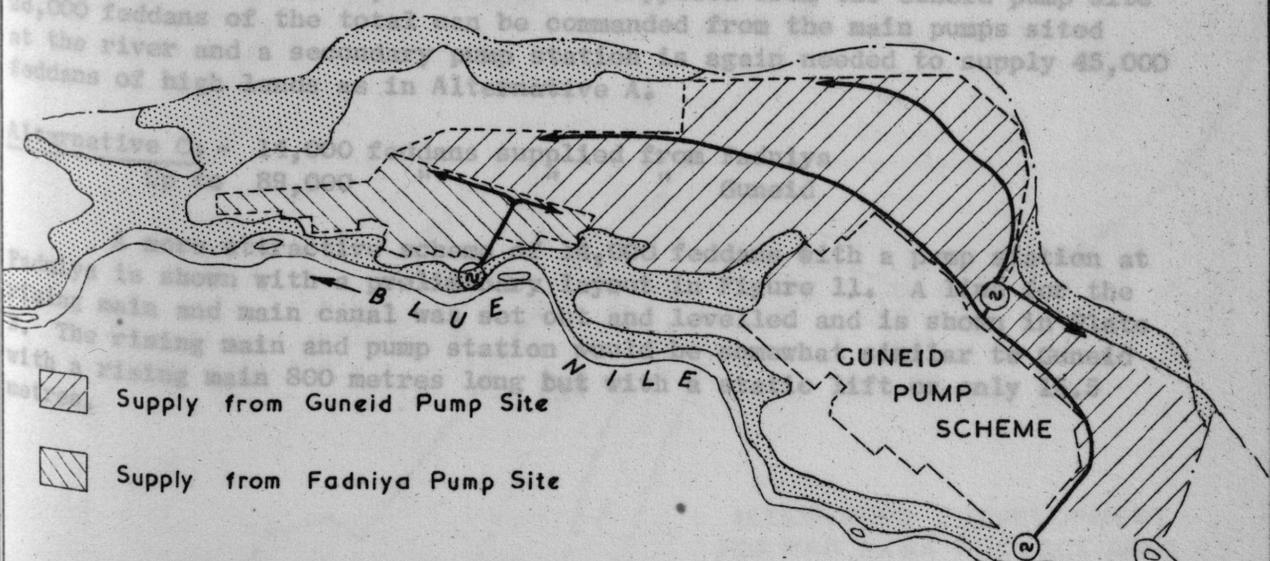
ALTERNATIVE B



Supply from Guneid Pump Site

Supply from Wad en Nur Pump Site

ALTERNATIVE C



Supply from Guneid Pump Site

Supply from Fadniya Pump Site

IRRIGATION SUPPLY
FOR WAD RAWA - GUNEID AREA

Scale: 1 : 500,000

The possibility of establishing self contained schemes, independent of the existing Guneid Pump Scheme was investigated. Two such schemes are possible, one of 30,000 feddans gross area supplied from pumps near Wad en Nur and smaller scheme of 14,000 feddans gross area supplied from pumps at Fadniya. With both of these self contained schemes it is not possible to obtain development of the whole area unless a supply for the higher lands is arranged from the Guneid pump site. Also the secondary pump station to serve 45,000 feddans of high lands to the east of Guneid Scheme is required with each alternative. The relative merits of the three alternatives are described below.

Alternative A:-103,000 feddans supplied from Guneid

The excellent characteristics of the Guneid site with its high voltage electricity and other services on site make a new high lift pump station a favourable proposition. Although the new canal would be aligned along the boundary of the new Guneid extension and would not irrigate until Kilometer 30 it could command about 58,000 feddans in the Wad Rawa area and if there were pressure for additional irrigated lands in Guneid-Wad Rawa area then it may be economically feasible to install a booster pump for irrigation of lands up to the 400 metres contour. A secondary pump station lifting 2.8 metres from the new canal at Kilometer 20 would command some 34,000 feddans in the north together with an area of 10,000 feddans between the existing Guneid boundary and the 400 metre contour and running south to the limit of Area 3c.

Alternative B: - 30,000 feddans supplied from Wad en Nur
Up to 73,000 " " " Guneid.

For this project 30,000 feddans is developed as an independent scheme which is supplied from pumps sited five kilometres west of Wad en Nur.

The pump site is a good one requiring a relatively short rising main to raise the water some 17 metres to a level of approximately 396.0 metres which is needed to command the area. The main canal would be required to cross a deep depression, which runs parallel to the Blue Nile from Fadniya to the limits of the existing Guneid scheme. The high cost of this section of the main canal together with its maintenance over a 3 kilometre length where the height of the bank across the depression would be 2-5 metres discouraged the idea of this scheme when set against the alternative developments.

The remaining 73,000 feddan is supplied from the Guneid pump site 28,000 feddans of the total can be commanded from the main pumps sited at the river and a secondary pump station is again needed to supply 45,000 feddans of high lands as in Alternative A.

Alternative C: - 14,000 feddans supplied from Fadniya
Up to 89,000 " " " Guneid

A more attractive scheme of 14,000 feddans with a pump station at Fadniya is shown with a preliminary layout in Figure 11. A line for the rising main and main canal was set out and levelled and is shown in Plate 3. The rising main and pump station would be somewhat similar to Guneid with a rising main 800 metres long but with a static lift of only 15.5 metres.

LEGEND

- 20 Metre Isopotamon Line
- Area for Semi-Detailed Soil Survey
- Lands with Ground Slope greater than 1 in 1000

With this project 38,000 feddans can be commanded from the Blue Nile site. 44,000 feddans can be commanded from the Main Nile site. 44,000 feddans requires a secondary pump station.

5.73 Elilafun Project

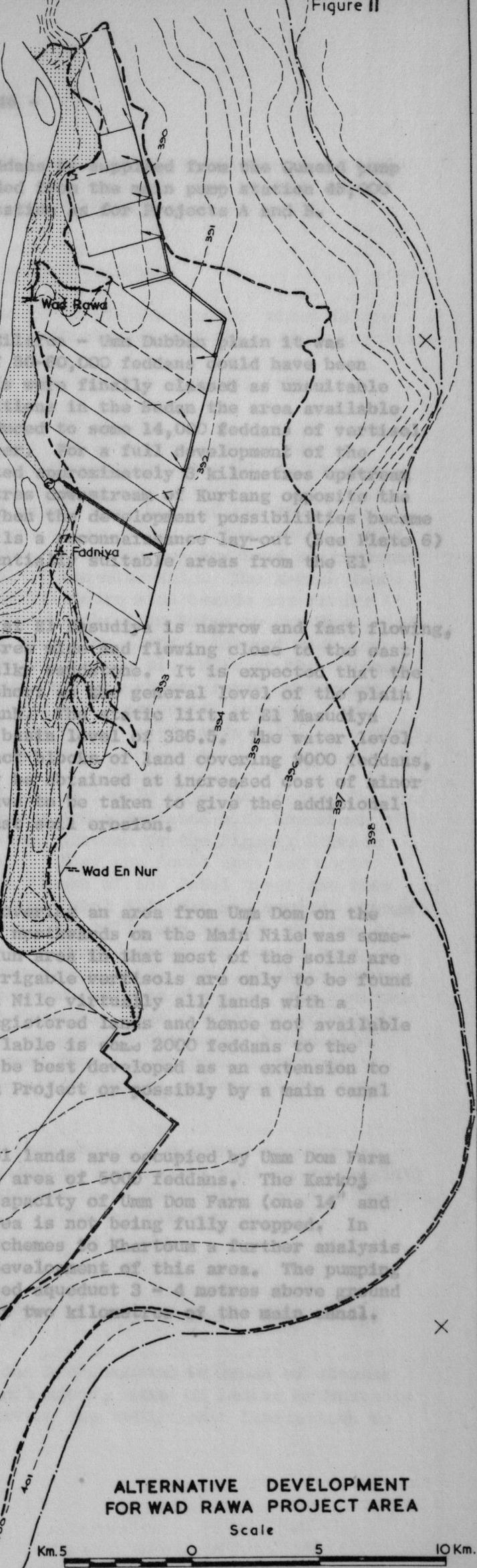
From the topography of the area it was initially expected that a project of 20,000 feddans would have been developed but when the arid soil was finally classified as unsuitable for development in the present conditions the area available for development on the plain was reduced to 14,000 feddans. The soils lying in a strip along the river are of a type which requires a pump station. Sites were located at the west bank village of El Masudiya. The development possibilities were limited to the areas of vertisol soils. A preliminary layout (see page 6) was prepared for irrigation of the available areas from the Masudiya site.

The low water river is narrow and fast flowing, the channel being only about 15 metres wide. The bank which is formed by a heavy silt deposit is following class to the length of rising main will be 12.5 metres to a discharge of 386. The water level would then command a series of compact blocks and covering 1000 feddans, any increase in this area could only be obtained at increased cost of canalisation and also steps would have to be taken to give the additional blocks a measure of protection against erosion.

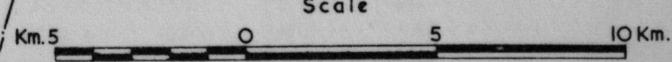
5.73 Umm Don Project

The remaining area available for an area from Umm Don on the Blue Nile to Khartoum. The area on the Main Nile was somewhat similar to the Elilafun area. Most of the soils are classed as arid soils. The irrigable soils are only to be found as a river strip. The Main Nile is a river of all lands with a vertisol classification are registered and hence not available for development; The only area available is the 200 feddans to the north of Khartoum's farm which would be best developed as an extension to the new United States Aid Dairy Farm Project possibly by a main canal from Khartoum on the Main Nile.

In the area the vertisol lands are occupied by Umm Don Farm and the Karfoj scheme which covers an area of 1000 feddans. The Karfoj scheme is derelict and the pumping capacity of Umm Don Farm (one 14 and one 10) indicates that this area is not being fully cropped. In view of the proximity of these two schemes, Khartoum's further analysis would probably reveal a need for reevaluation of this area. The pumping lift required is 12 metres at a lined duct 3 metres above ground level. The line would be required for the first two kilometers of the main canal.



ALTERNATIVE DEVELOPMENT FOR WAD RAWA PROJECT AREA



With this project 89,000 feddans is supplied from the Guneid pump site. 44,000 feddans can be commanded from the main pump station 45,000 feddans requires a secondary pump station as for Projects A and B.

5.72 Eilafun Project

From the topography of the Eilafun - Umm Dubban plain it was initially expected that a project of 50-60,000 feddans could have been developed but when the aridisol soils were finally classed as unsuitable for development in the present conditions in the Sudan the area available for development on the plain was reduced to some 14,000 feddans of vertisol soils lying in a strip along the river. For a full development of the plain, pump station sites were located approximately 3 kilometres upstream of Kurtang and at a point 12 kilometres downstream of Kurtang opposite the west bank village of El Masudiya. When the development possibilities became limited to the areas of vertisol soils a reconnaissance lay-out (See Plate 6) was prepared for irrigating the potentially suitable areas from the El Masudiya site.

The low water river channel at El Masudiya is narrow and fast flowing, the channel being only about 120 metres wide and flowing close to the east bank which is formed by a bed of chalky sandstone. It is expected that the length of rising main will be very short as the general level of the plain is maintained almost to the river bank. The static lift at El Masudiya would be 12.5 metres to a discharge basin level of 386.5. The water level would then command a series of compact blocks of land covering 9000 feddans, any increase in this area could only be obtained at increased cost of minor canalisation and also steps would have to be taken to give the additional blocks a measure of protection against soil erosion.

5.73 Umm Dom Project

The remaining project area covering an area from Umm Dom on the Blue Nile to Khogalab, 30 kilometres northwards on the Main Nile was somewhat similar to the Umm Dubban-Eilafun area in that most of the soils are classed as aridisols and that the irrigable vertisols are only to be found as a riverain strip. Along the Main Nile virtually all lands with a vertisol soils classification are registered lands and hence not available for development; The only area available is some 2000 feddans to the north of Kifouri's farm which would be best developed as an extension to the new United States Aid Dairy Farm Project or possibly by a main canal from Shambat on the Main Nile.

On the Blue Nile the vertisol lands are occupied by Umm Dom Farm and the Karkoj scheme which cover an area of 5000 feddans. The Karkoj scheme is derelict and the pumping capacity of Umm Dom Farm (one 14" and one 12" pump) indicates that this area is not being fully cropped. In view of the proximity of these two schemes to Khartoum a further analysis would probably reveal a need for redevelopment of this area. The pumping lift required is 12 metres but a lined aqueduct 3 - 4 metres above ground level would be required for the first two kilometres of the main canal.

CHAPTER 6

LAND SUITABILITY CLASSIFICATION

LIMITING PHYSICAL FACTORS TO LAND DEVELOPMENT

6.1

Similar general specifications for soil, topographic and drainage limitations were used to those in Area 1 (Gezira extension).

As in Area 1, impeded drainage was rarely a limiting factor to land development.

6.11 Topographic Limitations to land developments were encountered in two different environments in area 3d, as follows: -

a) The Kerrib lands on the east bank of the Blue Nile. This is a zone of short, steep-sided gullies which, after occasional heavy rains, carry floodwaters from the adjacent plains to the channel of the Blue Nile. The kerrib lands form a zone about one kilometre wide beside the river; it extends with one or two breaks from Rufaa to Umm Dom. There is an eastward extension along a lateral wadi (the Wadi Marah) that enters the Blue Nile at the northern end of the Guneid Pump Project. These lands, which are considered as unsuitable for development purposes, are shown on the maps as sloping gullied lands with the symbols, S.G.L.

b) Sloping lands at higher levels adjacent to the 20 metre isopotamon. These lands are associated with the break of slope from the sandstone plateau to the highest terrace of the old flood plain. They are found east and north of Umm Dubban, on the flanks of the Jebel Direr and then extend northwards to the Jebel Sileitat and beyond. These lands are often scored with rills and shallow gullies which occasionally carry runoff waters following heavy rains. In the neighbourhood of the Jebel Sileitat there are two large well defined drainage channels, the Wadi el Garwaqa and the Khor Kabbashi. The surface is often strewn with sandstone or granite stones and boulders whilst wind - blown sand from the plateau to the north and east forms mounds around bushes and occasional stony outcrops.

Because of the high pump lift that would be required to serve these lands and the topographic limitation mentioned above, as well as uncertainty about the soils, these lands are considered to be unsuitable for development. On the soil map these lands include the following classes: -

- Orthic Orthustents
- Lithic Orthustents
- Natrargidic Orthustents
- Durargids

In some cases these soil classes are included in areas of sloping gullied lands, designated S.G.L. In all cases, areas of Lithic Orthustents and Durargids should be regarded as having the topographic limitations to development that are mentioned above.

6.12 Soils Limitations

The lands of Area 3d have a much wider range in topographic and soils conditions than those of the Gezira and the Gezira extension. More than half the area studied has soils (Aridisols) which are neither cracking clays (Vertisols) nor riverain silts (Entisols) which together include almost all the irrigated soils of the Sudan. The soils limitations therefore include, as well as salinity, alkalinity and low clay content (of Vertisols), the additional limitations of low fertility and stoniness of Aridisols.

The soils limitations are described as follows: -

- i) Alkalinity is the chief soils limitation of the area studied. Of the 26 sites sampled for soil analysis, 13 were alkali soils i.e. the E.S.P. exceeded 15 in one or more horizons in the top one metre of soil. The majority of these soils were Natrargids which have a characteristic subsoil horizon of clay accumulation in which the E.S.P. ranges from 25 to 50. Because of their high alkalinity these soils are considered unsuitable for agricultural development. Other alkali soils include one grumustert, five Mazusterts and one Orthustent profile. Two of these sites were considered as marginal and the remainder as unsuitable for agricultural development.
- ii) Salinity is only a minor soils limitation in Area 3d. Slight salinity (E.C. 4 to 8) is evident in the lower half metre of most Natrargids and in some Vertisols and Entisols. The Haplargids and Durargids are non saline, non alkali soils.
- iii) Low Clay percentage of Vertisols (35-50% clay) which would result in reduced yields of long staple cotton is found in some Vertisol profiles.
- iv) Low Fertility Status would be expected in the sandy Haplargid and the loamy Durargid soils. Neither of these soil classes has previously come under irrigation in the Sudan so that little is known of their potentialities under irrigated agriculture. These soils are excluded from consideration for development in Area 3d because of their low fertility, the high pump lift and the unfavourable topography.

6.2

BASIS OF SELECTION OF LANDS FOR FURTHER STUDY

6.21 Agricultural Considerations

The agricultural aspects of land selection were concerned chiefly with the physical bases of potential agricultural production. The limiting physical factors mentioned above in 6.1 were used to reject areas of topographically unsuitable lands and to provide a provisional land classification at each site selected for soil examination. An examination of the base map on which the soil sites had been plotted, together with stereoscopic examination of air photos and photo interpretation of prints and mosaics then enabled a provisional land suitability classification to be worked out. The large areas of Natrargid soils were rejected outright at this stage because of their gross alkalinity.

6.22 Engineering Considerations

The engineering surveys were concerned with establishing the position of the 20 metre isopotamon and, as well, with locating suitable pump sites on the Blue Nile and suitable lines for irrigation canals. Consideration of the engineering aspects enabled the elimination of further, mostly marginal, lands requiring a high pump-lift and/or a long supply canal through difficult terrain.

6.23 Land Tenure Considerations

Registered lands (privately owned) line the bank of the Main Nile northwards from Khartoum. Although there are some small strips and pockets of Government owned lands on the high side of the registered lands there is nowhere a sufficient area to form the basis of a new irrigation project. Similar considerations apply to Khartoum North where the industrial and urban areas are steadily expanding on to potentially agricultural lands. At Khartoum North there is also the older agricultural development known as Kifouri's Farm and, beside it, the lands currently under development for the Department of Animal Husbandry. Because of this expansion, which is expected to continue, it is considered not worth while to attempt development of the small remaining area of Vertisols.

6.3 LOCATION AND EXTENT OF LANDS RECOMMENDED FOR SEMI-DETAILED SURVEYS

The lands recommended for semi-detailed surveys are shown on Plate 5 and are as follows: -

<u>Locality</u>	<u>Area,</u> <u>(Feddans)</u>
Umm Dubban	6,250
Eilafun	14,600
Wad Rawa-Guneid	<u>151,000</u>
Total	<u>171,850</u>

6.31 Umm Dom Lands 6,250 feddans

This is an isolated area of Vertisols beside the Blue Nile, close to Khartoum. Most of the lands are intersected by canals and ditches, some used for seasonal irrigation by the Umm Dom pump project and some derelict from the abandoned Karkoj pump project. There is a small area close to the Umm Dom pumps near the river which is used for the permanent irrigation of forage, vegetable and horticultural crops. Some of this land is registered but little of it is fully developed. It is considered a suitable area for further study because of its proximity to Khartoum, the comparatively low pump lift (12 metres) required to command it and the possibility of intensive crop production if the soils are shown to be suitable.

6.32 Eilafun Lands 14,600 feddans

This is an irregularly shaped area of Vertisols extending south eastwards from Eilafun, more or less parallel to the river. It is covered with a network of "terus", dividing it into fields for the cultivation of rain grown dura. Many of these fields appear not to have been cultivated for several years; it is assumed that the intensity of dura production is not high and that yields are low in most years.

There is a suitable pump site at El Masudiya with a static lift of 12.5 metres; only a short rising main would be required and a series of compact blocks totalling 9000 feddans could be commanded in this area.

6.33 Wad Rawa-Guneid Lands 151,000 feddans

This is a large block of Vertisols which is continuous with the existing Guneid scheme (Gross Area of Scheme about 53,000 feddans). All the lands to the north and east of the Guneid scheme are subdivided by "terus" into fields for rainfed dura production.

Only 59,400 feddans out of a total of 151,000 feddans has been covered by the reconnaissance soil survey. Because limited ground inspection together with air photo analysis has shown these soils to be Vertisols and because of the favourable engineering considerations mentioned in Chapter 5, however, it is recommended that these lands should be included in the semi-detailed soil and land suitability classification surveys.

APPENDIX I

Descriptions of 26 soil profiles with laboratory data of the soil samples.

- A. Orthic Grumusterts:- RO01
RO64
- B. Natrargidic Grumusterts:- RO02
- C. Natrargidic Mazusterts:- RO05
RO26
RO63
RO74
RO75
- D. Natrargids:- RO12 X
RO17 X
RO21
RO25
RO95
DR106
DR107
DR117
DR118
DR125
DR131 - Nov 24
- E. Haplargids:- RO88
DR101
DR137 - P27 X
- F. Durargids:- RO20 - Near
DR143 - P29 X
- G. Orthustents:- DR151 X
DR156

NOTE: "Kankars" are hard Calcium Carbonate concretions.

Laboratory Analyses

Soil Particles %			Incorp Carbon %	pH		S.C. Sat. Extr.	Soluble Ca m- eq. per litre	Emb. Ca m eq. per 100 gm soil	E.S.P
Sand	Silt	Clay		Soil Paste	1.5 Soil suspension				
77	23	50	2.00	7.41	7.62	0.8	0.2	2.2	4
72	22	48	2.14	7.42	7.71	0.47	0.05	2.2	5
60	27	33	4.86	7.53	7.82	0.48	0.07	2.2	7
45	17	18	4.90	7.60	7.75	1.09	0.16	1.9	11
40	25	15	4.50	7.58	7.76	0.8	0.16	2.2	15

Orthic Grumustert
Non-saline
Land Class 2/3

A. Orthic Grumusterts

Pit RO01

Location 15° 40 N, 32° 31 E. Date: 20-11-62.

Topography Flat, with small irrigation channels

Cultivation and Land Use Abandoned patch, possibly due to lack of water. Nearby are a field of patchy Sorghum and land being ridged for winter vegetables.

Vegetation Young Acacia seyal scrub, with Calotropis procera and Crotalaria sp. 30% cover of Cynodon dactylon and Aristida sp., heavily grazed. Some Cyperaceae

Surface Dry, hard, with polygonal cracks up to 3 cm. wide.

Profile description

0 - 15 cm. Dry 10YR4-2, Moist 10YR3-2. Clay. Dry, hard, moderate medium angular blocky with some fine pores and many cracks. Rapidly water absorbent. Many fine roots. No salts.

15 - 60 cm. Dry 10YR3-3, Moist 10YR3-2. Clay. Dry, hard, moderate coarse subangular blocky with some fine pores and deep vertical cracks disappearing at 60 cm. Moderately water absorbent. Many fine roots. No salts.

60 - 103 cm. Dry 10YR4-2. Moist 10YR3-2. Clay. Dry, hard, structureless, no cracks, many fine pores. Moderately water absorbent. Rare fine roots. Many small Calcium carbonate concretions.

103 - 146 cm. Dry 10YR4-3, Moist 10YR3-3. Fine Sandy Loam. Dry, soft, structureless, with no cracks and many fine pores. Rapidly water absorbent. Rare fine roots. No salts.

146 - 175 cm. Dry 10YR5-4, Moist 10YR4-2. Silt Loam. Dry, slightly hard, weak fine subangular blocky with no cracks and many fine pores. Rapidly water absorbent. Few roots, up to 5 mm. diameter. No salts.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na m. eq. per litre	Exch. Na m eq. per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension.				
0-15	27	23	50	2.00	7.41	7.62	0.8	0.2	2.2	4
15-60	30	22	48	2.14	7.42	7.71	0.42	0.05	2.2	5
60-103	40	27	33	4.86	7.53	7.82	0.48	0.07	2.2	7
103-146	65	17	18	4.90	7.60	7.75	1.05	0.16	1.9	11
146-175	60	25	15	4.50	7.58	7.76	0.8	0.16	2.2	15

Orthic Grumustert
 Non-saline.
 Land Class 2/3

Pit R064
Location 15° 14' N, 33° 05' E. Date: 14-12-62
Topography Flat, bottom of a broad depression 10-12 ft deep.
Cultivation and Land Use Sorghum stubble
Vegetation Balanites aegyptiaca, Acacia seyal and Acacia arabica 10 to 40 yds apart. Coarse grass in a nearby run-off channel.
Surface Dry, slightly uneven, loose and crumbling, with polygonal cracks 4 to 5 cm wide.

Profile Description

0 - 44 cm Dry and moist 10YR3.5-2. Clay. Dry, hard, strong coarse prismatic, with few pores. Many wide vertical and fine horizontal cracks. Rapidly water absorbent. Few roots. Few dark Calcium Carbonate concretions. Little sand and gravel.
 44 - 98 cm Moist 10YR 3-2.5 Clay. Slightly moist, very firm, moderate medium angular blocky, with no pores and many fine cracks. Some vertical cracks extending to the bottom of this horizon. Rapidly water absorbent. Few roots. No salts.
 98-147 cm Moist 10YR3-2.5. Clay. Moist, very firm, structureless with no pores or cracks. Moderately water absorbent. No roots. No salts.
 147-173 cm Moist 10YR3-2.5. Silty clay. Moist, very firm, structureless with no pores or cracks. Moderately water absorbent. No roots. Common white Calcium carbonate concretions. Some rust mottling in old root channels.

Laboratory analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C.	Soluble Na Meq per litre	Exch. Na meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil suspension.				
0-44	25	10	65	2.29	7.70	7.70	0.39	0.21	2.2	3
44-99	30	10	60	3.22	7.60	7.61	0.90	0.6	3.9	6
99-147	27	10	63	3.08	7.53	7.80	1.7	1.6	4.7	8
147-173	25	12	63	2.40	7.57	7.88	2.2	1.8	4.1	7

Orthic Grumustert
 Land Class 2.

Retranctic Grumustert
 Non-saline
 Land Class 6.

B. Natrargidic Grumusterts

Pit R002
Location 15° 38 N, 32° 34 E. Date: 21.11.62
Topography Flat, intersected by canals
Cultivation and Land Use Field ploughed and levelled for winter cultivation.
Vegetation A few Cynodon dactylon
Surface Not ploughed at the pit site. Level, hard, with polygonal cracks 2-3 cm wide.

Profile Description

0- 18 cm Dry, 10YR3-2, Moist 10YR3-2. Clay. Dry, very hard, moderate medium angular blocky, with no pores and many cracks. Moderately water absorbent. Many roots. Some fine gravel and Kankars.

18- 35 cm Moist, 10YR2-2. Clay. Slightly moist, very hard, moderate medium angular blocky with no pores and many cracks. Slowly water absorbent. Few roots. Much gravel and kankars.

35- 64 cm Moist, 10YR2-2 with 20% mottles, 7.5YR3-2. Clay. Moist, very firm, weak medium subangular blocky with no pores and some fine cracks. Moderately water absorbent. Few roots. Many white salt crystals and Kankars,

64- 97 cm Moist, 10YR2-2 with some patches of 10YR5-3. Clay Loam. Moist, firm, structureless, with no pores or cracks. Moderately water absorbent. Some white salt crystals and Kankars.

97-114 cm Moist, 10YR4-3 with clay infills (10YR2-2) in cracks. Sandy Clay Loam. Moist, firm structureless, with no pores or cracks. Moderately water absorbent, Rare roots. No salts.

114-172 cm Moist, 10YR4-3. Loam. Moist, friable, structureless with no pores or cracks. Rapidly water absorbent. Rare roots. No salts. Much gravel.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C.	Soluble Na Meq per litre	Exch. Na meq per 100 gm soil	E.S.P.
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension				
0-18	40	12	48	5.26	8.15	8.64	1.25	0.8	12.9	27
18-35	25	15	60	3.38	8.34	8.60	2.35	2.4	20.3	34
35-64	27	20	53	2.21	7.81	8.02	7.5	4.6	21.5	40
64-97	25	20	55	1.82	7.95	8.15	8.0	4.6	29.8	54
97-114	47	13	40	4.07	8.01	8.25	6.5	6.4	13.8	35
114-172	75	7	18	6.90	8.20	8.90	4.25	2.2	7.9	44

Natrargidic Grumustert
 Non-saline
 Land Class 6.

C. Natrargidic Mazusterts

Pit R005
Location 15° 40 N, 32° 35 E. Date: 23-11-62
Topography Flat
Cultivation and Land Use Not cultivated. Heavily grazed.

Vegetation Sparse dried-up fine grass, grazed short. Scattered small Acacia erhenbergiana bushes with sand accumulated around them.

Surface Dry, loose, with many small Kankars up to 5 mm. across.

Profile description

0- 2 cm Dry 10YR4-2, Moist 10YR4-2. Gravelly clay loam. Dry, loose, structureless. Rapidly water absorbent. Many grass remains. Many Kankars.

2- 23 cm Dry 10YR4-2, moist 10YR4-2. Gravelly clay loam. Dry, slightly hard, strong coarse angular blocky with many cracks and few pores. Rapidly water absorbent. Many fine roots. Many Kankars.

23- 45 cm Dry 10YR4-2, moist 10YR4-2. Clay loam. Dry, slightly hard, moderate coarse angular blocky with many fine cracks and few pores. Rapidly water absorbent. Many fine roots. Common Kankars.

45-102 cm Dry and moist 10YR3-1. Clay Loam to clay. Dry, very hard, moderate medium angular blocky with many fine cracks and few pores. Moderately water absorbent. No roots. Some Kankars and white salt 'eyes'.

102-183 cm Dry and moist 10YR3-1. Clay loam to clay. Dry, very hard, weak medium angular blocky with few cracks. Moderately water absorbent. No roots. Some Kankars and white salt 'eyes'.

Laboratory analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C.	Soluble Exch. Na Na meq		E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension		Sat. Extr.	Meq per litre	
0- 2	60	7	33	4.46	8.22	8.52	3.35	1.7	9.8	30
2- 23	55	7	38	4.21	8.65	8.83	1.7	0.9	15.8	42
23- 45	45	10	45	5.45	8.43	8.92	4.8	4.0	22.4	50
45-102	40	12	48	5.81	8.12	8.46	13.0	7.8	24.9	52
102-183	37	10	53	6.17	8.61	8.79	4.75	5.7	24.3	46

Natrargidic Mazustert
 Non-saline
 Land Class 6

Pit RO26
Location 15° 27' N, 32° 45' E. Date 1-12-62
Topography Flat
Cultivation and Land Use Area of rain-fed cultivation, not cultivated recently. Some grazing.
Vegetation 20% cover of Aristida sp (tufty)
Surface Dry, soft or loose to 2-3 cm. Uneven, with polygonal cracks 2-3 cm wide, generally filled in.

Profile description

0- 39 cm Dry and moist 1OYR4-2. Clay. Dry, slightly hard, weak to moderate coarse prismatic with no pores and wide vertical cracks. Rapidly water absorbent. Some roots. No salts. Some coarse sand and gravel.
 39- 66 cm Dry and moist 1OYR3-2 with 30% mottle 1OYR2-2. Clay. Dry, hard, moderate medium angular blocky with no pores and many fine cracks. Rapidly water absorbent. Few roots. Some small white Calcium carbonate concretions. Some gravel.
 66- 98 cm Dry and moist 1OYR3-2 with 30% mottle 1OYR2-2. Clay. Dry, very hard, structureless with no pores or cracks. Rapidly water absorbent. No roots. Some small white Calcium carbonate concretions. Some gravel.
 98-177 cm Dry and moist 1OYR2-1 with 30% mottle 1OYR3-2. Clay. Dry, very hard, structureless with no pores or cracks. Rapidly water absorbent. No roots. Some white Calcium carbonate concretions and Gypsum crystals.

Laboratory analyses

Depth (cm)	Soil particles %			Incorp Carbon %	PH		E.C.	Soluble Na Meq, per litre	Exch Na Meq per 100 gm Soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension				
0- 39	37	10	53	3.65	8.15	8.56	0.66	0.45	11.7	22
39- 66	35	7	58	3.94	8.27	8.42	1.5	1.05	14.8	26
66- 98	32	10	58	2.97	8.02	8.40	3.8	3.4	17.8	31
98-177	32	8	60	6.44	8.10	7.97	7.8	8.4	13.5	22

Natrangidic Mazustert
 Land Class 6

Pit R063

Location 15° 02'N, 33° 17'E. Date: 14-12-62

Topography Flat

Cultivation and Land Use Near the edge of a patch of rainfed sorghum.

Vegetation 30% cover of Schoenefeldiagracilis on uncultivated land. None in the sorghum stubble. Balanites aegyptiaca and Acacia tortilis 100 to 400 yds apart.

Surface Dry, soft to 1 cm with a thin crust mostly broken up by treading. A few cracks up to 2 cm wide visible - most are filled in.

Profile description

0 - 8 cm Dry and moist 10YR3.5-2. Gravelly clay loam. Dry, soft, moderate medium to fine crumb with few pores and many fine cracks. Rapidly water absorbent. Many roots. Many dark coloured Calcium Carbonate concretions.

8 - 31 cm Dry and moist 10YR3.5-2. Gravelly clay loam. Dry, slightly hard, moderate coarse prismatic with few pores and many fine cracks (non over 3mm wide). Rapidly water absorbent. Few roots. Many dark coloured Calcium Carbonate concretions and much other sand and gravel, especially in old cracks.

31 - 97 cm Dry and moist 10YR3.5-2. Gravelly clay loam. Dry, hard, weak medium angular blocky with no pores and few fine cracks. Rapidly water absorbent. No roots. Many dark Calcium carbonate concretions and much other sand and gravel in old cracks. Occasional shell fragments. Few fine white Calcium carbonate streaks.

97 - 141 cm Moist 10YR3-1, with some 10YR3-2 material in old cracks. Clay, slightly moist, very firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. Few dark Calcium carbonate concretions. Occasional shell fragments. Few white Calcium carbonate concretions and Gypsum crystals.

141-158 cm Moist 10YR3-1 and 10YR4-3. Clay loam slightly moist, very firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. No shells. Common large light coloured Calcium carbonate concretions and Gypsum Crystals.

158 - 175 cm Moist 10YR4-3 with 30% mottle 10YR3-2. Clay loam. Slightly moist, very firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. No shells. Common large light coloured Calcium Carbonate concretions and Gypsum Crystals.

R063

R074

15° 13' N, 119° 10' E Date: 16-12-62

Flat

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension				
0-8	55	10	35	2.97	8.10	8.10				
8-31	47	10	43	3.44	8.07	8.32	0.54	0.3	4.9	14
31-97	42	10	48	3.33	7.76	8.30	1.5	0.85	8.3	19
97-141	37	10	53	3.27	7.77	8.22	4.25	4.3	9.7	20
141-158	35	12	53	4.30	7.70	7.92	5.0	4.3	9.9	19
158-175	35	10	55	3.87	7.72	7.90	5.2	4.0	10.1	19
							5.7	4.4	10.1	18

Natrargidic Mazustert
Non-saline

Land Class 6

11 - 48 cm

pores and many fine cracks. Rapidly water absorbent. Many dark Calcium carbonate concretions. Many small fragments. MOYR3-2. Gravelly clay loam. Dry, slightly hard, moderate coarse prismatic with many wide vertical cracks and fine horizontal cracks. Rapidly water absorbent. Few roots. Many dark Calcium carbonate concretions. Few white Calcium carbonate streaks.

48 - 91 cm

Moist MOYR3-1 Clay with old wide cracks infilled with MOYR3-2 Gravelly clay loam. Slightly moist, firm, structureless with few vertical cracks disappearing about 70 cm. Rapidly water absorbent. No roots. Common Gypsum crystals especially in the dark clay.

91 - 125 cm

Moist MOYR3-1 with few MOYR3-2 mottles. Clay. Slightly moist, very firm structureless with no cracks or pores. Rapidly water absorbent. No roots. Common Gypsum Crystals.

125 - 154 cm

Moist 7.5YR4-2, with old cracks infilled with MOYR3-1 material. Clay. Moist, very firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. Many Gypsum crystals. Common white Calcium carbonate concretions.

154 - 183 cm

Moist 7.5YR4-2. Clay. Moist, very firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. Many large white Calcium carbonate concretions. No Gypsum.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension				
11	55	10	35	2.97	8.10	8.10				
8	47	10	43	3.44	8.07	8.32	0.54	0.3	4.9	14
31	42	10	48	3.33	7.76	8.30	1.5	0.85	8.3	19
97	37	10	53	3.27	7.77	8.22	4.25	4.3	9.7	20
141	35	12	53	4.30	7.70	7.92	5.0	4.3	9.9	19
158	35	10	55	3.87	7.72	7.90	5.2	4.0	10.1	19
175							5.7	4.4	10.1	18

Marginal Orthic Chromustert/Natrargidic Mazustert
Land Class 1/6.

Pit R074
Location 15° 13' N, 33° 10' E. Date: 16-12-62
Topography Flat
Cultivation and Land Use Old Sorghum patch. No stubble visible.
Vegetation Very sparse Aristida sp. Acacia tortilis trees 300 to 400 yds apart.
Surface Dry, soft, with a finely cracked cap. Many dark Calcium carbonate concretions. Uneven, with a faint polygonal pattern of infilled cracks. Many 'sink' holes over cracks up to 6 cm. wide.

Profile Description

0 - 11 cm Dry 10YR4-2, moist 10YR3.5-2. Clay loam. Dry, soft, moderate fine subangular blocky with few pores and many fine cracks. Rapidly water absorbent. Common roots. Many dark Calcium carbonate concretions. Many shell fragments.

11 - 48 cm Dry and moist 10YR3-2. Gravelly clay loam. Dry, slightly hard, moderate coarse prismatic with many wide vertical cracks and fine horizontal cracks. Rapidly water absorbent. Few roots. Many dark Calcium carbonate concretions. Few white Calcium carbonate streaks.

48 - 91 cm Moist 10YR3-1 Clay with old wide cracks infilled with 10YR3-2 Gravelly clay loam. Slightly moist, firm, structureless with few vertical cracks disappearing about 70 cm. Rapidly water absorbent. No roots. Common Gypsum crystals especially in the dark clay.

91 - 125 cm Moist 10YR3-1 with few 10YR4-3 mottles. Clay. Slightly moist, very firm structureless with no cracks or pores. Rapidly water absorbent. No roots. Common Gypsum Crystals.

125 - 154 cm Moist 7.5YR4-2, with old cracks infilled with 10YR3-1 material. Clay. Moist, very firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. Many Gypsum crystals. Common white Calcium carbonate concretions.

154 - 188 cm Moist 7.5YR4-2. Clay. Moist, very firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. Many large white Calcium carbonate concretions. No Gypsum.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 soil sus-pension				
0-11	50	5	45	6.30	8.08	8.27	0.57	0.3	5.4	12
11-48	45	7	48	6.37	8.06	8.52	0.68	0.4	7.8	16
48-91	40	10	50	7.16	7.8	8.5	6.7	5.2	10.4	20
91-125	30	7	63	7.73	7.75	8.45	7.2	7.8	12.2	20
125-154	27	18	55	7.26	7.63	8.38	6.9	7.8	9.8	18
154-188	20	17	63	6.17	7.94	8.6	4.0	4.2	14.2	22

Marginal Orthic Grumustert/Natrargidic Mazustert
 Land Class 3/6.

Pit R075
Location 15°9'N, 33° 14'E. Date: 16-12-62
Topography Flat
Cultivation and Land Use Not cultivated. Grazing land with low bunds.
Vegetation No trees for over 1Km. Patchy Schoenefeldia gracilis, up to 50% cover.
Surface Dry, hard, level with no cracks and occasional 'sink' holes and abundant loose dark coloured Calcium carbonate concretions.

Profile description

0 - 7 cm Dry 10YR4-2, moist 10YR3.5-2. Gravelly clay loam. Dry, soft, weak medium subangular blocky with few pores and no cracks. Moderately water absorbent. Many fine roots. Many dark Calcium carbonate concretions.

7 - 28 cm Dry 10YR3.5-2, moist 10YR3-2. Gravelly clay loam. Dry, slightly hard, strong fine prismatic with no pores and many fine cracks. Rapidly water absorbent. Many fine roots. Many dark Calcium carbonate concretions.

28 - 49 cm Dry 10YR3.5-2, moist 10YR3-2. Gravelly clay loam. Dry, hard, weak coarse prismatic with no pores and few vertical cracks. Rapidly water absorbent. No roots. Many dark Calcium carbonate concretions.

49 - 98 cm Moist 10YR3-2. Gravelly clay. Slightly moist, very firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. Common dark Calcium carbonate concretions. Many Gypsum crystals.

98 - 144 cm Moist 10YR3-2, with few 10YR4-3 mottles. Gravelly clay moist, very firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. Common Gypsum crystals and hard white Calcium Carbonate concretions.

144 - 172 cm Moist 10YR3-3 with few 10YR4-3 mottles. Clay loam. Moist, very firm, structureless, with no pores or cracks. Rapidly water absorbent. No roots. Few Gypsum crystals and hard white Calcium carbonate concretions.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 soil sus-pension				
0-7	62	10	28	7.33	8.0	8.13	0.42	0.2	0.5	2
7-28	52	10	38	7.62	8.11	8.62	0.75	0.5	5.8	15
28-49	55	5	40	7.14	7.89	8.85	5.5	4.2	10.8	27
49-98	42	15	45	6.32	7.86	8.52	7.5	8.4	17.2	38
98-144	35	7	58	5.45	7.89	8.72	8.5	7.6	23.6	40
144-172	25	15	60	6.61	8.2	8.85	4.25	6.1	28.9	48

Marginal Natrargidic Mazustert

Land Class 6

D, Natrargids

Pit R012

Location 15° 33' N, 32° 40' E. Date: 27-11-62

Topography Flat

Cultivation and Land Use

Not cultivated. Grazed by cattle and sheep.

Vegetation

Acacia erhenbergiana bushes ten to twenty yards apart. 10% cover of fine grasses.

Surface

Dry, slightly hard, finely cracked cap, 2 mm. thick. Much gravel.

Profile Description

- 0 - 18 cm Dry 10YR4-4, moist 10YR4-3. Gravelly clay loam. Dry, slightly hard, moderate medium subangular blocky with few pores and many fine cracks. Rapidly water absorbent. Many roots. Few Kankars.
- 18 - 55 cm Dry and moist 10YR3-2. Gravelly clay loam. Dry, hard, moderate coarse prismatic with few pores and many wide vertical cracks. Moderately water absorbent. Few fine roots. Some amorphous white salts.
- 55 - 97 cm Dry and moist 10YR3-2. Clay loam. Dry, hard, structureless, with no pores or cracks. Moderately water absorbent. No roots. Some white salt crystals. Some gravel.
- 97 - 161 cm Dry, moist 10YR5-4 with 10YR5-8 mottles. Loamy gravel. Dry, hard (cemented), structureless, with no cracks or pores. Rapidly water absorbent. No roots. Some white salt crystals. Some iron staining and iron concretions especially near the upper edge of the horizon.
- 161 - 185 cm Dry and moist 10YR8-3 with 10YR6-3 mottles. Loamy gravel. Dry, hard (cemented), structureless, with no cracks or pores. Rapidly water absorbent. Some white salt crystals. Little or no iron staining.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil suspension				
0-18	72	8	20	7.01	7.93	7.98	0.48	0.21	2.9	15
18-55	55	10	35	1.74	8.64	8.86	2.25	2.0	13.6	40
55-97	55	7	38	4.10	8.35	8.65	7.75	7.6	15.4	44
97-161	62	8	30	14.32	8.25	8.55	8.25	7.6	8.7	29
161-185	57	20	23	61.58	8.45	8.80	3.25	3.4	6.7	29

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Land Class 6

6as

Pit R017

Location 15° 33' N, 32° 42' E. Date: 28-11-62

Topography Flat

Cultivation and Land Use Not cultivated. Grazed by cattle and sheep.

Vegetation Open plain with Acacia erhenbergiana and Acacia tortilis 50-100 yards apart. 30% cover of short fine grasses (Schoenefeldiagracilis).

Surface Dry, slightly hard, not cracked.

Profile description

0 - 14 cm Dry 10YR5-4, moist 10YR4-3. Gravelly clay loam. Dry, slightly hard, moderate medium to fine subangular blocky with no pores and many fine cracks. Rapidly water absorbent. Many roots. No salts.

14 - 42 cm Dry and moist 10YR3-2. Sandy clay. Dry, very hard, strong coarse prismatic, with no pores. Vertical cracks up to 1/2 cm wide and fine horizontal cracks. Moderately water absorbent. Few roots. Some dark Kankars.

42 - 74 cm Dry and moist 10YR3-2. Sandy Clay. Dry, hard, structureless with no pores and few vertical cracks. Moderately water absorbent. No roots. Some white Gypsum crystals.

74 - 134 cm Dry and moist 10YR3-2. Clay Loam. Dry, hard, structureless, with no pores and few vertical cracks disappearing about 100 cm. Moderately water absorbent. No roots. Many gypsum crystals.

134 - 185 cm Moist 10YR3-2 with 10YR4-4 mottles. Sandy clay. Slightly moist, hard, structureless to weak medium angular blocky with some fine cracks. Moderately water absorbent. No roots. Some gypsum crystals. Much gravel in patches. Some Kankars.

185 - 194 cm Moist 10YR3-2 to 10YR5-8. Gravelly loam. Slightly moist, hard, structureless, gravel cemented by clay. Moderately water absorbent. No roots. No salts.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension				
0-14	67	10	23	4.72	8.12	8.25	0.57	0.2	0.8	4
14-42	47	13	40	9.62	8.40	8.73	1.0	0.6	11.5	29
42-74	42	10	48	4.51	8.21	8.27	8.5	7.2	18.6	40
74-134	45	10	45	5.55	8.13	8.09	10.0	7.2	15.4	34
134-185	37	10	53	7.23	8.10	8.25	6.5	6.1	18.3	35
185-194	55	5	40	1.25	8.21	8.46	5.7	4.6	12.8	32

Natrargid

Land Class 6 3asv

Pit RO21
Location 15° 27'N, 32° 48' E. Date: 29-11-62
Topography Flat
Cultivation and Land Use Not Cultivated. Grazed by cattle, sheep and goats.
Vegetation Schoenefeldia gracilis and Aristida sp. 60-70% cover. Acacia tortilis bushes 10 to 20 yds apart.
Surface Dry, hard, level, with polygonal cracks $\frac{1}{2}$ cm wide.

Profile Description

0 - 38 cm Dry 10YR4-3, moist 10YR3-3. Coarse Sandy clay loam. Dry, slightly hard, moderate coarse prismatic, with no pores. Vertical cracks $\frac{1}{4}$ cm wide and fine horizontal cracks. Rapidly water absorbent. Many roots. No salts. Some gravel.

38 - 59 cm Moist 10YR4-2 with 50% mottle 10YR3-2. Coarse sandy clay. Moist, very firm, structureless, with no pores or cracks. Moderately water absorbent. Few roots. Many vertical white Calcium Carbonate streaks.

59 - 83 cm Moist 10YR4-2 with 50% mottle 10YR3-2. Coarse sandy clay. Moist, firm, structureless, with no pores or cracks. Slowly water absorbent. Few roots. Few white CaCO₃ concretions and Gypsum crystals.

83 - 154 cm Moist 10YR4-2 with 50% mottle 2.5Y4-2. Coarse sandy clay. Moist, firm, structureless with no pores or cracks. Slowly water absorbent. Few roots. Very many Gypsum crystals. No calcium carbonate.

154-180 cm Moist 10YR4-2 with 50% mottle 2.5Y4-2. Clay. Very moist, very firm, structureless with no pores or cracks. Slowly water absorbent. No roots. No salts. Some gravel appearing towards the bottom of this horizon.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension				
0-38	82	5	13	3.15	8.10	8.23	0.43	0.2	1.7	13
8-59	72	5	23	6.80	8.55	8.65	0.68	0.44	7.8	34
9-83	67	8	25	6.59	8.52	8.67	2.55	1.6	9.7	39
3-154	55	5	40	9.03	8.15	8.25	8.8	7.2	13.6	34
4-180	50	10	40	7.02	8.54	8.75	4.0	2.5	23.9	60

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Land Class 6

Pit R025
Location 15° 26' N, 32° 48' E. Date: 1-12-62
Topography Flat
Cultivation and Land Use Not cultivated. Grazed by sheep, goats and cattle.
Vegetation Acacia tortilis up to 10 yards apart. Some A. erhenbergiana. 50% cover of Schoenefeldia gracilis.
Surface Dry, hard, level, with no cracks.

Profile Description

0 - 12 cm Dry and moist 10YR4-4. Coarse sandy clay loam. Dry, slightly hard, weak coarse angular blocky with few pores and fine cracks. Rapidly water absorbent. Many roots. No salts.

12 - 44 cm Dry and moist 10YR4-3 with 30% mottle 10YR3-3. Coarse sandy clay loam. Dry, hard, weak coarse prismatic with no pores and few vertical cracks. Rapidly water absorbent. Rare roots. Many vertical streaks of white Calcium Carbonate.

44 - 72 cm Moist 2.5Y4-2. Coarse sandy clay loam. Slightly moist, hard, structureless with no pores or cracks. Moderately water absorbent. No roots. Many vertical white streaks of Calcium carbonate. Some Gypsum crystals.

72 - 94 cm Moist 2.5Y4-2 with 20% mottle 10YR4-2. Coarse sandy clay. Moist, firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. Many Gypsum crystals. Little Calcium carbonate.

94 - 180 cm Moist 2.5Y4-2 with 20% mottle 10YR4-2. Coarse sandy clay. Moist, very firm, structureless with no pores or cracks. Moderately water absorbent. No roots. Little Gypsum and Calcium carbonate.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P.
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension				
12	75	10	15	3.38	8.00	8.22	0.39	0.16	1.2	8
44	65	10	25	9.31	8.62	8.90	1.7	0.9	11.3	45
72	67	8	25	10.31	8.47	8.65	7.0	5.2	6.3	25
94	65	5	30	11.71	8.13	8.35	7.7	6.8	11.7	39
180	52	10	43	7.41	8.62	9.01	2.5	3.3	18.6	43

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Land Class 6

Pit R095
Location 15° 16' N, 33° 04' E. Date: 22-12-62
Topography Very gentle slope to South-West.
Cultivation and Land Use Not cultivated. Grazing land.
Vegetation Schoenefeldia gracilis, 40% cover, up to 18 inches high. No trees.
Surface: Dry, hard, level, finely cracked, with no 'sink' holes.

Profile Description

- 0 - 4 cm Dry 1OYR4.5-2 moist 1OYR3.5-2. Gravelly clay loam. Dry, soft, weak medium platy, with few pores and fine horizontal cracks. Rapidly water absorbent. Many fine roots. Much quartz gravel and some dark Calcium carbonate concretions.
- 4 - 13 cm Dry 1OYR4-2, moist 1OYR3.5-2. Gravelly clay loam. Dry, soft, weak medium subangular blocky with few fine cracks and pores. Rapidly water absorbent. Many fine roots. Much quartz gravel and some dark Calcium Carbonate concretions. Few white Calcium carbonate streaks.
- 13 - 39 cm Dry and moist 1OYR3.5-2. Gravelly clay loam. Dry, hard, strong fine prismatic with no pores and many vertical cracks up to 0.5 cm wide. Common fine horizontal cracks. Rapidly water absorbent. Common fine roots. Much quartz gravel and some dark Calcium carbonate concretions. Few white Calcium Carbonate streaks.
- 39 - 53 cm Dry and moist 1OYR3-2. Sandy clay loam. Dry, hard, structureless with no pores or cracks. Rapidly water absorbent. Few fine roots. Common quartz gravel. Few white Calcium Carbonate streaks.
- 53 - 105 cm Moist 1OYR3-1. Sandy Clay. Slightly moist, hard, structureless with few fine pores and cracks. Rapidly water absorbent. No roots. No quartz gravel. Few white Calcium Carbonate streaks. Common Gypsum crystals.
- 105 - 136 cm Moist 1OYR4-4 with some 1OYR3-1 material infilled in old cracks. Gravelly clay loam. Dry, hard structureless with no pores or cracks. Moderately water absorbent. No roots. Many hard light coloured Calcium Carbonate concretions.
- 136 - 168 cm Moist 1OYR4-4 with few 1OYR5-6 mottles. Gravelly clay loam. Dry, hard, structureless with no pores or cracks. Moderately water absorbent. No roots. Many hard light coloured Calcium Carbonate concretions.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil suspension				
0-4	75	7	18	3.99	7.84	7.85	0.48	0.2	0.13	1
4-13	62	10	28	4.79	7.88	8.40	0.38	0.3	0.40	2
13-39	52	13	35	10.64	8.20	8.75	2.1	1.1	7.90	23
39-53	43	22	35	9.44	8.40	8.90	2.35	1.5	11.50	33
53-105	45	10	45	9.29	7.80	8.50	8.0	6.8	11.60	26
105-136	55	12	33	12.56	8.10	9.00	3.6	3.4	10.60	32
136-168	65	7	28	8.97	8.49	9.05	2.4	1.9	9.70	34

Common fine roots. No salts.

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Land Class 6

0-31 cm

Dry and firm with 10% moisture. Gravelly clay loam. Dry, hard, strong medium prismatic with no pores and many fine cracks. Rapidly water absorbent. Common fine roots. No salts.

31-61 cm

Moist LOYR4-3 with 20% moisture. Sandy clay loam. Slightly moist, very firm, structureless and compact with no pores or cracks. Rapidly water absorbent. No roots. Common vertical white Calcium carbonate streaks.

61-122 cm

Moist LOYR4-3 with 20% moisture. Sandy clay loam. Slightly moist, very firm, structureless and compact with no pores or cracks. Rapidly water absorbent. No roots. Abundant soft white Calcium carbonate concretions about 1 cm diameter. Common dark manganese stains.

122-183 cm

Moist LOYR4-3 with 20% moisture. Gravelly clay loam. Moist, very firm, structureless and compact with no pores or cracks. Moderately water absorbent. No roots. Abundant soft and hard light coloured Calcium carbonate concretions. Many small dark manganese concretions.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil suspension				
57	3	10		2.4	8.28	8.35	0.37	0.33	0	nil
72	3	25		1.23	8.10	8.10	0.43	1.1	5.30	21
86	2	16		2.72	8.02	8.05	1.05	1.7	5.60	31
92	5	13		7.44	8.25	8.25	3.0	2.0	6.00	45
113	7	30		21.56	8.52	9.30	2.1	2.8	14.40	39

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Land Class 6

Pit DR106
Location 15° 19' N, 32° 55' E. Date: 7.1.63
Topography Flat
Cultivation and Land Use Not cultivated - grazing land.
Vegetation Acacia tortilis trees 10-20 ft high, 20-50 yards apart. Grass recently burned off.
Surface Dry, hard, level with no cracks, almost entirely covered by a thin layer of loose quartz sand.

Profile Description

0 - 4 cm Dry 10YR5-4, moist 10YR4-3. Sandy loam. Dry, slightly hard, structureless with few pores and no cracks. Laminated. Rapidly water absorbent. Common fine roots. No salts.

4 - 31 cm Dry and moist 7.5YR4-4 with 10% mottle 7.5YR5-6. Gravelly clay loam. Dry, hard, strong medium prismatic with no pores and many fine cracks. Rapidly water absorbent. Common fine roots. No salts.

31 - 81 cm Moist 10YR4-3 with 20% mottles 10YR5-2 and 10YR5-6. Sandy clay loam. Slightly moist, very firm, structureless and compact with no pores or cracks. Rapidly water absorbent. No roots. Common vertical white Calcium carbonate streaks.

81 - 122 cm Moist 10YR4-3 with 20% mottles 10YR5-2 and 10YR5-6. Sandy clay loam. Slightly moist, very firm, structureless and compact with no pores or cracks. Rapidly water absorbent. No roots. Abundant soft white Calcium carbonate concretions about 1 cm diameter. Common dark ? Manganese stains.

122- 185 cm Moist 10YR4-3 with 20% mottles 10YR4-2. Gravelly clay loam. Moist, very firm, structureless and compact with no pores or cracks. Moderately water absorbent. No roots. Abundant soft and hard light coloured Calcium carbonate concretions. Many small dark ? Manganese concretions.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil suspension				
0-4	87	3	10	2.4	8.28	8.35	0.27	0.05	0	nil
4-31	72	3	25	1.23	8.10	8.48	0.43	0.3	5.30	21
31-81	80	2	18	2.72	8.09	8.95	3.05	1.9	6.60	37
81-122	82	5	13	7.44	8.25	9.55	3.0	2.0	6.00	46
122-185	55	7	38	21.56	8.50	9.60	2.1	2.8	14.40	38

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 Land Class 6

Pit DR107
Location 15° 21' N, 32° 55' E. Date: 8-1-63
Topography Flat
Cultivation and Land Use No cultivation. Grazing land.
Vegetation Acacia tortilis and Acacia seyal, 5 to 40 yards apart, 10-15 ft high. Grass mostly burned off, but a few patches of Schoenefeldia gracilis remain beneath trees.
Surface Dry, slightly uneven, with low wind-accumulated sandy hammocks. Slightly hard, with no cracks and no 'sink' holes.

Profile Description

0 - 12 cm Dry 10YR5-3, moist 10YR4-2. Loam. Dry, slightly hard, very weak coarse prismatic with common fine pores and few fine cracks. Rapidly water absorbent. Many fine roots. No salts. Little gravel.
 12 - 41 cm Dry and moist 10YR3.5-2, Coarse sandy clay loam. Dry, hard, moderate medium prismatic with few fine pores and many cracks up to 0.5 cm wide. Rapidly water absorbent. Few fine roots. Some large roots. Some patches of vertical Calcium Carbonate streaks.
 41 - 79 cm Moist 10YR3.5-2 with 30% mottle 10YR4-3. Coarse sandy clay loam. Slightly moist, very firm, structureless with few pores and no cracks. Moderately water absorbent. Few large roots. Common vertical Calcium Carbonate streaks.
 79 - 157 cm Moist 10YR3.5-2 with 20% mottle 10YR4-4. Coarse Sandy Clay Loam. Slightly moist, very firm, structureless with no pores and no cracks. Moderately water absorbent. Rare fine roots. Common Gypsum crystals. No Calcium Carbonate.
 157 - 186 cm Moist 10YR3.5-2 with 20% mottle 10YR4-4. Coarse Sandy clay loam. Slightly moist, very firm, structureless with no pores or cracks. Moderately water absorbent. No roots. Common soft white and hard nodular Calcium Carbonate concretions.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P.
	Sand	Silt	Clay		Soil Paste	1.5 Soil suspension				
0-12	80	7	13	7.73	7.93	8.22	0.4	0.07	0	nil
12-41	62	10	28	6.37	8.43	9.67	0.8	0.4	8.10	30
41-79	67	8	25	7.73	7.97	9.25	3.0	1.8	11.20	45
79-120	62	10	28	10.12	7.95	8.21	6.0	6.0	9.10	32
120-157	62	8	30	8.46	8.76	9.15	7.7	5.2	7.90	26
157-186	65	7	28	9.35	8.22	9.23	2.8	2.5	11.40	41

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 Land Class 6

Pit DR117
Location 15° 24' N, 32° 52' E. Date: 10-1-63
Topography Flat
Cultivation and Land Use: Grazing
Vegetation No trees. 60% cover of Schoenefeldia gracilis
Surface Dry, hard, level with no cracks. 'Sink' holes 2 to 5 yards apart. Common loose quartz sand.

Profile Description

0 - 10 cm Dry 10YR5-4, moist 10YR4-3. Loam. Dry, slightly hard, weak medium subangular blocky with few fine pores and cracks. Rapidly water absorbent. Many fine roots. Common quartz gravel and dark Calcium Carbonate concretions.

10 - 32 cm Dry 10YR4-2, moist 10YR3.5-2. Gravelly clay loam. Dry, hard, strong coarse prismatic with no pores and many cracks. Vertical cracks up to 0.5 cm wide. Much quartz gravel and many dark Calcium Carbonate concretions in old cracks.

32 - 53 cm Moist 10YR3.5-2 with few mottles 10YR4-3. Gravelly clay loam. Slightly moist, very firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. Common small white Calcium Carbonate streaks.

53 - 72 cm As above with few small white Calcium Carbonate streaks and common Gypsum crystals.

72 - 185 cm Moist 10YR3-2 with 10YR5-1 and 10YR4-4 mottles. Gravelly clay loam. Slightly moist, very firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. Many hard and some soft light coloured Calcium Carbonate concretions. No Gypsum.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P.
	Sand	Silt	Clay		Soil Paste	1.5 soil sus-pension				
10	65	12	23	9.27	8.16	8.98	0.41	0.2	0.50	2
32	55	12	33	11.7	8.40	9.32	1.2	0.6	9.80	30
53	55	10	35	12.36	8.63	9.31	2.4	1.6	11.00	31
72	57	8	35	11.67	7.72	8.01	7.0	5.6	8.3	24
80	62	8	30	16.34	8.25	9.02	2.6	2.2	9.6	32
85	60	7	33	14.28	8.39	9.00	1.55	1.7	11.1	24

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 Land Class 6

DR118

Pit:

Location:

15°22'N, 32°53'E

Date: 10-1-63

Topography:

Flat.

Cultivation and
Land Use:

Grazing (burned off).

Vegetation:

Burnt grass stubble. No trees or bushes.

Surface:

Dry, hard, level with a finely cracked cap about 2 mm thick. 'Sink' holes up to 5 yds. apart. Common loose quartz sand and gravel and dark Calcium Carbonate concretions.

Profile Description:

- 0-12 cm Dry 10YR4.5-2, moist 10YR4-2. Sandy clay loam. Dry, slightly hard, structureless with few fine pores and cracks. Rapidly water absorbent. Many fine roots. Much quartz gravel. Many dark Calcium Carbonate concretions.
- 12-31 cm Dry and moist 10YR3.5-2. Sandy clay loam. Dry, hard strong, medium prismatic with few fine pores and many cracks. Vertical cracks up to 0.5 cm. wide. Rapidly water absorbent. Common fine roots. Much Quartz gravel. Many dark Calcium Carbonate concretions. Few soft white Calcium Carbonate streaks.
- 31- 53 cm Moist 10YR3.5-2 with few mottles 10YR4-3. Sandy clay loam. Slightly moist, firm, structureless with no pores or cracks. Rapidly water absorbent. Few roots. Few soft white Calcium Carbonate streaks. Much quartz sand. Many dark Calcium Carbonate concretions.
- 53-85 cm As above with no roots, many hard light coloured Calcium Carbonate concretions, and common Gypsum crystals.
- 85-114 cm Dry and moist 10YR3-2 with 20% mottles 10YR4-3. Sandy clay loam. Dry, hard, structureless with no pores or cracks. Rapidly water absorbent. No roots. Common hard light coloured Calcium Carbonate concretions. No Gypsum.
- 114-173 cm Dry and moist 10YR3-2 with 40% mottles 10YR 4-4. Sandy clay loam. Dry, hard, structureless with no pores or cracks. Rapidly water absorbent. No roots. Common hard light coloured Calcium Carbonate concretions. Common dark coloured Manganese stains and soft iron concretions.

Pit: DR125
Location: 15°28'N, 32°53'E. Date: 11-1-63.
Topography: Flat with low sandy mounds around bushes.
Cultivation and Land Use: Sparse grazing land.
Vegetation: Acacia tortilis and A. erenbergiana bushes up to ten feet high, generally in clumps 20 to 100 yds apart. Schoenefeldiagracilis, 10% cover, mostly grazed short.
Surface: Dry, hard, level, with no cracks or 'sink' holes. Much loose quartz sand and some gravel.

Profile Description:

- 0 - 2 cm Dry and moist 7.5YR4-4. Sandy loam. Dry, slightly hard, structureless with no pores or cracks. Rapidly water absorbent. Few roots. No salts.
- 2 - 25 cm Dry and moist 7.5YR4-4. Sandy clay loam. Dry, hard, strong medium prismatic with no pores and cracks up to 1 cm. wide, infilled with loose sand. Rapidly water absorbent. Few roots. Few patches of Calcium Carbonate streaks.
- 25 - 83 cm Moist 10YR4-3. Sandy clay loam. Slightly moist, very firm, structureless with no pores or cracks. Some old vertical cracks infilled with material from above. Rapidly water absorbent. No roots. Many white Calcium Carbonate streaks.
- 83 - 139 cm Moist 10YR4-3 with few mottles 7.5YR5-6. Sandy clay loam. Slightly moist, very firm, structureless with no pores or cracks. Rapidly water absorbent. No roots. Few white Calcium Carbonate streaks. Common dark Manganese stains. Few hard Calcium Carbonate concretions with dark ?Manganese flecks.
- 139 - 184 cm Moist 10YR4-3 with many mottles 7.5YR 5-6. Sandy clay loam. Slightly moist, very firm, structureless, with some clay skins in cracks. Moderately water absorbent. No roots. Common hard Calcium Carbonate concretions with dark ?Manganese flecks.
- 184 - 190 cm Moist 10YR 4-3 with 50% mottle 10YR5-4. Gravelly clay loam. Slightly mdst, very firm, structureless. Moderately water absorbent. Many hard Calcium Carbonate concretions.

Laboratory Analyses:

15° 43' N, 127° 34' E. Elev. 15-1-41
 Flat, with low sandy mounds

Soil Particles%			Incorp Carbon %	P.H.		E.C. Sat. Extr.	Sol. Na. Meq. per litre	Exch. Na Meq. per 100 gm. soil	E.S.P.
Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension				
75	7	18	0.48	7.38	7.70	0.55	0.19	0.0	NIL
70	7	23	3.22	8.20	9.15	0.72	0.34	3.76	16
85	2	13	4.51	8.45	9.60	1.4	0.64	6.26	48
80	5	15	3.68	8.50	9.45	2.25	1.60	6.20	41
75	5	20	8.91	8.49	9.32	2.9	2.40	7.60	38
65	7	28	8.17	8.35	9.10	4.25	4.93	8.67	31

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 Land Class 6

15-18 cm
 10YR3-1. Sandy Clay loam. Slightly moist, long coarse prismatic with many cracks up to 1 cm wide. Old cracks up to 10 cm wide filled with material from above. Rapidly water absorbent. Few fine roots. Few white Calcium Carbonate streaks.

18-20 cm
 Moist 10YR3-1. Sandy clay. Moist, firm, structureless with no pores or cracks. Some old cracks up to 3 cm wide filled with sandy loam. Moderately water absorbent. Many gypsum crystals. Few white Calcium Carbonate streaks.

20-30 cm
 Moist 10YR3-2 with 50% matrix 10YR3-3. Sandy clay. Moist, very firm, structureless with no pores or cracks. Moderately water absorbent. No roots. Common gypsum crystals. Common soft and hard Calcium Carbonate concretions.

Laboratory Analyses

Soil Particles %			Incorp Carbon %	P.H.		E.C. Sat. Extr.	Soluble Na Meq. per litre	Exch. Na Meq. per 100 gm soil	E.S.P.
Sand	Silt	Clay		Soil Paste	1.5 soil sus-pension				
80	2	8	1.25	7.93	8.38	0.24	0.37	0.0	NIL
57	10	33	4.64	8.17	9.05	2.7	1.08	7.05	15
70	7	43	6.84	8.08	8.90	10.2	11.00	10.20	25
57	10	45	4.64	8.15	8.35	2.2	8.20	13.00	25

Natrargid (Aridisol)
 Land Class 6

Pit Natrargid DR131
Location 15° 43' N, 32° 34' E. Date: 16-1-63.
Topography Flat, with low sandy mounds
Cultivation and Land Use Sparse grazing
Vegetation Capparis decidua, up to 12 ft high, 10 to 30 yards apart, commonly on low sandy mounds. Schoenefeldia gracilis, 1% cover, 1 to 2 inches high.
Surface Dry, soft, sandy with no cracks or 'sink' holes. Many dark Calcium Carbonate concretions.

Profile Description

0 - 15 cm Dry 10YR5-4, moist 10YR4-3. Sandy loam. Dry, soft, structureless with no cracks and few fine pores. Rapidly water absorbent. Common fine roots. No salts. Common dark Calcium Carbonate concretions.

15 - 58 cm Moist 10YR3-1. Sandy Clay loam. Slightly moist, firm, strong coarse prismatic with many cracks up to 1 cm wide. Old cracks up to 10 cm wide infilled with material from above. Rapidly water absorbent. Few fine roots. Few white Calcium Carbonate streaks.

58 - 120 cm Moist 10YR3-1. Sandy clay. Moist, firm, structureless with no pores or cracks. Some old cracks up to 3 cm wide infilled with sandy loam. Moderately water absorbent. Many Gypsum crystals. Few white Calcium Carbonate streaks.

120 - 170 cm Moist 10YR3-2 with 50% mottle 10YR4-3. Sandy clay. Moist, very firm, structureless with no pores or cracks. Moderately water absorbent. No roots. Common Gypsum crystals. Common soft and hard Calcium Carbonate concretions.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		F.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 soil sus-pension				
0-15	90	2	8	1.25	7.93	8.38	0.24	0.07	0.0	Nil
15-58	57	10	33	4.64	8.17	9.05	1.7	1.08	7.62	23
58-120	50	7	43	6.84	8.08	8.90	10.2	11.40	10.20	24
120-170	45	10	45	4.64	8.15	8.35	9.2	8.20	12.60	28

Natrargid (Aridisol)
 Land Class 6

E. Haplargids

Pit R088
Location 15° 16'N, 33° 06'E. Date: 20-12-62
Topography Flat, with low sandy mounds around bushes.
Cultivation and Land Use Not cultivated. Grazing land.
Vegetation Acacia nubica bushes up to 5 yds apart. Patchy cover of Aristida sp.
Surface Dry, hard, level with no cracks and few 'sink' holes. Much loose sand and some gravel.

Profile Description

0 - 15 cm Dry, 2.5U5-2, moist 2.5Y4-2. Sandy clay loam. Dry, slightly hard, weak coarse subangular blocky with few pores and cracks. Rapidly water absorbent. Common fine roots. Much quartz sand and gravel.

15 - 36 cm Dry 10YR4-2, moist 10YR3.5-2. Clay loam. Dry, slightly hard, strong fine prismatic with few pores and many fine cracks. Rapidly water absorbent. Many fine roots and some large roots. Common quartz sand and gravel.

36 - 53 cm Moist 10YR3-2. Clay loam. Slightly moist, very firm, moderate coarse prismatic with no pores and common fine cracks. Occasional vertical cracks up to 1 cm wide. Rapidly water absorbent. Few fine, common large roots. Common quartz sand and gravel.

53 - 183 cm Moist 10YR3-2. Clay loam. Slightly moist, very firm, structureless with no pores and occasional cracks up to 1 cm wide extending to the bottom of the pit. Rapidly water absorbent. Much sandy material infilled in old cracks. Few coarse roots, associated with old cracks. Few white Calcium carbonate concretions.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P.
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension				
15	72	8	20	4.61	7.86	8.01	0.32	0.09	0.24	1
36	55	12	33	6.17	7.72	7.82	0.35	0.1	1.70	5
53	50	7	43	7.44	7.70	7.72	0.34	0.33	2.12	5
100	47	8	45	7.51	7.8	7.92	0.47	0.4	3.60	8
150	45	10	45	7.26	7.72	8.15	0.65	0.5	4.30	10
183	40	10	50	7.26	7.80	7.95	1.7	1.3	5.00	10

Haplargid
 Non-saline, Non-Alkali
 Land Class 2/4

Pit DR101
Location 15° 21'N, 32° 57'E. Date: 7-1-63
Topography Part of a broad low sandy ridge, with a very gentle slope to the North-West.

Cultivation and Land Use Sparse grazing.

Vegetation Acacia tortilis bushes 20-50 yds apart.
 2% cover of fine grasses, grazed short.

Surface Dry, hard, level with a thin, very finely cracked cap. No 'sink' holes. Much loose sand and gravel.

Profile Description

0 - 2 cm Dry 10YR5-4, Moist 10YR4-3. Gravelly sandy loam. Dry, soft, weak fine platy with few pores and many fine horizontal cracks. Rapidly water absorbent. Many fine roots. No salts. Much quartz gravel.

2 - 33 cm Dry 10YR4-3, Moist 10YR3-2, sandy loam. Dry, soft structureless with common pores and no cracks. Rapidly water absorbent. Many fine roots. No salts. Much quartz gravel and occasional shell fragments.

33 - 58 cm Dry and moist 10YR4-3. Sandy clay loam. Dry, hard, weak medium prismatic. Hard compact prisms with few fine vertical cracks and few pores. Rapidly water absorbent. Few fine roots. Few small white Calcium Carbonate streaks.

58 - 101 cm Dry and moist 10YR4-4 with 50% 10YR5-6 mottle, and many large infills of 10YR4-3 material from above. Sandy Clay loam. Dry, hard, weak medium prismatic. Hard compact prisms with few fine vertical cracks and few pores. Moderately water absorbent. No roots. Few small white Calcium Carbonate streaks. Common soft dark (purplish) concretions (?Manganese).

101 - 131 cm Dry and moist 10YR4-4 with 50% 10YR5-6 mottle. Sandy clay loam. Dry, hard, structureless with no pores or cracks. Moderately water absorbent. No roots. No Calcium carbonate concretions. Common dark purplish ?Manganese concretions.

131-180 cm Dry and moist 10YR5-6 with 30% 10YR5-2 mottle. Sandy clay loam. Dry, hard, structureless with no pores or cracks. Moderately water absorbent. No roots. Common dark purplish ?Manganese concretions.

Laboratory analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Coil suspension				
2	82	8	10	1.87	8.03	8.11	0.32	0.06	0	nil
33	82	8	10	1.74	8.12	8.29	0.24	0.05	0	nil
58	67	5	28	1.82	8.02	8.66	0.26	0.1	0.50	2
101	72	3	25	1.52	8.16	8.58	0.38	0.2	1.20	5
131	80	2	18	1.45	8.20	8.40	0.52	0.2	0.82	5
180	80	2	18	1.71	8.00	8.49	0.82	0.4	0.80	4

Haplargid, Non saline, Non-alkali
 Land Class 2/4

Pit DRI37
Location 15°41'N, 32° 38'E. Date: 17-1-63
Topography Flat
Cultivation and Land Use Sparse grazing
Vegetation Acacia tortilis trees, up to 12 ft tall, 10 to 30 yds apart. Scattered A. erhenbergiana and Capparis decidua.
Surface Dry, slightly hard, sandy, with no cracks or 'sink' holes. Some quartz gravel and dark Calcium Carbonate concretions.

Profile description

0 - 4 cm Dry 10YR5-4, moist 10YR4-4. Sandy loam. Dry, soft, structureless (laminated) with no pores or cracks. Rapidly water absorbent. Common fine roots. No salts. Some quartz gravel and dark Calcium carbonate concretions.

4 - 24 cm Dry 10YR5-4, moist 10YR4-3 Loam. Dry, soft, structureless with no laminations; no pores or cracks. Moderately water absorbent. Common fine roots. Few patches of white Calcium Carbonate streaks (associated with local areas of prismatic structure).

24 - 51 cm Dry 10YR5-4, moist 10YR4-3. Sandy clay loam. Dry, hard, strong fine prismatic with few pores and many cracks. Vertical cracks up to 0.5 cm. wide. Rapidly water absorbent. Few roots. Common white Calcium Carbonate streaks.

51 - 116 cm Moist 10YR4-3. Sandy clay loam. Slightly moist, very firm, structureless, with no pores and few vertical cracks. Moderately water absorbent. No roots. Many white Calcium Carbonate streaks.

116 - 158 cm Moist 10YR4-3 with 20% mottle 10YR4-4. Sandy clay loam. Slightly moist, very firm, structureless with no pores or cracks. Moderately water absorbent. No roots. Common hard white Calcium Carbonate concretions.

158 - 181 cm Moist 10YR4-3 with 50% mottles 10YR5-2 and 10YR5-8. Sandy clay loam. Slightly moist, very firm, structureless with no pores or cracks. Moderately water absorbent. No roots. Many hard white Calcium carbonate concretions. Common Gypsum crystals. Few dark Manganese stains.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carb %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P.
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension				
0-4	87	3	10	0.71	7.68	7.65	0.8	0.19	0.0	nil
4-24	75	7	18	1.95	7.78	8.22	0.32	0.04	0.0	nil
24-51	62	8	30	4.31	8.30	9.03	0.62	0.34	4.16	14
51-116	62	8	30	6.99	8.42	9.10	1.6	0.76	6.24	21
116-158	65	7	28	5.96	8.07	8.95	3.1	3.38	4.42	16
158-181	67	8	25	8.98	7.86	8.50	4.5	3.32	2.58	10

F. Durargids

Pit RO20
Location 15° 31'N, 32° 44'E. Date: 29-11-62
Topography Flat, with low gravelly jebels to the North-East.
Cultivation and Land Use Not Cultivated. Sparse grazing.
Vegetation Acacia erhenbergiana and A. tortilis bushes up to 8 ft high, 5-20 yards apart. Ground is mainly bare, with some fine grasses in slight depressions.

Surface Dry, loose to $\frac{1}{2}$ cm, with much loose gravel.

Profile description

0 - 33 cm Dry and moist 5YR3-4. Sandy clay loam. Dry, slightly hard, structureless to weak medium subangular blocky, with few fine pores and cracks. Rapidly water absorbent. Many roots. No salts. Some gravel.

33 - 79 cm Dry and moist 7.5YR3-4. Sandy clay. Dry, hard, structureless with no pores or cracks. Moderately water absorbent. Few roots. No salts. Some gravel.

79 - 104 cm Dry and moist 7.5YR4-4. Gravelly clay loam. Dry, hard, structureless, with no pores or cracks. No roots. No salts.

104 - 168 cm Dry and moist 10YR4-4. Gravelly loam. Dry, hard, structureless, gravel cemented by clay. Moderately water absorbent. Many rounded iron concretions and some iron pans 2-3 cm thick from 140 to 168 cm.

168 - 180 cm Dry and moist 10YR5-6 to 4-4. Gravelly clay loam. Dry, hard, structureless, gravel cemented by clay. Few iron concretions. No pans.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P
	Sand	Silt	Clay		Soil Paste	1.5 Soil suspension				
-33	72	8	20	0.57	7.76	7.85	0.24	0.02	0.68	(very low)
-79	62	5	33	1.25	7.73	7.96	0.5	0.07	0.43	
-104	57	8	35	2.47	7.75	7.8	0.52	0.09	0.61	
-168	65	5	30	2.04	7.70	7.73	0.55	0.24	0.76	
-180	62	5	33	1.75	7.95	8.12	0.95	0.42	2.2	

Durargid

Above command level.

Pit DR143
Location 15° 43'N, 32° 40 E. Date: 19-1-63
Topography 1 to 2% slope to West, dissected by shallow gullies, 100 to 200 yds apart. Pit situated midway between two gullies.
Cultivation and Land Use Sparse grazing.
Vegetation Acacia tortilis trees up to 20 ft high, 5 to 30 yds apart. Some Aristida sp.

Surface Dry, soft, sandy with no cracks or 'sink' holes. Much quartz sand and fine gravel.

Profile description

0 - 10 cm Dry 7.5YR5-6, moist 7.5YR4-4. Loamy sand. Dry, soft, structureless (Laminated) with few pores and fine vertical cracks about 18 inches apart. Rapidly water absorbent. Many fine roots. No salts.
 10 - 31 cm Dry and moist 5YR4-6. Sandy Loam. Dry, soft, structureless with no laminations. No pores, fine vertical cracks about 18" apart. Rapidly water absorbent. Many fine roots. Few old large roots. No salts.
 31 - 57 cm Dry 5YR4-6, moist 5YR4-4. Sandy clay loam. Dry, slightly hard, weak medium prismatic with common fine pores and cracks. Rapidly water absorbent. Many fine roots. Few old large roots. No salts.
 57 - 98 cm Dry 5YR4-6, moist 5YR4-4. Sandy clay loam. Dry, slightly hard, structureless with no pores or cracks. Rapidly water absorbent. Few fine roots. No salts.
 98 - 146 cm Dry and moist 5YR4-4. Gravelly loam. Dry, slightly hard, structureless with no cracks or pores. Rapidly water absorbent. No roots. No salts. Iron stained quartz gravel with rounded grains all 2 to 5 mm diameter.
 146 - 183 cm Dry and moist 10YR6-4, with 30% mottles 7.5YR5-6. Loamy gravel. Dry, slightly hard, structureless with no cracks or pores. Rapidly water absorbent. No roots. No salts. Iron stained quartz gravel with rounded grains all 2 to 5 mm diameter.

Laboratory Analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq per litre	Exch Na Meq per 100 gm soil	E.S.P.
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension				
10	92	3	5	0.24	7.25	7.32	0.28	0.03	0.0	nil
31	77	5	18	0.21	7.45	7.45	0.28	•	0.0	nil
57	72	5	23	0.15	7.00	7.67	0.23	0.03	0.0	nil
98	70	2	28	0.31	7.47	7.95	0.27	0.03	0.0	nil
146	67	3	30	0.66	7.78	7.98	0.23	0.05	0.0	nil

Haplargid/Durargid

above command level, 3 (sandy)

Pit: DR151
Location: 15° 49' N, 32° 36' E Date: 19.1.63.

Topography: Flat

Cultivation and Land Use Very sparse grazing.

Vegetation: Acacia erhenbergiana bushes up to 10 ft. high, about 100 yds. apart. Scattered Capparis decidua. Schoenfeldia gracilis, 1% cover, cropped short.

Surface: Dry, slightly hard, level, with no cracks and few small 'sink' holes. Many dark Calcium Carbonate concretions.

Profile Description.

- 0 - 14 cm Dry 10YR4.5-3, moist 10YR4-3. Gravelly clay loam. Dry, hard, strong medium prismatic with no pores and many cracks. Moderately water absorbent. Common fine roots. Common dark Calcium Carbonate concretions. Some sand in cracks.
- 14 - 29 cm Dry and moist 10YR4-3 with 20% mottles 7.5YR5-3 (moist 7.5YR4-3). Sandy clay loam. Dry, slightly hard, moderate medium subangular blocky with no pores and common fine cracks. Rapidly water absorbent. Few fine roots. Common white Calcium Carbonate streaks.
- 29 - 107 cm Dry and moist 10YR4-3 with 20% mottles 7.5YR5-3 (Moist 7.5YR4-3) loam. Dry, slightly hard, structureless with no cracks or pores. Rapidly water absorbent. No roots. Common white Calcium Carbonate streaks.
- 107 - 172 Cm Dry and moist 10YR4-3 with 30% mottle 10YR3-2. Silt loam. Dry, slightly hard, structureless with no pores or cracks. Rapidly water absorbent. No roots. Many soft white Calcium Carbonate concretions.

Laboratory analyses

Depth (cm)	Soil Particles %			Incorp Carbon %	PH		E.C. Sat. Extr.	Soluble Na Meq. per litre	Exch Na meq per 100 gm soil	E.S.P.
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus-pension				
0-14	57	10	33	7.32	8.40	9.10	0.92	0.34	15.86	48
14-29	67	8	25	6.62	8.70	9.30	3.4	2.1	14.9	60
29-70	67	10	23	7.68	8.30	9.20	6.2	5.2	14.8	64
70-107	67	8	25	5.15	8.42	9.21	6.0	6.4	15.2	61
107-172	70	7	23	7.07	8.62	9.32	4.4	5.07	16.33	71

Natrargidic Orthustent.
 Land Class 6.

Gas

Pit: DR.156

Location: 15°53'N, 32° 38'E Date: 21-1-63.

Topography: Slight slope to the West, near the bottom of a low Westward-sloping grassy ridge.

Cultivation and Land Use: Grazing.

Vegetation: A few Acacia tortilis bushes up to 8 ft. high nearby. Otherwise no trees. Schoenfeldiagracilis and Aristida sp.

Surface: Dry, slightly hard, level, with a very finely cracked crust. No 'sink' holes. Much coarse gravel and many stones. Some areas of boulders further East.

Profile description:

0- 7 cm	Dry 10YR5-4, moist 10YR4-3. Loam. Dry, soft, weak medium subangular blocky with few pores and fine cracks. Rapidly water absorbent. Many fine roots. No salts. Much coarse Quartz gravel.
7- 18 cm	Dry 10YR3.5-2, moist 10YR 3-2. Clay loam. Dry, slightly hard, moderate fine prismatic with few pores and many fine cracks. Rapidly water absorbent. Many fine roots. Much coarse quartz gravel. Few small hard white Calcium Carbonate concretions.
18- 55 cm	Dry 10YR3.5-2, moist 10YR3-2. Clay loam. Dry, slightly hard, moderate medium prismatic with few pores and many cracks. Rapidly absorbent. Common fine roots. Common quartz gravel and small hard white Calcium Carbonate concretions.
55-103 cm	Dry and moist 10YR3-2. Clay loam. Dry, hard, structureless with no pores and few verticle cracks. Rapidly water absorbent. No roots. Common quartz gravel and small hard white Calcium Carbonate concretions.
103-158 cm	Dry and moist 10YR3-1. Clay. Dry, hard, weak medium angular blocky with no pores and common fine cracks. Many shiny surfaces - ?slickensides. Rapidly water absorbent. No roots. Little gravel. Common small hard and soft white Calcium Carbonate concretions.
158-182 cm	Dry and moist 10YR3-2 with 20% mottle 10YR4-3. Clay loam. Dry, hard, structureless with no pores or cracks. Rapidly water absorbent. No roots. Little gravel. Many hard and soft white Calcium Carbonate concretions.

Laboratory analyses:

Depth cm	Soil Particles %			Incorp Carbon %	P.H.		E.C.	Soluble Na	Exch. Na meq per 100 gm soil	E.S.P.
	Sand	Silt	Clay		Soil Paste	1.5 Soil sus- pension				
0-7	70	10	20	1.69	8.05	8.05	0.38	0.15	0.0	Nil
7-18	52	15	33	2.83	8.31	9.00	0.40	0.17	0.83	3
18-55	45	17	38	4.34	8.10	8.70	1.2	0.61	4.59	12
55-103	45	15	40	3.09	7.79	8.51	4.2	2.15	5.45	14
103-158	42	18	40	2.58	7.50	8.20	5.75	3.60	5.10	13
158-182	37	13	50	3.31	7.64	7.90	6.1	3.80	4.50	9

Orthic Orthustent
Above command level.

					8.347	8.17	207.87			
					8.490	19.27	208.07			
					8.591	16.28	210.80			
					0.898	4.32	301.15			
					1.378	18.74	301.15			
					1.503	19.70	301.15			
					1.878	18.47	301.15			
					2.108	20.00	301.15			
2	35°	371.39	14.950		0.000	14.75	207.30		Orthic Orthustent	
					0.372	18.05	207.30		307, 100000	
					0.770	18.31	207.30		307, 100000	
					1.220	18.05	207.30		307, 100000	
					1.380	18.05	207.30		307, 100000	
					2.070	18.05	207.30		307, 100000	
					3.400	18.05	207.30		307, 100000	
					3.427	18.05	207.30		307, 100000	
					4.120	18.05	207.30		307, 100000	
3	35°	370.99	13.600		0.000	18.05	207.30		Orthic Orthustent	
					0.397	18.05	207.30		307, 100000	
					1.028	18.05	207.30		307, 100000	
4	35°	370.38	9.250		0.000	18.05	207.30		Orthic Orthustent	
					0.372	18.05	207.30		307, 100000	
					1.077	18.05	207.30		307, 100000	
					1.558	18.05	207.30		307, 100000	
					3.121	18.05	207.30		307, 100000	
					3.591	18.05	207.30		307, 100000	

APPENDIX II

AREA 3d ENGINEERING RECONNAISSANCE

Extensions to Sudan Survey Department Cross Section Number 1 - 6 Khartoum

Province Right Bank

Section No.	Bearing (Mag.)	NMWL (Metres) A.S.L.	Length of SSD Cross Section (kilometres)	Distance from 15.0 metres isopotamon (Km.)	Height above NMWL	Reduced ground Level (Metres) A.S.L.	Remark
1	95°	371.80	18.600	0.000	15.00	386.800	Conc. Post 504 -Broken
				0.243	16.12	387.92	
				0.470	16.87	388.67	
				0.747	17.19	388.99	
				0.996	18.32	390.12	
				1.375	18.74	390.54	
				1.598	19.10	390.90	
				1.878	19.88	391.78	
2	95°	371.39	14.950	0.000	15.00	386.39	Concrete Post 507 (Broken to Ground Level) MMP 105 Iron Stake
				0.394	15.36	386.75	
				0.770	15.42	386.81	
				1.258	15.65	387.04	
				1.790	16.13	387.52	
				2.376	16.94	388.33	
				3.027	17.93	389.32	
				3.621	18.89	390.28	
3	95°	370.99	12.500	0.000	15.00	385.99	Conc. Post 510 Conc. Post 1168
				0.647	18.06	389.05	
				1.085	20.09	391.08	
4	95°	370.58	9.950	0.000	15.00	385.58	Conc. Post 469 MMP Iron Stake 101
				0.572	16.14	386.72	
				1.077	16.62	387.20	
				1.559	17.32	388.90	
				2.131	19.41	389.99	
				2.344	20.00	390.58	

Section No.	Bearing (Mag.)	NMWL (Metres) A.S.L.	Length of SSD Cross Section (Kilometres)	Distance from 15.0 metres isopotamon (Km.)	Height above NMWL	Reduced ground Level (Metres) A.S.L.	Remarks
5	95	370.18	10.300	0.000	15.00	385.18	Conc. Post 483 MMP Iron Stake 103
				0.618	16.84	387.02	
				1.113	17.94	388.12	
				1.614	18.50	388.68	
				2.133	19.93	390.11	
6	95	369.77	9.400	0.000	15.00	384.77	Conc. Post 468 MMP 099 Iron Stake
				0.555	15.82	385.59	
				0.944	16.34	386.11	
				1.446	17.00	386.77	
				1.868	17.35	387.12	
				2.257	18.15	387.92	
				2.721	18.73	388.50	
				3.132	19.39	389.16	
				3.510	20.02	389.79	

THE REPUBLIC OF THE SUDAN
MINISTRY OF AGRICULTURE
ROSEIRES SOIL SURVEY

BLUE NILE EAST BANK RECONNAISSANCE
SECTIONS SHEET No. 1

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

SCALE:
AS SHOWN
DRG. No. SU.14
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