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THE REPUBLIC OF THE SUDAN

MINISTRY OF FINANCE AND ECONOMICS

ROSEIRES PRE-INVESTMENT SURVEY

REPORT No. 2

RAHAD PROJECT

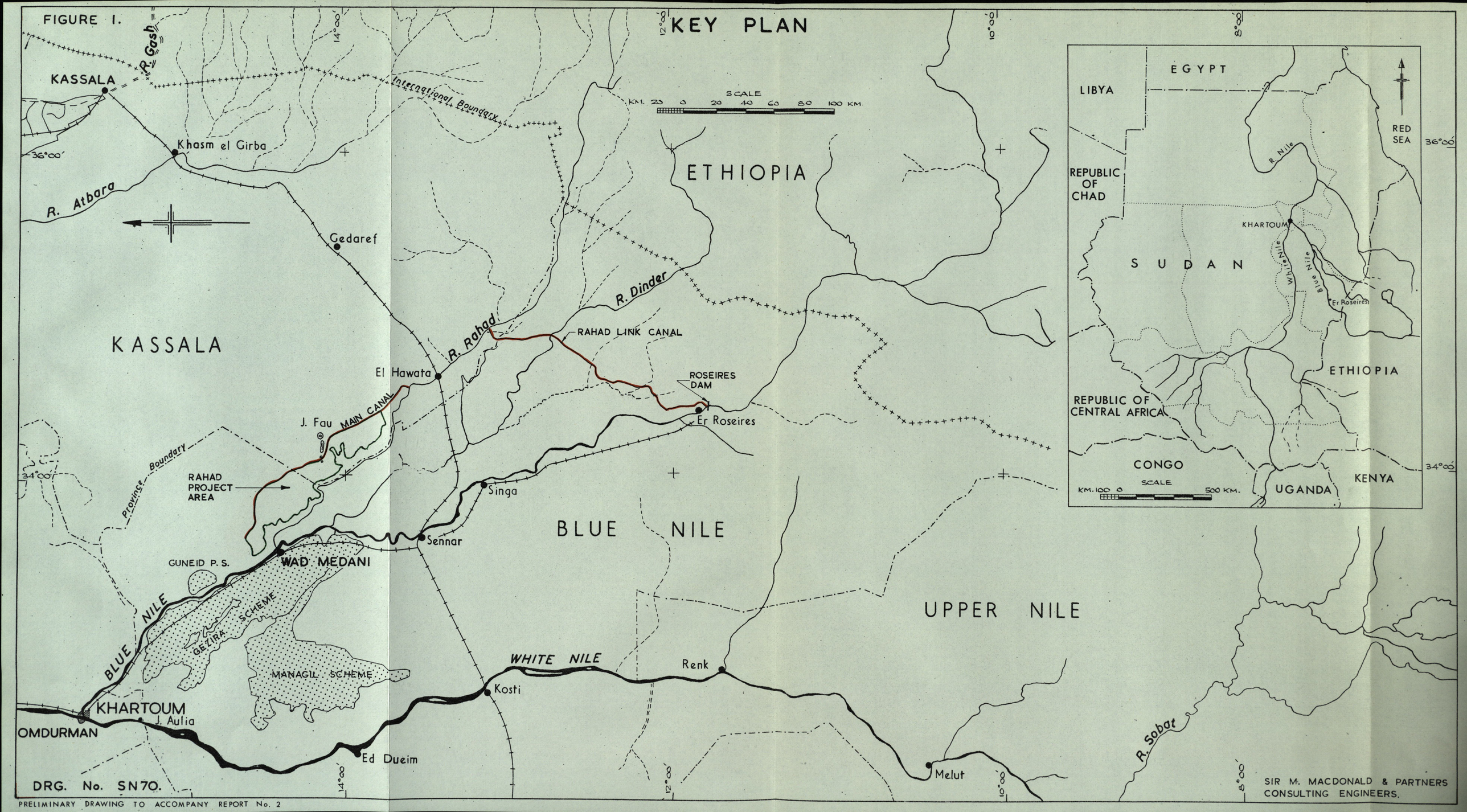
PART III
ENGINEERING

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

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

MAY 1965

FIGURE 1.



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SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS.

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

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Sir M. MacDonald & Partners
CONSULTING ENGINEERS

PARTNERS:
R. H. MACDONALD, M.A., M.I.C.E.
A. A. MIDDLETON, B.Sc., M.I.C.E.
R. G. SMITH, B.Sc., M.I.C.E., M.I.MECH.E.
I. S. G. MATTHEWS, M.A., M.I.C.E., M.A.S.C.E.

CONSULTANTS:
F. NEWHOUSE, F.C.G.I., B.Sc., M.I.C.E., M.CONS.E.
G. LACEY, C.I.E., F.C.G.I., B.Sc., M.I.C.E., M.CONS.E.
A. M. R. MONTAGU, C.I.E., F.C.G.I., M.I.C.E.

LION HOUSE,
72-75, RED LION STREET,
LONDON, W.C.1.

TELEPHONES: CHANCERY 5747-8-9
CABLES: SCREETAN LONDON

The Under Secretary for Economic Planning,
Ministry of Finance and Economics,
Khartoum,
REPUBLIC OF THE SUDAN.

31st March 1966.

Dear Sir,

ROSEIRES PRE-INVESTMENT SURVEY
REPORT NO. 2 RAHAD PROJECT
PART III ENGINEERING

We have pleasure in submitting our Report No. 2, Part III Engineering, for the Rahad Irrigation Project, which study was entrusted to us by the Sudan Government in the Agreement signed on 25th October 1964. The Report covers the engineering aspects of the development of the project area which lies on the East Bank of the River Rahad extending from the vicinity of Malek in the south to the Rahad-Blue Nile confluence in the north. The area can be irrigated from a barrage on the River Rahad at Malek.

The semi-detailed soil survey carried out under the Roseires Soil Survey has defined an area of 453,000 feddans of arable lands and a further area of 47,000 feddans were being soil surveyed at the time of the writing of the Report. It is planned that a net cultivable area of 430,000 feddans will be utilised, 405,000 feddans in the rotation and 25,000 feddans for village gardens and livestock areas.

The Report records the outcome of our investigations on the Link Canal from the Roseires Dam to the River Rahad and recommends a route some 191 kilometres long. The capacity of the Link Canal is only 65 cumecs, since during the period of peak demand the supply from Roseires can be supplemented by water from the River Rahad flood. The capacity of the Project Main Canal from the Rahad Barrage is 110 cumecs. Preliminary study shows that additional areas near Guneid can also be irrigated from the tail of the Project Main Canal if a carrier canal some 16 kilometres long is built.

The capital cost for the project works including contingencies, engineering and supervision but excluding agricultural machinery is estimated to be LS.36.2 million or LS.84 per feddan.

The water requirements have been based on an 83⅓% cropping intensity, made up of

Cotton	33⅓%
Groundnuts	33⅓%
Dura	16⅔%

The Engineering Report is the third part of the full Roseires Pre-investment Survey Report No. 2 on the Rahad Project which is made up of four parts as follows

Part I	Summary
Part II	Economics
Part III	Engineering
Part IV	Agriculture

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

Yours faithfully,

I.S.G. Matthews

SIR M. MACDONALD & PARTNERS

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SUMMARY

Introduction

1. The Rahad project area is located on the east bank of the River Rahad between Tuneidba, 50 kilometres north of Hawata, and the confluence with the Blue Nile (see Figure 1). The area is about 130 kilometres in length and varies in width between 5 and 26 kilometres.

2. The project canal commands an area of 563,000 feddans of which 505,000 feddans is usable irrigable land. The net cultivable area amounts to 430,000 feddans of which 405,000 is recommended for inclusion in a planned rotation, the balance to be utilized for village gardens and livestock areas. In addition, 45,000 feddans of Class 6 land is to be used for forests and fodder.

3. The area forms part of the vast clay plains of the Sudan at an elevation varying between 400 and 430 metres above sea level. It is superficially uniform and featureless with a gentle rise to the east and south. Except in the north, where vegetation has been cleared for cultivation, belts of kitr (acacia mellifera) alternate with open grassland.

Soil Survey

4. The semi-detailed soil survey of lands within the project area produced the following results:

Land Class	Area (feddans)	% of Total
2	159,740	28.4
3	224,620	39.9
4	68,850	12.2
6	63,130	11.2
Not surveyed *	46,660	8.3
TOTAL	563,000	100.0

* The semi-detailed soil survey of this part of the area was not carried out until 1965 and the results were not available at the time of preparation of this report.

Cropping Pattern

5. The cropping pattern that gives the optimum return to land and capital is 1/3 medium staple cotton, 1/3 groundnuts, 1/6 dura, 1/6 fallow, on the assumption that dura must be included. Dura is a very unprofitable crop under irrigation and there are several other crops which have roughly similar growing periods and give a greater return to the economy and the farmer. With large rainland dura schemes nearby, constructive efforts should be made to encourage the farmer to change from growing dura to some other crop and buy in his dura.

6. The design of the rotation takes heed of the fact that irrigation water during the long period November to June inclusive must be supplied by a long link canal. Consequently peak demands during this period have been minimized, thereby economizing in the size of the link canal. On the other hand, the rotation has been designed to make the best possible use of the flood waters of the River Rahad between the months of August and October.

7. The rotation consists of :

Year	1	Groundnuts
"	2	Cotton
"	3	Groundnuts
"	4	Cotton
"	5	Fallow
"	6	Free choice - e.g. dura

Water Requirements

8. The water requirements for the rotation crops have been calculated using the theoretical free water surface evaporation and estimated monthly rainfall figures for the project area, in accordance with the Penman method.

9. The area has a tropical continental climate with the rainfall associated with the southerly winds which are concentrated in the months of July, August and September. Main necessity for irrigation water is from April to January with a maximum demand of 22 cubic metres/feddan/day in September and October.

Canal Design Procedure

10. The recommended gross factors for design (cubic metres per feddan per day) allow for 5/6ths cropping and are as follows:

	Minor Canals	Major Canals	Main Canal at Malek	Link Canal at Roseires
Canal Excavation in Dry	26.6	25.0	22.1	13.1
Canal Structures	33.2	31.2	27.6	16.4

11. The design procedure for the canalization has generally been in accordance with standard Sudan practice. A night storage system has been adopted. Over part of the area where the ground slopes are flattest, the same minor canalization layout as practised in the Gezira can be used. In the remainder, where the ground slopes are steeper, a modified layout will be necessary, with watercourses parallel instead of normal to the minor canals.

Supply Route

12. The feeder canal from Roseires reservoir to the River Rahad is 191 kilometres in length. For the first 27 kilometres, where the canal is in deep cutting, it is recommended that it be constructed to a larger size, to anticipate further expansion of either the Rahad or the Roseires projects. The size recommended, which is a

preliminary figure, is 132 cumecs.

13. From K.0. to K.27 the canal runs parallel to the Blue Nile. Thereafter it turns eastwards and heads towards the River Rahad, which it reaches at K.191 after crossing the River Dinder at K.137 and the Khor el Atshan at K.178. The crossing of each of these streams will be effected by siphoning the canal under the stream.

14. After reaching the Rahad the water will be conveyed in the river channel to the diversion site at Malek, 175 kilometres downstream, although only about 70 kilometres in a straight line. A study has been made of this reach of the river in order to estimate the safe carrying capacity. It was concluded that above about 140 cumecs spilling takes place towards the Khor el Atshan.

15. The barrage to divert the water into the Project main canal is located at Malek, about 30 kilometres north of Hawata. The main canal has a design capacity of 110 cumecs and is a carrier canal without offtakes for 22 kilometres. The main obstacle encountered is the Qal'at Arang range of jebels, which the canal skirts between K.65 and K.80. Some rock excavation will be necessary here. Otherwise the canal alignment is straight forward. The tail regulator is located at K.163.

16. The plan for irrigation operation and maintenance follows the practices of the Gezira and Managil Schemes, the project area making up a standard Irrigation Division subdivided into three Sub-Divisions.

Communications

17. A detailed study was made of the relative cost of road and rail transport, the result of which favoured road transport within the project area and to Wad Medani. The existing railway would be used for transportation of the agricultural produce from Wad Medani to Port Sudan. It is recommended that an all-weather road be built from the

project headquarters to Wad Medani, a distance of 25 kilometres. The cost of this road, including the bridges over the Blue Nil and the River Rahad would not be more than the cost of the 110 km. railway link which would be required from the Sennar-Gedaref line into the project area. In addition, the cost of the lorry fleet required would be less than the cost of a light railway system.

Services

18. A single ginning factory consisting of four units is proposed to be sited at the project headquarters and powered by mains electricity. Groundnut decortication will be done at block village level. Fifteen plants will handle the produce from the total planted area of 135,000 feddans.

19. A central mechanical workshop will be established at the project headquarters. Major repairs to heavy earthmoving plant will be carried out at the existing workshop in Wad Medani. Each of the 15 block villages will have a small workshop. Bulk storage for cotton and groundnuts will be provided at the project headquarters and a limited amount of storage for fertilizer, sacks and seeds will be available at each block village.

20. A conventional network of telephones with automatic exchanges is proposed for the project area. A communications line is also provided for the 360 kilometre supply route from Roseires to the project area.

21. It is proposed that mains power from the Sennar to Burri power line be provided to the project headquarters. Block and group villages will be provided with electric lighting by diesel generators.

22. Groundwater supplies from tubewells are likely to be adequate in the northern part of the project area, but in the south, where there is no groundwater potential, it is proposed to treat raw canal water at individual village filter plants.

Buildings

23. Although economies are proposed in the scale of housing, the existing Sudan practice of providing housing for all staff will be continued. A total of 2,202 houses are proposed for the agricultural and irrigation staff and these will cost LS. 3.6 million. A further 88 houses costing LS. 188,000 will be required for the social services staff.

24. Agricultural management and irrigation offices are proposed at the project headquarters and at each of the three management groups. In addition there will be agricultural offices at each of the 15 block villages.

25. Schools have been provided for at each new village and dispensaries at each block village.

26. Due to the very high cost of permanent housing it will not be economic to provide housing for the new tenant farmers as this would cost about LS. 30 million if provided to a similar standard as at Khashm el Girba. It may be necessary to subsidize the new immigrants for the initial construction of a traditional thatched tukl. The new villages will be laid out and each family will receive a plot of 400 square metres.

Summary of Cost

27. The summary of costs of the project works is as follows:

(1,000 LS.)

Item	Description	Amount	Foreign Exchange	Customs Duty
I.	Irrigation Works, Buildings and Services	28,871	15,701	3,324
II.	Agricultural Processing Plants	1,020	641	168
III.	Excavating Plant	328	255	62
IV.	Land Preparation	756	465	82
V.	Agricultural Management	2,332	1,557	416
VI.	Contingencies	3,331	1,862	405
VII.	Engineering and Supervision	3,000	1,500	-
	TOTAL	39,638	21,981	4,457

Interest charges during the construction period are not included in the above table. The additional cost is LS. 3.52 million, assuming an interest rate of six per cent.

The annual cost of irrigation and maintenance is estimated at LS. 365,000.

CHAPTER 1

GENERAL DESCRIPTION OF THE AREA

1.1 LOCALITY OF THE PROJECT

The Rahad East Bank Project shown on Plate 1 occupies an area about 130 Kilometres in length and varying in width from 5 - 26 kilometres. The southern boundary of the Project is close to the River Rahad at the village of Tuneidba (13° 43' N 34° 23' E). The northern limit of the Project is close to the Blue Nile about 12 kilometres north of the River Rahad confluence. The distance from this boundary to Khartoum is 160 kilometres.

The Project Area is divided equally between the Blue Nile and Kassala Provinces. The province boundary extends from the River Rahad at Ein el Luweiqa north-eastwards to Jebel Buweida on the eastern edge of the scheme. The southern half, in Kassala Province, is all under the administration of the Gedaref North Rural Council. The northern half, in Blue Nile Province, is divided between two rural councils. The larger part of the area, from just north of Sherif Yacoub, is administered by the Shukriya Rufa'a Council and the area between Sherif Yacoub and Ein el Luweiqa is administered by El Hosh Council.

There are no large urban centres in the Project Area, the largest, a village, being Sherif Yacoub. Wad Medani, the administrative centre for Blue Nile Province, is sited on the west bank of the Blue Nile within ten kilometres of the Project boundary. Rufa'a on the Blue Nile east bank is about 25 kilometres north of the Project boundary. In the south Mafaza is situated about 25 kilometres and El Hawata 50 kilometres upstream on the River Rahad.

There are no all-weather roads and no railways in the Project Area. The Sudan Railways line south of Khartoum follows the west bank of the Blue Nile to Wad Medani and Sennar. From Sennar a branch line runs eastwards through El Hawata to Gedaref, Kassala and Port Sudan.

1.2 DESCRIPTION OF THE AREA

The Project Area consists of a cracking clay plain bounded on the western side by the River Rahad. Most of the area appears to the eye to be completely flat although in fact there is a gentle slope rising to the east. The flattest part of the area is the central part between the villages of Ein el Luweiqa and Sherif Yacoub. Here the ground slope is less than 0.5 metre per Kilometre. Elsewhere in the Project Area the ground slope is generally between 0.5 and 1.0 metre per kilometre.

Near the river there is a zone of undulating and gullied lands known as "kerrib" which varies in width from about 0.5 to 3.0 kilometres. This zone of eroded land is unsuitable for irrigation and it is therefore excluded from the Project Area.

The area is dominated in the centre by the Qal'at Arang and El Fau range of hills. This granitic range extends over about 25 kilometres and restricts the width of the Project Area at this point. The level of the plain is several metres higher on the northern side of the hills and the main irrigation canal will be forced westwards here. There are no other hills in the area except for Jebel Buweida, a small isolated hill which is on the eastern boundary 25 kilometres north of the Qal'at Arang - El Fau range.

In the northern part of the area the only relief is formed by a large area of high ground which rises to about 15 metres above the general level of the plain. This area is centred about 10 kilometres north of Sherif Yacoub and forms an island of land excluded from the Project which extends 15 kilometres eastwards from the river.

Although the clay is highly impermeable the ground slopes are generally so flat that there are few natural drainage channels in the area. Some well-defined but shallow drainage lines take the run-off from the Qal'at Arang - El Fau hills and flow into the Project Area. This run-off from the hills is more marked on the southern side where there are fairly well defined depressions which carry the surface run-off to the River Rahad in the vicinity of Kumar Hag es Sid, (lat. 14° 0'N).

There are some well defined drainage depressions associated with the eroded "kerrib" lands adjacent to the Rahad as it approaches its confluence with the Blue Nile. Here the height difference between the river bed and the clay plain is greatest and the eroded low lands extend for several kilometres into the Project Area. These valleys form natural boundaries for the area irrigated by each major canal system in this part of the scheme.

1.3 POPULATION AND TRIBAL AFFILIATION

The results of the social survey gave an estimate of 77,000 for the population of the proposed scheme area including a strip five kilometres in width outside the boundary and the riverain strip adjacent to the Blue Nile as far north as Rufa'a. This figure does not include the population of Rufa'a town. Most of the people are living in villages in the northern part of the area. Eighty-four per cent or more than 64,000, are living north of Sherif Yacoub and only sixteen per cent occupy the remainder of the area to the south. It is estimated that thirty-nine per cent of

the population live close to the River Rahad or Blue Nile and use these rivers as their main source of water supply. The remainder live further to the east and are dependent on wells. Three villages in the area have tube wells with motor pumps and water storage tanks.

The people of the area are nearly all Arab, the majority belonging to the Shukriya tribe. The nazirs of both Rufa'a and Gedaref North Rural Councils are Shukriya. Tribesmen of several other tribes including Rufa'a, Cuahla, Misellamiya, Sherafa, Lahawin, and Arakiw are in the northern part of the area. In the south there are some small villages of West Africans some of whom have lived in the area for more than thirty years.

1.4 CLIMATE

The area has a tropical continental climate which is dominated by the movement north and south of the boundary between dry northely winds and moist southerly winds. This boundary reaches its northerly limit in mid-summer and its southerly limit in mid-winter. Rain is associated with the southerly winds and the duration of the rainy season is determined by the period for which the southerlies prevail. This period tends to be shorter in the north than in the south, although the difference is not significant over the length of the Project Area. Most of the rain is of the shower or thunderstorm type and falls in the afternoon and evening.

Mean monthly rainfall figures for Wad Medani and Mafaza for the period 1931 - 1960 are shown in Table 1.1. Wad Medani is close to the northern end of the Project and Mafaza is situated about 25 kilometres south of the southern boundary. The mean annual rainfall increases from north to south over the length of the Project and at the southern boundary is probably about fifty per cent greater than at the northern end of the Project Area.

Climatological Normals for Wad Medani for the period 1931 - 1960 are shown in Table 1.2. Temperatures are lowest during December, January and February and highest during April, May and June. Relative humidity is low throughout the dry season and only increases in the rainy season during the months July, August and September.

Table 1.1: Mean Monthly Rainfall in Millimetres at Wad Medani and Mafaza 1931 - 1960

	WAD MEDANI				MAFAZA			
	Lat. 14° 25'N. Long. 33° 31'E				Lat. 13°36'N		Long.34°32'E	
Month	Mean	Max Daily Fall	Days per month with rainfall greater than 1.0mm	10.0mm	Mean	Max Daily Fall	Days per month with rainfall greater than 1.0mm	10.0mm
Jan.	-	-	-	-)				
Feb.	-	0.4	-	-)	Records not available for			
March	0.3	5.7	0.1	-)				
April	2.0	23.0	0,4	0.1)	these months			
May	16.4	32.8	3.0	0.5	24.4	51.4	2.5	0.9
June	31.4	36.5	4.6	1.0	64.2	87.9	7.0	2.7
July	118.8	79.6	9.5	4.1	174.9	87.3	10.8	5.2
August	127.4	71.3	11.5	4.5	187.6	99.4	12.0	5.4
Sept.	53.0	71.9	6.0	1.9	102.4	93.0	7.4	3.0
Oct.	16.3	34.1	2.9	0.4	24.9	51.0	2.8	0.9
Nov.	0.7	15.0	0.1	-	1.9	12.8	0.5	-
Dec.	-	-	-	-	-	-	-	-
	366.3	370.3	38.1	12.5	580.3	482.8	43.0	18.1

Table 1.2: Climatological Normals for Wad Medani, 1931-1960

Month	Air Temperature °Centigrade		Relative Humidity % Times are GMT		
	Mean Daily Maximum	Mean Daily Minimum	0600 hrs	1200 hrs	1800 hrs
Jan.	33.9	13.7	37	17	28
Feb.	35.4	14.8	28	12	21
March	38.5	17.5	20	8	15
April	41.0	21.0	17	9	14
May	41.2	23.7	30	14	23
June	39.6	24.6	47	22	33
July	35.6	22.8	68	38	54
August	33.1	21.9	78	50	69
Sept.	35.2	21.8	72	41	62
Oct.	38.0	21.6	51	25	43
Nov.	36.7	17.8	35	17	31
Dec.	34.1	14.6	39	18	31

Table 1.3: Rainfall in millimetres for months of July, August and September and total for year, 1931 - 1960, at Wad Medani and Mafaza

	WAD MEDANI				MAFAZA			
Year	July	August	Sept.	Total Year	July	August	Sept.	Total Year
1931	111.7	107.7	87.3	336.4	143.0	105.8	144.1	458.6
32	72.5	190.5	74.7	423.9	104.9	287.5	30.0	566.3
33	80.5	117.1	52.0	351.7	208.5	175.0	159.6	710.2
34	174.9	93.0	41.5	380.6	172.6	170.9	69.9	570.5
35	71.2	123.5	38.7	325.2	83.8	219.4	167.0	686.6
36	98.3	207.4	48.1	455.4	237.1	117.9	152.1	686.1
37	238.7	73.8	57.4	458.0	247.6	107.8	114.0	621.1
38	134.4	170.4	48.1	356.4	235.9	129.5	152.3	538.1
39	234.4	129.1	50.3	549.8	185.7	160.8	152.1	527.1
40	85.3	113.3	15.9	299.5	182.8	127.9	31.4	557.1
1941	85.7	149.6	6.2	279.3	94.6	278.3	68.3	619.9
42	119.2	189.1	9.9	374.2	100.9	333.2	46.2	589.2
43	88.6	135.7	50.0	316.3	161.2	197.1	40.1	557.0
44	290.6	83.9	38.8	476.9	30.1	203.6	35.7	636.6
45	47.9	95.1	44.3	252.1	125.8	275.7	50.0	655.5
46	159.6	125.6	86.6	424.8	126.7	278.3	178.3	809.0
47	46.7	97.6	27.9	250.3	309.5	180.9	100.3	730.6
48	150.5	97.1	97.3	446.6	143.7	72.1	136.8	481.5
49	48.1	47.4	57.2	247.4	128.9	165.3	165.6	629.1
50	149.6	101.4	83.7	416.5	159.5	157.2	23.5	496.3
1951	29.7	125.1	37.4	237.5	211.6	179.5	100.9	628.7
52	75.0	173.3	65.0	382.4	234.4	238.3	108.9	736.5
53	84.9	158.4	38.9	376.4	94.0	146.6	94.8	434.8
54	158.0	161.7	106.7	462.8	259.7	337.1	146.1	869.8
55	77.2	73.1	73.5	319.6	237.7	228.4	205.0	759.1
56	120.9	159.7	103.6	441.2	248.8	108.0	130.2	727.9
57	113.1	160.6	32.2	325.7	186.6	143.7	70.0	455.7
58	212.4	115.4	42.0	439.6	123.6	122.3	38.9	383.4
59	160.8	273.3	82.6	556.3	136.4	182.8	66.7	465.3
60	143.4	33.9	47.9	270.0	160.9	187.5	94.4	528.2

The variability of the rainfall is very marked both in respect of total for the year and between recording stations for the same month. The degree of variability is shown very clearly in Table 1.3 for the two stations Wad Medani and Mafaza during the period 1931 - 1960.

1.5 HISTORY OF THE PROJECT

A plan for a gravity diversion scheme to utilise the flow in the River Rahad was prepared by the Ministry of Irrigation and H.E.P. in 1961. This plan envisaged a regulator sited on the river about 80 kilometres from its confluence with the Blue Nile. The gravity canal was to be designed for a discharge of 3.5 million cubic metres per day and would extend for 100 kilometres to a point above the Guneid Pump Scheme. A supply of up to 1.0 million cubic metres per day would be given to the Guneid Scheme from the proposed gravity canal and so effect a considerable economy in the pumping costs during the period from July to October. The area to be irrigated is situated on the east bank of the River Rahad and extends north of the confluence along the Blue Nile east bank to the town of Rufa'a.

The September 1962 Contract for the Roseires Soil Survey included the proposed Rahad Flood Project lands as "Area 3C". The original survey programme was 'extended' in December 1962 to include the semi-detailed survey of Area 3C lands in the 1962/63 season's operations.

Some engineering reconnaissance was carried out during April 1963 on behalf of the Ministry of Irrigation and H.E.P. This limited survey showed quite clearly that there would be an advantage in siting the diversion regulator a considerable distance further upstream than the site suggested in the Ministry's report. Accordingly the Ministry arranged for an investigation and report to be prepared on the proposed Rahad barrage and the irrigation project to utilise the flow in the River Rahad. In addition this study was to include recommendations for providing a domestic water supply to the Project area and also to assess the advantage of a supplementary irrigation supply to the Project from the Sennar reservoir on the Blue Nile. The Contract for the study of the Rahad Barrage and Flood Irrigation Project was signed on 25th November, 1963. The investigation started immediately after this date and continued until May 1964.

By January 1964 the survey had advanced far enough to show that Malek, 3 kilometres downstream of Mafaza, would be the most favourable site for the proposed river diversion. The cultivable area commanded by gravity from the Malek site was expected to be about 400,000 feddans. This represented a large increase in Project area from the 150,000 feddans envisaged in the original flood diversion scheme. Meanwhile the semi-detailed soil survey had shown the project to have the first sizeable block of irrigable land lying south of Khartoum. The soil survey was therefore extended to include semi-detailed survey of the additional command area in the 1963/64 season's operations. The additional area was defined as Area 3C extension.

Now that an area of 400,000 feddans might be developed on the east bank, it was apparent that the irrigation supply for the project could not be met from the River Rahad. A supply would be needed from the Blue Nile. To obtain a gravity supply the canal would need to offtake directly from the Roseires reservoir. It was considered a matter of some urgency for an exploratory survey to prove the feasibility of a link canal to deliver water from the reservoir to the River Rahad. Authority to proceed with this survey, together with a reconnaissance survey of the canal route from Roseires Dam to the Roseires Project Area was given by Ministry of Finance and Economics in February 1964. Fieldwork was carried out during the period from February to May 1964 and a preliminary report, Roseires Pre-Investment Survey, Report No.1, on the results of these two surveys was submitted in December 1964. It was concluded in this Report that the Rahad Link Canal between Roseires Dam and the River Rahad would be a costly but feasible engineering proposition.

Meanwhile, in October 1964 the Consultants were instructed to carry out the Pre-Investment surveys for the Rahad Project and the Roseires Project (Blue Nile Right Bank from Roseires to Dinder confluence). The estimated irrigable areas were -

Rahad Project	400,000 fenddans
Roseires Project	700,000 "

Engineering surveys and enquiries under the terms of the Pre-Investment Contract commenced at the beginning of October 1964 and continued in the Sudan until May 1965 for both Projects.

CHAPTER 2

SOILS AND AGRICULTURE

2.1 SOILS

The greater part of the project area is covered by dark coloured cracking clays similar to those of the Gezira area. A typical soil profile is described as follows :-

Surface: Level or slightly hummocky with a system of wide cracks, which may be partly or completely obscured by a granular, of fine blocky mulch, 1 to 2 cm deep, though in places it may extend to 5 cm.

Solum: 2-50 cm Dark greyish brown (10 YR 4/2 to 2.5 Y 4/2) clay. The surface mulch overlies strong coarse prisms separated by wide cracks. The prisms show secondary platiness or blockiness as well as laminations which are slightly concave between the main vertical cracks. Few pores are visible. Roots are frequent, especially towards the surface. Dark coloured calcium carbonate concretions (kankars) are present in considerable numbers and very small white carbonate concretions are also present. The wide vertical cracks generally disappear at the base of this horizon.

Subsoil: 50 - 100 cm. Very dark greyish brown (2.5Y 3/2) clay, occasionally weakly mottled. The structure is weak to moderate, coarse angular blocky with many fine cracks. Pores are rare and ped faces appear smooth. Roots are common, associated with cracks. There are occasional kankars but very small white calcium carbonate concretions are common. Near the top of this horizon the cracking is oblique and is often associated with small smear surfaces or slickensides. The slickensides increase in size down the profile, reaching a maximum at the base of this horizon.

Deep Subsoil: 100 - 160 cm. This is generally very dark greyish-brown (2.5 Y 3/2 to 10 YR 2/1) clay. Weak brownish mottles are frequent. Structure is generally weak, coarse angular or subangular blocky. There are large slickensides, especially near the base of the horizon, at angles of up to 60° to the horizontal; these interesect to give rise to diamond shaped structures. Few pores are visible. Occasional roots are found, associated with wide cracks. Calcium carbonate is present in the form of large soft aggregates and hard white concretions up to one centimetre diameter which may amount to 2 or 3 per cent of the soil mass near the base of the horizon. Gypsum crystals are found in this horizon in some profiles.

Substratum: below 160 cm. This is generally dark greyish brown clay with strong dark grey, brown or yellowish brown mottles. The structure is moderate, medium to coarse

angular blocky and the soil is less compact than in the horizon aboye. Large slickensides are abundant, at angles of up to 60° to the horizontal, and diamond shaped parallellepiped structures are common. Few pores are visible. Roots are found only in a few profiles, generally in dense Acacia spp scrub. Calcium carbonate is present as large whitish concretions and soft aggregates comprising up to 2 or 3 per cent of the soil mass. Gypsum crystals are present in some profiles.

Mechanical analysis of these soils shows them to contain from 60 to 75 per cent clay particles (less than 0.002 mm. diameter) throughout the profile. The clay particles are mostly montmorillonite types which swell markedly on wetting and shrink on drying out to form wide cracks in the solum. In the rainlands and in irrigation schemes water enters the dry soil through the cracks and penetrates to a depth of 50 to 100 cm. The wetted soil then swells, closing the cracks, and the soil mass becomes virtually impermeable so that further immediate additions of water tend to lie on the surface. It is only after water has been lost by evapo-transpiration to the point where the soil shrinks sufficiently to crack open that further applications of water can readily penetrate the solum. The irrigation regime of the Gezira Scheme and most other irrigation schemes in the rainlands of the Sudan is correlated with the cracking cycles in the clay soils. Tests carried out in the project area shown that the hydraulic conductivity of the wet soil is extremely low; all valid tests showed that the hydraulic conductivity is less than 10 cm.per day at unit gradient. In fact, the irrigation projects have developed on what are virtually non-draining soils.

The montmorillonitic clays have very high cation exchange capacities of the order of 50 to 60 milliequivalents per 100 gm. of soil: in fact the C.E.C. is approximately equal to one milliequivalent per gram of clay. The absorption complex is saturated throughout, being dominated by calcium with lesser amounts of magnesium, sodium and potassium. In an average solum the exchangeable cations consist of the following:- Calcium 30-40 m.e., magnesium 12-18 m.e., sodium 5-10 m.e. and potassium less than 2 m.e. There is a tendency for exchangeable sodium to increase in the subsoil generally at the expense of magnesium and calcium.

The clay soils are mostly non-saline. The average E.C. in the solum is about one millimho per cm. at 25°C. The E.C. increases with depth to an average of 2.5 mhos in the subsoil and an average 3.0 mhos in the deep subsoil. The soluble are mostly sodium salts, the sulphates predominating over chlorides and bicarbonates.

The pH measurements show the soils to be moderately

alkaline. The pH on soil paste varies from 7.4 to 8.3 whilst on 1:5 suspension the variation is from 7.6 to 9.4. This range is lower than might be expected in alkali soils. A possible explanation is the high reserve of free calcium carbonate (about 5%) which neutralizes the carbon dioxide produced by plant roots and soil organisms. In the absence of these reserves of calcium carbonate the carbon dioxide, as carbonate and bicarbonate ions, would be neutralized by sodium ions from the exchange complex to form sodium carbonate or bicarbonate which would raise the pH of the soil solution.

As might be expected from the virtual absence of visible organic matter the content of organic carbon (less than one per cent) and nitrogen (0.02 to 0.04 per cent) is very low. Both constituents are distributed fairly evenly down the profile to a depth of two metres. It is expected that irrigated crops in the project area will respond well to nitrogenous fertilizers and green manures as do crops in the Gezira area. On the other hand, it is expected that reserves of phosphate and potassium will be adequate for crops as in the Gezira area.

The clay soils belong to the Soil Order of Vertisols (U.S.D.A., 1960) the Sub-Order of Usterts and the Great Group of Grumusterts (self-mulching clays). The Grumusterts are further divided into Orthic and Natrargidic Sub-Groups; Orthic Grumusterts have E.S.P.'s less than 15 whereas Natrargidic Grumusterts have E.S.P.'s exceeding 15. The Subgroups are divided into families on the basis of clay content and into series on the basis of their soluble salt content. The salinity status is regarded as a suitable differentiating criterion for soil series in Vertisols because of their very low permeability and the relative stability of the salt profile. The following series were mapped in the project area between Tuneidba and Rufa'a:-

V2: 40 sites. clay content 35-50 per cent. Non saline (E.C.less than 4 in solum) Non-alkali (E.S.P. less than 15 in solum).

V3: 8 sites. Clay content over 50 per cent. Saline (E.C. greater than 4 in solum). Non alkali (E.S.P. less than 15 in solum).

V4: 1662 sites. Clay content over 50 per cent.

Non-Saline - Non Alkali Soils

NV1: 5 sites. Clay content 35-50 per cent. Saline - alkali soils.

NV2: 36 sites. Clay content 35-50 per cent. Non saline - alkali soils.

NV3: 28 sites. Clay content over 50 per cent. Saline - alkali soils.

NV4: 634 sites. Clay content over 50 per cent. Non saline - alkali soils.

In addition to the Vertisols, 28 sites were classified as Entisols (U.S.D.A., 1960) and mapped as an Entisol Complex without further differentiation. The Entisols are soils without natural genetic horizons or with only the beginnings of horizons. The Entisols of the project area have less clay and more sand than the Vertisols. They belong to the Sub-Order of Ustents, to the Great Group of Orthustents and to the Sub-Group of Orthic Orthustents.

2.2 WATER QUALITY IN BLUE NILE AND RAHAD RIVERS:

2.21 River Rahad: Samples were taken at Abu Haraz gauge site in September - October 1963, on the following dates - 2, 7, 8, 14, 15, 26, 28 September - 1, 5, 7, 9, 12, 20 October. Samples were taken in triplicate from three depths in the river: at half a metre below surface, at half depth and at half a metre above bed level. The river depth varied from 6.00 metres on 2.9.63 to 1.89 metres on 20.10.63.

The quantity of suspended solids varied from 500 to 2,500 p.p.m. A typical mechanical analysis (sampled on 2nd September, 1963) is :-

Coarse sand	nil %
Fine sand	10 %
Silt	25 %
Clay	65 %

As the river level fell the fine sand fraction increased appreciably at the expense of clay.

The total soluble salt content remained steady at 0.012% (120 p.p.m.) from 2nd-15th September and must be regarded as typical of the peak flood water of August and September. As the river level fell through the second half of September and until sampling ceased on 20th October the salt content showed a slight but irregular increase, reaching a maximum of 0.017% (170 p.p.m.) on 30th October. The salt content of the Rahad water is very low and is of the same order of magnitude as the Blue Nile. It is reasonable to assume that the Rahad water has the same favourable ratio of sodium to calcium plus magnesium ions as the Blue Nile water which is an excellent irrigation water. The pH measurements show variations from 7.0 to 8.2. This is a neutral to slightly alkaline water.

2.22 River Blue Nile: Analyses of Blue Nile water are rare. The usual reference is to the analyses of Beam carried out in 1906. Beam found considerable seasonal variation but the content of total soluble salts is always

very low. The average content from July to December 1906 was 115 p.p.m. of total soluble salts and 689 p.p.m. of suspended solids. The content of soluble sodium was very low (6.5 p.p.m. of Na_2O) and the relative amounts of sodium compared with calcium and magnesium was also low, Because of its low salt content and the dominance of calcium and magnesium Ions in the soluble fraction with Blue Nile water is classed as excellent for irrigation purposes.

2.3 CLIMATICALLY ADAPTED CROPS:

The climatically adapted crops of the northern rainlands of the Republic of the Sudan are essentially tropical and have been grouped into three categories, those grown commercially within the northern rainlands, those tested at the research stations but not grown commercially, and those that have had a trial planting at some time or another. The commercial crops are further subdivided into those grown under irrigation as against the rain-grown crops. These crops are listed in Table 2.1.

It is surprising at first sight to note the small number of crops grown commercially in this large zone. The explanation for this probably lies in the environmental control exercised by the harsh, semi-arid, lowland climate together with excessively low permeability of clay soils as in the project area or with excessively high permeability and low water holding capacity of sandy soils as in Northern Kordofan.

Only eleven crops are grown commercially within the northern rainlands. The most important of these are grown under irrigation in the Gezira and Managil Schemes and the private pump schemes on the Blue Nile and White Nile :- long staple cotton grown on a wide rotation with dura (a grain sorghum) and lubia (a forage legume). Two other cash crops, wheat and groundnuts, have recently been introduced into the Gezira and Managil irrigation schemes. The pulse crop, pigeon pea, is also grown extensively there as a windbreak at the edges of the cotton fields. Onions and garlic are grown as garden crops in the small plots in which the Gezira and Managil tenant farmers may grow crops of their own choice.

Sugar cane is a very recent addition to the irrigated commercial crops of the northern rainlands. As part of the Ten Year Plan of Economic and Social Development 1961-62 to 1970-71, sugar cane replaced long staple cotton as the chief cashcrop of Government's Guneid Pump Scheme on the Blue Nile between Wad Medani and Khartoum (see Roseires "soil survey" Report No. 7). The sugar cane is processed in a new sugar factory with a capacity of 60,000 tons of refined sugar per year which commenced operations at Guneid early in 1963.

A number of commercial crops are grown without

irrigation in the rainlands. These consist of dura, short staple cotton and sesame on the clay lands and dukhn, groundnuts and sesame on the sandy lands. It is worth emphasizing here that the rain-grown groundnut of the Northern Kordofan sands is a different variety from the groundnut grown under irrigation on the Gezira clays and that these varieties are not interchangeable from one environment to the other.

Table 2.1 Climatically Adapted Crops of the Northern Rainlands of the Sudan

Type of Crop	1. Commercial Crops Irrigated	1. Commercial Crops Rain-grown	2. Research Tested Crops	3. Other Crops
Fibres	Cotton (long staple) (med. ")	Cotton (short staple)	Jute Kenaf	Sunn Hemp Roselle
Cereals	Dura Wheat	Dura Dukhn	Maize Rice	
Oilseeds	Groudnuts	Groundnuts Sesame	Safflower Castor	Sunflower Soya Bean
Fodders	Lubia		Phillipesara Clitoria	Leucena glauca Sudan grass
Pulses	Pigeon Pea		Cowpea	Cluster Bean Velvet Bean
Garden Crops	Onions garlic		Chillies	Tomatoes Melons
Industrial Crops	Sugarcane		Sugar Beet Tobacco	
Fruits			Citrus Mangoes	Bananas Guavas

Bearing in mind that the soils of the project area consist almost entirely of virtually undrainable clay soils we have prepared a list of crops (Table 2.2) which may be considered agronomically suitable for irrigated agriculture on the Rahad East Bank lands.

Of the climatically adapted crops that are considered probably unsuitable for the project area some, such as dukhn and melons, are adapted to sandy soils. Others, such as castor, tobacco, citrus, mango and banana are known to

require a free draining soil and would not be expected to grow well on the impermeable clays of the project area. Yet, others, such as soya bean, velvet bean and sugar beet have not yielded well under test and must be regarded as being only marginally adapted to the climatic environment of the northern rainlands.

A considerable number of crops are listed as being probably suitable for irrigation on the Rahad East Bank lands. These include such potentially important crops as jute, kenaf, sunn hemp, maize, sunflower, and sugar cane. At the present time there is insufficient knowledge, either from trials or commercial experience to be more definite as to their agronomic suitability for the project area. It is hoped, however, that these crops will be further considered when more information as to their suitability becomes available.

The crops of proven agronomic suitability for clay soils of the northern rainlands are:- cotton (long, medium and short staple), dura, wheat, rice, groundnuts, sesame, safflower, Lubia, phillipesara, clitoria, pigeon pea, onions and garlic. Most of these are commercial crops but a few, such as safflower and rice which have been fully tested at the research stations, have not yet been grown commercially in the northern rainlands.

Only in the case of long staple cotton is there a sufficiently detailed record of commercial crop yields, together with research findings, to justify an accurate prediction of yields in the project area.

Table 2.2 Estimated Agronomic Suitability of the Climatically Adapted Crops to the Clay Soils of the Project Area

Type of Crop	1. Crops of Proven Suitability	2. Crops Probably Suitable	3. Crops Probably Unsuitable
Fibres	Cotton long staple med. " short "	Jute Kenaf Sunn Hemp Roselle	
Cereals	Dura Wheat Rice	Maize	Dukhn
Oilseeds	Groundnuts Sesame Safflower	Sunflower	Castor Soya

Table 2.2 (Continued)

Type of Crop	1. Crops of Proven Suitability	2. Crops Probably Suitable	3. Crops Probably Unsuitable
Fodders	Lubia Phillipesara Clitoria	Cowpea Sudan Grass Guinea Grass	
Pulses	Pigeon Pea	Cowpea	Cluster Bean Velvet Bean
Garden Crops	Onions Garlic	Chillies Tomatoes	Melons
Industrial Crops		Sugar Cane	Sugar Beet Tobacco Citrus
Fruits		Guava	Mango Banana

2.4 SOIL CONDITIONS AFFECTING COTTON YIELDS IN THE GEZIRA

The Department of Agriculture's Research Division over the years has studied the productivity records of the Gezira Scheme and of some pump projects, notably Dueim, endeavouring to find relationships between yield variations and measurable soil characteristics. The following criteria were found to be of importance to the yield of long staple cotton :-

(i) Clay Content

Research work in the Sudan shows that long staple cotton, the chief cash crop of the irrigated lands, yields best on soils of high clay content which do not contain limiting amounts of soluble salts or exchangeable sodium. Finck and Ochtman (1961) show that, on the Vertisol soils south of Khartoum, cotton yields are positively correlated with clay contents between 40 and 70 per cent. The actual yields shown below (see Table 2.3) are from Tom's (1960) paper on soil productivity of the Sudan Gezira as expressed by cotton yields. The basic mean yield of the Gezira Scheme is taken as 4.45 Kantars per feddan of Lambert cotton.

Table 2.3 The Relationship Between Clay Content of Vertisols and Yield of Long Staple Cotton

Clay Content per cent	Relative Yield per cent	Actual Yield Kantars/Feddan
70	130.6	5.81
65	117.7	5.24
60	104.9	4.67
58	100.0	4.45
50	79.2	3.52
46.4	70.0	3.12
40	53.5	2.38

The causal factor linking yields of long staple cotton to clay content has not been determined. It has been suggested, however, that the excellent crumb structure of the self mulching soils which is related to high clay content may be the factor enhancing cotton yields. In view of the fact that all soils, both of low and high clay content, contain appreciable exchangeable sodium it is possible that a deterioration of soil structure occurs first in soils of lower clay content at E.S.P. levels that would not cause structural deterioration in soils of high clay content.

It is not known whether the correlation between clay content and high yield is valid for other crops beside long staple cotton.

(ii) Extractable Sodium

Investigations had also shown the yield of long staple cotton to be correlated inversely with the content of extractable sodium (soluble plus exchangeable) in relation to clay content of the top 3 feet (90 cm) of soil. This relationship was then used to evaluate soils for long staple cotton production on the basis of their "sodium values" (extractable Na per 100 gram of even dry clay in the 0-90 cm. layer) as follows :-

Sodium Value	Land Class
0-25	good
26-35	medium
over 35	bad

Finck and Ochtman (1961) considered that although the correlation between cotton yield and "sodium value" was not as good as that between cotton yield and clay content, nevertheless the sodium value had a use in excluding sodic (alkali) soils. These authors point out that if one assumes that 50 per cent of the extractable sodium is exchangeable

then a sodium value of 30 would correspond to an E.S.P. of 15 which is the Internationally accepted limit for sodic (alkali) soil. Our own investigations have shown, however, that exchangeable sodium almost always exceeds soluble sodium in Gezira type soils and that a "sodium value" of 30 would correspond to an E.S.P. of about 20 to 25. From this indirect evidence we can assume that in soils of high clay content (over 50 per cent clay) the long staple cotton can tolerate an E.S.P. somewhat in excess of 15 without suffering a serious reduction in yield.

(iii) Salinity

The salinity standards used in the Sudan since 1942 for the selection of cotton lands are as follows :-

(a) Good lands have less than 0.3 per cent total soluble salts.

(b) Medium lands have less than 0.5 per cent total soluble salts.

As pointed out by Finck and Ochtman (1961) these salinity levels are rarely encountered and so land tended to be judged on "sodium value" and clay content alone.

In view of the fact that the Gezira type soils are virtually undrainable we consider that lower salinity levels than those generally used internationally may become limiting under irrigated conditions. We therefore place the salinity limits for arable lands as follows :-

	E.C.
Surface horizon (0-60 cm)	Less than 6
Sub-surface horizon	Less than 8

Research work has shown that under the extensive type of irrigation practised in the Gezira, salt contents of this order tend to diminish in the top metre and to increase slightly in the second metre of soil where they do not interfere with crop yields.

(iv) Subsoil Salinity - Alkalinity

Investigations of unthrifty cotton crops in the Managil Extension Scheme by the Gezira Research Division show that cotton plants become unthrifty and yields suffer if the cotton roots are unable to penetrate to a full depth of 90 cm. The tendency of roots of unthrifty plants to branch off horizontally at certain depths was attributed by the investigation team to the presence of highly saline layers or to dense clays of high exchangeable sodium content in the subsoil. For this reason our specification for salinity and alkalinity limits has been extended to 90 cm.

2.5 LAND CLASSIFICATION

The Sudan Government specifications for the semi-detailed land classification are based on those of the United States Department of the Interior, Bureau of Reclamation Manual, Vol. V., Irrigated Land Use 1951.

The objective of the soil survey and land suitability classification is to assess the suitability of the land for irrigated cultivation in general and for specific crops in particular for the purpose of delineating lands to be irrigated within the project area.

The results of the survey were incorporated into a land suitability classification map for irrigated cultivation, classifying in broad lines according to the U.S. Bureau of Reclamation standards, but adjusted where necessary for satisfactory application under Sudan conditions. The land suitability classification maps at scale 1:50,000 show land classes 1, 2, 3, 4 and 6 and are the most objective method available of delineating the irrigable areas.

The Bureau of Reclamation capability classes are numbered from 1 to 6. The higher the number, the lower is the capability rating. The first three classes, 1, 2, and 3, are considered arable with progressively increasing limitations on their use and/or with increasing costs of reclamation and management. Class 4 is land suited only to special uses. Class 5 is land needing further investigation, and Class 6 is permanently non-arable.

The observation density used on the project was approximately one 2m. bore per 250 feddans with every twentieth to 3m. This closely approximates to the standards given in the Manual for "semi-detailed" reconnaissance. The objective of this type of survey is to separate arable from non-arable land with considerable accuracy, while delineating boundaries between classes and sub-classes in less detail. The Manual states "Generally, Classes 1, 2, 3 and 6 and their sub-classes are mapped. Special sub-classes under Classes 4 and 5 are differentiated when conditions warrant". In the project area Class 5 land was not differentiated but Class 4 was used to indicate those lands where, though profitable irrigation should still be possible, higher levels of exchangeable sodium may restrict the range of crops more seriously than can be accepted for Class 3 land.

The project lands are flat, level, open plains with thin tree and shrub cover so that clearing and development costs would be minimal. Further the plains, slope gently and uniformly to the north and west with few enclosed basins or other areas of impeded drainage. The soils themselves are of low permeability like those of the Gezira Scheme where no water tables have developed and where water losses from canals are negligible. The non-drainability of these soils

does raise other problems which are mentioned below but this characteristic does eliminate the possibility of waterlogging and salinity problems resulting from waterlogging.

It follows from the above discussion that the project lands, having no serious limitations due to uneven topography or waterlogging, are classified largely on soils limitations. The criteria in connection with salinity, alkalinity and clay content were adopted after full discussions with the Director and Officers of the Department of Agriculture's Research Division at Wad Medani. In this way the productivity records of the Gezira Scheme and of some pump projects, notably Dueim, in relation to local soil characteristics were incorporated into the land classification system which follows the general lines of the United States Bureau of Reclamation system but adjusted where necessary for satisfactory application under Sudan conditions.

Specifications for land classes 2, 3 4 and 6 are shown in Table 2.5. Because of limitations inherent in a non-drainable soil no land was considered eligible for Class 1 status. Some doubts have been expressed as to whether any land qualified for Class 2 or 3 status. We have taken the viewpoint, however, that as a variety of crops are grown on similar soils in the Gezira Scheme and in the pump projects and because these have remained profitable over a comparatively long period of time with no apparent soil deterioration, we are justified in delineating Class 2 and Class 3 lands.

The specifications for the land classes are on conventional lines and can be taken as applying to all the climatically adapted crops that are likely to be grown in the Sudan.

In view of the discussions above we consider that land Classes 2, 3a, 3s, 3as and 4a would be suitable for a long staple cotton rotation and that these classes should show a reasonable return on investment.

Long staple cotton would probably not be profitable on Land Classes 31, 3a1, 3as1, and 41 and these lands could be used for other crops such as wheat, groundnuts and forage crops and for pastures, forestry purposes, etc.

Table 2.4 shows the ares of land classes mapped within the project lands.

Table 2.4 Areas of Land Classes

Land Class	Area (feddans)
2	159,740
3	224,620
4	68,850
6	63,130
Total Area	516,340

2.6 POSSIBLE ROTATIONS:

There are certain limiting factors which have to be considered in planning the rotations. These are summarised below :-

a) A fallow year should be included in the rotation.

b) Adequate drying and cracking of the land between crops is beneficial.

c) The build up of soil alkalinity and salinity is likely to be accelerated by greater intensification of the cropping system.

d) Excessive seasonal labour and water peaks are undesirable.

e) Alternate legume and non legume crops should be grown.

f) Dura must be included at least as a "free choice" crop.

g) A dead season is desirable and care in crop selection is necessary to avoid pest and disease problems.

h) Production should provide satisfactory returns to the parties concerned in the project.

i) Weed control is an important factor which may influence ultimate choice of rotation.

It has been shown in the economic assessment of the various crops that Acala 442 cotton is by far the most attractive non legume crop and groundnuts the most attractive legume. These two crops have therefore been selected to form the basis of a rotation, to which a free choice crop, generally dura, is added.

Three rotations are considered as possible alternatives for the Project :

a) Four Course Rotation - 75% cropping

b) Six course rotation - 83 1/3% cropping

c) Eight course rotation - 87½% cropping

The proposed cropping pattern for each of these rotations is given below

a) Four course rotation - 75% cropping

The basic recommended rotation is :

Year	Crop
1	Groundnuts - Ashford
2	Cotton - Acala 442
3	Fallow
4	Free choice ½ Dura - Feterita ½ Groundnuts - Barberton

b) Six course rotation - 83 1/3 % cropping

The basic recommended rotation is :

Year	Crop
1	Groundnuts - Ashford
2	Cotton - Acala 442
3	Groundnuts - Ashford
4	Cotton - Acala 442
5	Fallow
6	Free choice: Dura - Feterita

c) Eight course rotation - 87½% cropping

The basic recommended rotation is :

Year	Crop
1	Groundnuts - Ashford
2	Cotton - Acala 442

3	Groundnuts - Ashford
4	Cotton - Acala 442
5	Groundnuts - Ashford
6	Cotton - Acala 442
7	Fallow
8	Free choice - Dura

In selecting the most suitable rotation three factors were considered to decide the limit of intensification which is safe for the Project. These are:

i) The need to maintain the physical condition of the soil.

ii) The risk of salinity problems under more intensive irrigation.

iii) The problems arising from infestations of perennial weeds.

After taking into account the limiting factors described above it is recommended that the six course rotation (with 831/3% cropping) is adopted

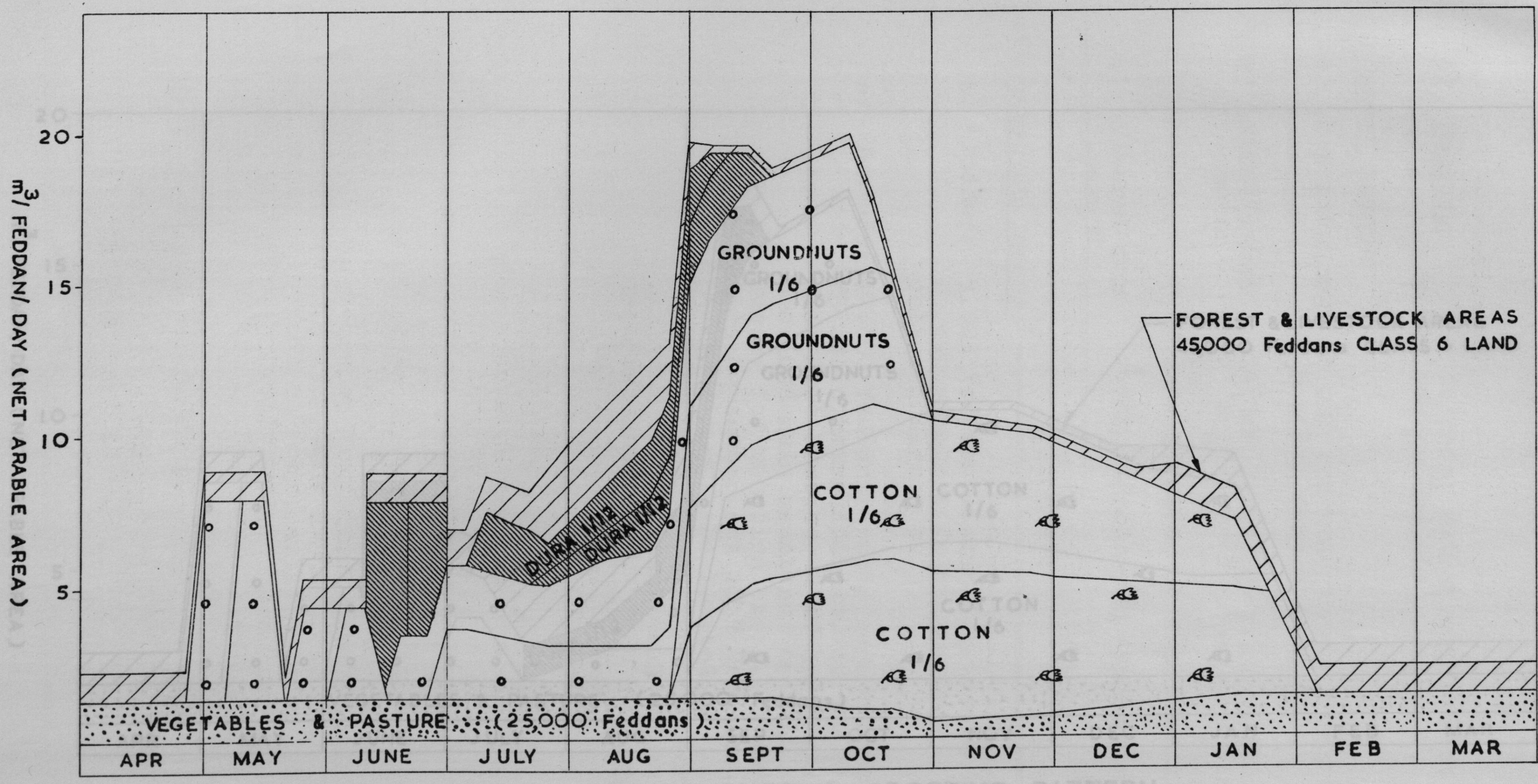
2.7 WATER REQUIREMENTS

In Part IV, Agriculture, of this Report the water requirements for the rotation crops have been calculated based on the theoretical openwater surface evaporation and estimated monthly rainfall figures for the Project area in accordance with the Penmen method. The breakdown of monthly rainfall and evaporation into ten day periods was made assuming regular distribution between the monthly figures. The calculations have been made for the extremes of climate within the Project area and the mean of the two requirements is taken as applying to the area as a whole.

The water requirements have been calculated for the median and ten per cent dry climatic years and the total seasonal irrigation requirement at farm outlet (watercourse head) is shown in Figure 2.1 and 2.2. In addition to the water requirements for the rotation crops, provision has been made for the following additional uses, also shown in Figures 2.1 and 2.2.

i) Village, garden and pasture areas

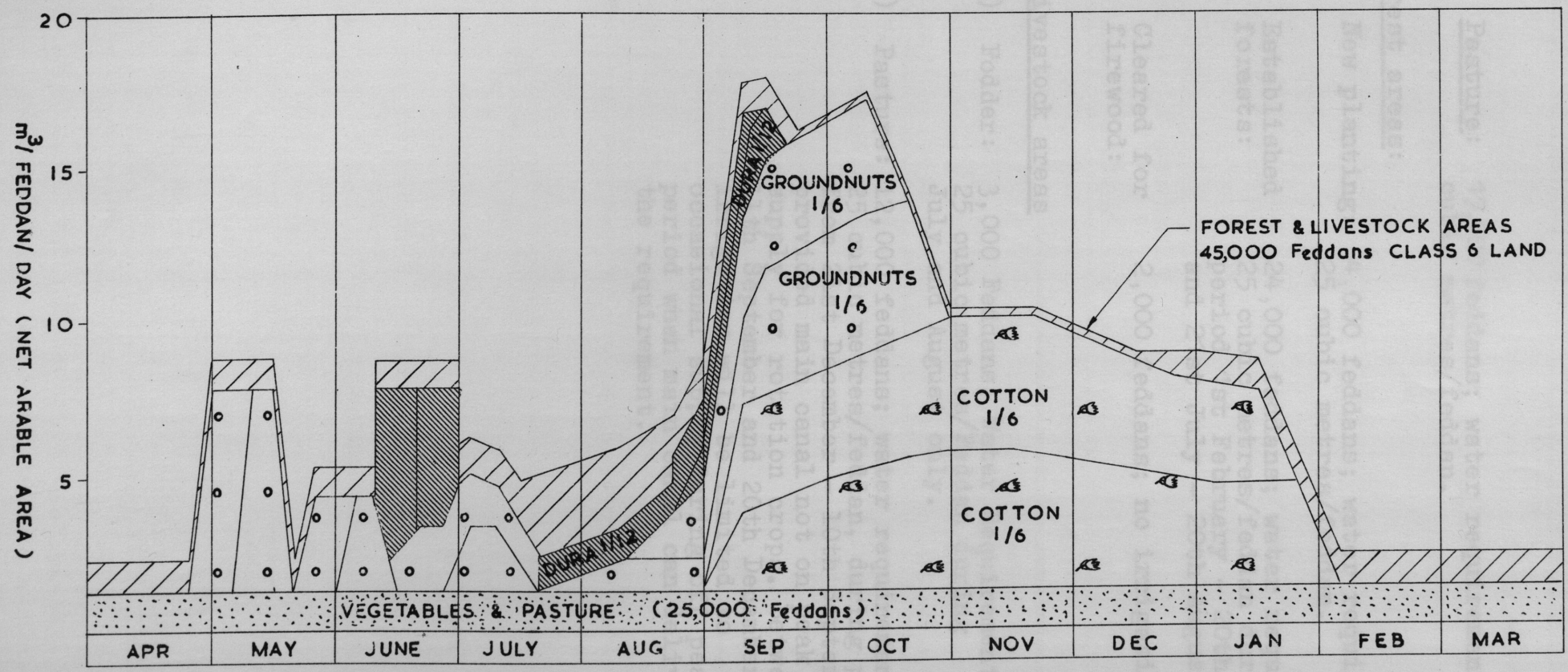
a) Vegetables: Total area 8,000 feddans of which 6,000 feddans cropped; water requirement 25 cubic metres/feddan allowed on gross area.



WATER REQUIREMENTS & CROPPING PATTERN
10 % DRY YEAR

FIGURE 2.1

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2



WATER REQUIREMENTS & CROPPING PATTERN
MEDIAN YEAR

FIGURE 2.2

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

b) Pasture: 17,000 feddans; water requirement 20 cubic metres/feddan.

ii) Forest areas:

a) New planting: 4,000 feddans; water requirement 25 cubic metres/feddan.

b) Established forests: 24,000 feddans; water requirement 25 cubic metres/feddan during period 1st February - 20th April and 21st July - 20th August.

c) Cleared for firewood: 2,000 feddans; no irrigation

iii) Livestock areas

a) Fodder: 3,000 Feddans; Water Requirement 25 cubic metres/Feddan during July and August only.

b) Pasture: 12,000 feddans; water requirement 25 cubic metres/feddan, during period from 21st December - 10th September, provided main canal not on peak supply for rotation crops. Between 11th September and 20th December, irrigation will be limited to occasional supply during off peak period when main canal can deliver the requirement.

TABLE 2.5 Criteria for determining land classes in the project area

Land Class	Sample depth	Clay content	E.C.	E.S.P.
2	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	exceeds 50% not limiting " "	less than 4 " " 5.3 " " 8	less than 15 " " 15 not limiting
3 l	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	35 - 50% not limiting " "	less than 4 " " 5.3 " " 8	less than 15 " " 15 not limiting
3 a	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	exceeds 50% not limiting " "	less than 4 " " 5.3 " " 8	less than 15 15 - 25 not limiting
3 a l	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	35 - 50% not limiting " "	less than 4 " " 5.3 " " 8	less than 15 15 - 25 not limiting
3 s	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	exceeds 50% not limiting " "	4 - 5.3 and/or 5.3 - 8 and/or 8 - 12	less than 15 " " 15 not limiting
3 s l	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	35 - 50% not limiting " "	4 - 5.3 and/or 5.3 - 8 and/or 8 - 12	less than 15 " " 15 not limiting
3 a s	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	exceeds 50% not limiting " "	4 - 5.3 and/or 5.3 - 8 and/or 8 - 12	less than 15 15 - 25 not limiting
3asl	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	35 - 50% not limiting " "	4 - 5.3 and/or 5.3 - 8 and/or 8.12	less than 15 15 - 25 not limiting
4 a	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	exceeds 50% not limiting " "	less than 5.3 " " 8 " " 12	15 - 20 less than 25 not limiting
4 l	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	5 - 35% not limiting " "	less than 5.3 " " 8 " " 12	less than 15 " " 20 not limiting
6 a	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	exceeds 5% not limiting " "	less than 5.3 " " 8 " " 12	exceeds 15 or 20 and/or exceeds 20 or 25 not limiting
6 s	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	exceeds 5% not limiting " "	exceeds 5.3 and/or exceeds 8 and/or exceeds 12	less than 15 or 20 less than 20 or 25 not limiting
6 a s	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	exceeds 5% not limiting " "	exceeds 5.3 and/or exceeds 8 and/or exceeds 12	exceeds 15 or 20 and/or exceeds 20 or 25 not limiting
6 l	0 - 45 cm. 45 - 90 cm. 90 - 150 cm.	less than 5% not limiting " "	not limiting " " " "	not limiting " " " "

NOTE: Not all categories shown on this table were mapped in the Project area.

CHAPTER 3

CANALIZATION DESIGN AND LAYOUT

3.1 AREA COMMANDED AND PERCENTAGE AVAILABLE FOR CROPS

It is planned that the flow in the River Rahad will be directed into a gravity canal at Malek, a small village 3 kilometres north of the market centre of Mafaza. A barrage is needed at the diversion site to maintain the upstream level in the river at about the present maximum flood level and a regulator to control the flow into the Project canal.

The gross area in the Rahad East Bank commanded by the Project canal is 563,000 feddans. Of this total 505,000 feddans gross area is described as usable irrigable lands, which includes Class 2, Class 3a and Class 4a lands. The only serious limitation in the quality of the soil is the degree of alkalinity and land Classes 2, 3a and 4a are all considered suitable for irrigated crops.

The eastern boundary of the present scheme has been fixed by the limit of command by gravity irrigation from the Malek diversion site. The western boundary is generally formed by the edge of the eroded gullied lands which form the "kerrib" between the river and the clay plain.

The gross area of non-arable (Class 6) lands within or adjacent to, the northern part of the scheme area amounts to only 15,000 feddans. There is, however, a larger area of about 40,000 feddans, mainly Class 6a lands, in the southern part of the area and situated between the western boundary and the "kerrib" lands adjacent to the river. It is proposed that the areas of Class 6 lands be used for establishing forest plots for firewood production and also for irrigated fodder. Throughout the Project it is estimated that the nett areas which will be available for these two uses are 30,000 feddans for firewood production and 15,000 feddans for irrigated fodder.

It is estimated that eighty-five per cent of the 505,000 feddans usable irrigable lands will be available for crops and the nett cultivable area is thus 430,000 feddans. Of this total 405,000 feddans will be included in the planned rotation of field crops and about 25,000 feddans will be used for the perennial village vegetable and fodder areas.

Details of the gross areas in the various land classes served from each regulator group on the main canal are given in Table 3.1. The nett cultivable area of usable irrigable lands is also included in this table. Small isolated areas of Class 6a land have been included in the total of usable irrigable lands after first checking the

results of the laboratory analyses. In most cases these results showed these small areas to be only marginally outside the specification for irrigable land.

Table 3.1: Rahad East Bank Project: Gross Commanded and Net Cultivable Areas (Feddans)

Main Canal Regulator Group	GROSS AREA						Net Cultivable area Included in Project
	Class 2	Class 3	Class 4	Class 6	Not Soil Surveyed	Total	
K 31	8,880	40,700	5,960	20,750	-	76,290	48,050
K 45	8,000	42,570	8,980	10,120	800	70,470	51,290
K 57	1,710	16,870	14,730	14,580	7,920	55,810	37,150
K 80	12,950	20,060	6,260	4,350	920	44,540	35,650
K 91.5	39,400	22,580	3,840	390	-	66,210	55,790
K 103	34,150	26,550	4,110	1,180	-	65,990	57,210
K 119.5	40,380	33,080	8,880	5,140	1,060	88,540	71,780
K 139	9,440	19,690	6,250	3,630	5,120	44,130	34,590
K 154	1,870	540	4,780	2,340	11,610	21,140	14,800
K 164	2,960	1,980	5,060	650	19,590	30,240	23,860
TOTALS	159,740	224,620	68,850	63,130	47,020	563,360	430,170

3.2 WATER REQUIREMENTS AT FARM OUTLETS AND AT CANAL HEADS

In Part IV, Agriculture, of this Report it has been concluded that the maximum quantity of water to be applied at any one irrigation should not exceed 420 cubic metres/feddan. In the same chapter the maximum irrigation requirement of Acala cotton in the northern (driest) part of the scheme, is shown as 420 cubic metres/feddan after an interval of 13 days between waterings during October for the ten per cent dry year. This represents a watering rate of 32.3 cubic metres/feddan per day for each feddan under cultivation and is known as the Peak Crop Factor.

In the case of the cropping pattern which is recommended for the East Bank Project, and which has been described in the previous chapter, the Peak Crop Factors

occur during the month of October when there are growing crops on two-thirds of the available cultivable lands. The maximum water use per day on the available cultivable area in the Project is known as the Peak Gross Factor. For the recommended cropping pattern the Peak Gross Factor is 21.1 cubic metres/feddan per day. The Agronomist has calculated the water requirements for two conditions of rainfall and temperature, viz. the median year and the ten per cent dry year. In each case the water requirements for the driest and wettest areas in the scheme have been obtained.

No measurements of seepage losses in canals have been taken during the present study. It is assumed that, since the soils in the Project Area are similar to the clays in the Gezira, the transmission losses in the canal system will also be similar to those which occur in the Gezira canals. These losses, which are computed annually for the system from the Head regulator of the Main Canal at Sennar at the minor canal heads are normally very low and sometimes appear to be negative. However, for the purpose of designing channel capacities and also for computing 10-day mean water requirements it is considered that an adequate allowance for transmission losses must be made and the same figures have therefore been used as those in the design estimates for the Gezira canalization. Percentage losses assumed are given in Table 3.2 below :-

Table 3.2: Percentage Transmission Losses in Canal System

Period	Percentage losses assumed			
	Minors	Main and Majors	Escapage	Total
July to December	3	5	5	13
January to June	3	3	2	8

The estimated Peak Gross Factors for the two conditions of median year and ten per cent dry year are given in Table 3.3, and are shown for the driest and wettest parts of the Project Area.

Table 3.3: Peak Gross Factors in Cubic Metres/feddan per day

Design Condition	Peak Gross Factor, Cubic Metres/feddan/day						Main Canal Head
	Farm Outlet			Minor Canal Head			
	Driest Area	Wettest Area	Av.for scheme	Driest Area	Wettest Area	Av.for scheme	
Median Year	18.0	15.9	17.0	18.6	16.4	17.5	19.2
10% Dry Year	21.1	18.6	19.9	21.8	19.2	20.5	22.5

3.3 RECOMMENDED GROSS FACTORS FOR DESIGN OF CANALS AND STRUCTURES

The calculated values for Peak Gross Factors shown in the table above occur during the second 10-day period of October. At this time one-third of the cultivable area is under Acala cotton and one-third under groundnuts. The dura crop which occupied one-sixth of the cultivable area ceased watering after the second 10-day period in September. For the proposed cropping pattern the peak water requirement therefore occurs when two-thirds of the area is being watered and not when the maximum area is under crops during September.

Gross factors for design for the planned cropping pattern and with provision made for five-sixths of the area to be cropped during October are given in Table 3.4 as items (1) and (2). The current design practice in Ministry of Irrigation and H.E.P. for the Gezira scheme is also shown as items (3) and (4) for two-thirds and five-sixths cropping respectively.

The design factors recommended for adoption in the East Bank Project are included in Table 3.4 as item (5) and provide for five-sixths of the area to be cropped during October. This provison should be regarded as a safety factor as it allows for some intensification of the cropping patterm which may be considered desirable in the future. The number of structures on the major and minor canals throughout the scheme is very numerous and it is not a practical proposition to enlarge all the canal structures at a later stage in the life of the Project.

The recommended factors for use in design of the

Rahad Link Canal are also included in Table 3.4.

Table 3.4: Gross Factors for Design in M3/ feddan per day

Cropping Pattern etc.	Minors	Majors	Main Canal at Malek	Main Canal at Roseires
(1) Planned for Project (1/3 cotton+1/3 Groundnuts+1/6 Dura)				
Canal excavation in dry	21.8	21.8	22.1	13.1
Canal Structures	27.2	27.2	27.6	16.4
(2) With provision made for 5/6 available area cropped during October				
Canal excavation in dry	25.5	25.5	25.8	
Canal structures	31.8	31.8	32.2	
(3) M.I.H.E.P. design factors for 2/3 cropping				
Canal excavation in dry	21.3	20.0	17.3	-
Canal structures	27.0	27.0	27.0	-
(4) M.I.H.E.P. design factors for 5/6 cropping				
Canal excavation in dry	26.6	25.0	21.6	-
Canal structures	33.0	33.0	33.0	
(5) Factors recommended for design of East Bank Project				
Canal excavation in dry	26.6	25.0	22.1	13.1
Canal structures	33.2	31.2	27.6	16.4

The design factors for main canal structures provide for a 25 per cent overload above the design capacity of the canal. The additional 25 per cent may be regarded as a safety factor and allows for some future enlargement of the canal. In the case of structures for the Project canalisation the margin allowed is about 50 per cent. This provides for the future enlargement of the canals to permit five-sixths cropping during October when the safety factor remaining will be 25 per cent as for structures on the Project Main Canal and on the Rahad Link Canal.

3.4 IRRIGATION LAYOUT - SYSTEM OF WATERING

The first consideration to be made in planning the irrigation layout of the proposed Rahad East Bank Project was whether to design the canals for continuous watering or whether to adopt the night storage system as is practised over most of the Gezira and Managil schemes.

From an engineering point of view the continuous watering system has several advantages. The area of fields watered from a watercourse can be made twice that of the standard adopted for the night storage system without increasing the watercourse capacity. This can be achieved because watering is continuous throughout the 24-hours of the day. With the standard 35 cm. outlet which discharges from the minor canal into the watercourse at the rate of 10,000 cubic metres per day a plot of 160 feddans would be irrigated in 6½ days. The initial cost of construction for the minor canals is less than half that for the night storage system as the spacing of these channels is twice the standard distance. As there is no storage provided above design water level the canal banks can be made lower and this provides an economy in the earthworks cost. Thus, less land is occupied by the minor canals and the drains and roads adjacent to them. Operation of continuous watering canals is easier than for night storage canals. There is also considerably less silt deposited in these channels and the growth of aquatic weeds is retarded so the maintenance cost is reduced.

The main disadvantage of the continuous watering system is that it is not possible to obtain adequate control of watering crops at night. Damage is done to young plants by excessive watering and cotton in particular, may be killed off by this submersion. The effect on more mature plants of excess water is to cause a reduction in yeild. Banks may be broken and the resulting flooding of the roads makes access difficult. This may prevent proper supervision and delay the completion of farming operations.

After discussion with senior officials of the Ministry of Agriculture and Ministry of Irrigation and H.E.P. it was decided that the better control of irrigation water which could be obtained with the night storage system justified the additional expenditure on capital cost and on maintenance. An estimate prepared by the Projects Division of Ministry of Irrigation and H.E.P. showed that night storage minor canals for the Rahad Project would cost about £S3/- to £S4/- more than continuous watering minors when these distributaries are aligned across the contours and down the steeper slopes in the scheme area.

The following comment was made by the Chief of the Ministry of Agriculture's Research Division at Wad Medani in a letter dated 9.2.65:-

"I would like to express the Research Division's opinion on the adoption of night storage or otherwise. Our experience in the Gezira and elsewhere in irrigated schemes is that water control by tenants even during the day is in most cases poor which results in overwatering of plots, leading to waterlogging of crops and poor yield. Water breaking onto roads and fallows is also frequent; this is easily observed from the air during the growing season. It is reasonable to assume that the weed infestation due to over-watering and water breaking on fallows which will be increased by night watering could compare favourably with canal weeds infestation due to night storage.

It is obvious that owing to lack of precision levelling of plots in most irrigated schemes, Gezira and Managil included, waterlogged patches conspicuous by stunted and yellow plants are quite common. Night watering will intensify this problem. We believe that the extra expenses incurred in maintaining night storage are justified for ensurance of more efficient watering and better yields. It is a great pity that Khashm El Girba has no night storage. It is our considered opinion that all future irrigated schemes should have night storage irrigation systems."

Signed: H. Idris.

It was therefore decided to plan the Project canalisation layout for the night storage system as the advantage of easier water control out-weighs the disadvantages described in the preceeding paragraphs.

3.5 FIELD DIMENSIONS

The layout of the field channels and minor canals is based on the dimensions of the standard field or "Number" which has been selected for the scheme. The following factors were considered in fixing the standard field dimensions:-

(1) The field must not exceed the area which can be watered by the standard watercourse in seven days, preferably less. This limitation on watering time is important as time is needed after the irrigation has been completed for the field to dry out so as to permit inter-row operations with tractors to be carried out.

(2) The size of watercourse is limited by the amount of water which the farmer can control. It is considered that the discharging rate of watercourse outlets in the Gezira scheme, 5,000 cubic metres in 12 hours, is about the maximum which can be controlled efficiently. This rate of flow is therefore recommended for the standard watercourse in the scheme.

(3) The dimensions of the field should be arranged so as to provide as long a run as possible for mechanised farming operations including ridging up, inter-row operations

and harvesting of crops. As the width of the field is varied so is the distance between watercourses and therefore the number of field outlet pipes which deliver the irrigation supply to these channels. The cost of field outlet pipes represents about one-third of the cost of the minor canalisation and so the fields should be made as wide as possible so as to avoid excessive cost on this item.

3.6 SIZE OF HOLDING

In the Economic Section (Part II) of this Report the factors governing size of holding are discussed in relation to income requirement of the farmer and labour available. The recommended size of holding is 12 feddans. The basic plot size is two feddans to that the farmer will have six plots sited one in each of six 80-feddan fields.

3.7 MINOR CANALIZATION LAYOUT

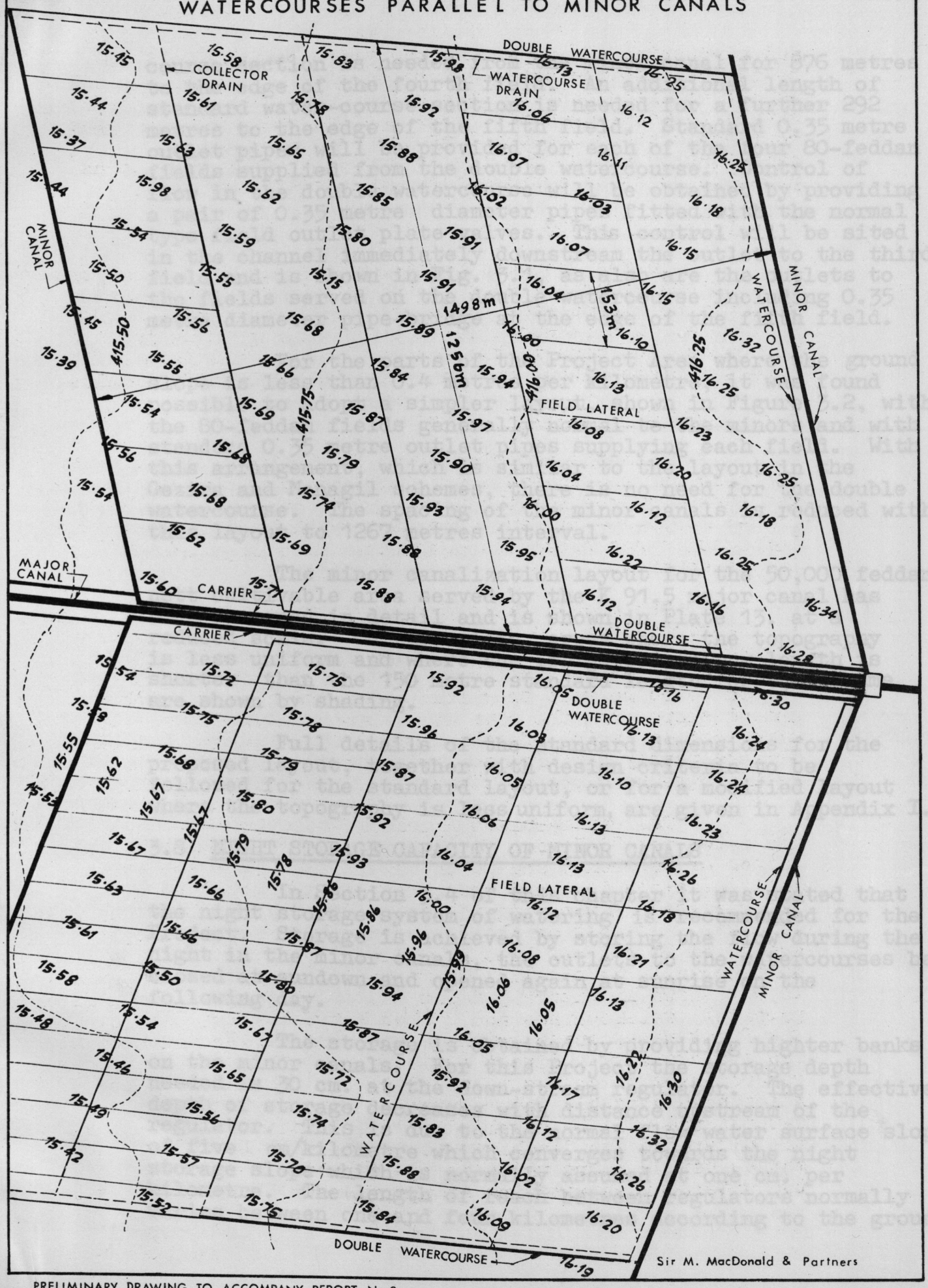
With the adoption of an 80-feddan field as the standard for the scheme a preliminary canalization layout was then prepared for the part of the Project Area north of Ein el Luweiqa - El Fau. The lack of detailed contour survey information has prevented completion of a layout plan for the whole area.

The ground slope over most of the Project Area is in the range from 0.4 to 0.1 metre per kilometre. With this degree of slope it was considered that the most satisfactory layout would be obtained by aligning the major canals across the contours so that they follow generally the steepest natural ground slope from the main canal towards the river. The minor canals which offtake from the majors can then be aligned nearly parallel to the contours so as to follow a natural ground slope of about 20 cm. per kilometre.

The watercourses which offtake from the minors and water the 80-feddan fields are required to have ground slopes of between 5 and 20 cm. per kilometre. The upper limit of slope is considered the maximum which can be accommodated in watering the 150-metre furrows between field laterals. As most of the Project Area has gound slope in excess of 20 cm. per kilometre it follows that the watercourses must normally be parallel to the minor canals. A standard layout shown in Figure 3.1 was therefore prepared with five parallel watercourses and fields between minor canals. The first watercourse which is adjacent to the minor canal can offtake with a direct outlet pipe. The remaining four watercourses which are parallel to but distant from the minor need a double watercourse to supply them. The double watercourse will be supplied by a 0.50 metre outlet pipe from the minor and its discharging capacity will be 10,000 cubic metres per 12 hours which is the capacity needed to supply two watercourses watering simultaneously. The double water-

FIGURE 3·1

CANALIZATION LAYOUT
WATERCOURSES PARALLEL TO MINOR CANALS



PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

course section is needed from the minor canal for 876 metres to the edge of the fourth field. An additional length of standard water-course section is needed for a further 292 metres to the edge of the fifth field. Standard 0.35 metre outlet pipes will be provided for each of the four 80-feddan fields supplied from the double watercourse. Control of flow in the double watercourse will be obtained by providing a pair of 0.35 metre diameter pipes fitted with the normal type field outlet plate valves. This control will be sited in the channel immediately downstream the outlet to the third field and is shown in Fig. 3.1, as also are the outlets to the fields served on the double watercourse including 0.35 metre diameter pipe-bridge at the edge of the fifth field.

For the parts of the Project Area where the ground slope is less than 0.4 metres per kilometre, it was found possible to adopt a simpler layout, shown in Figure 3.2, with the 80-feddan fields generally normal to the minors and with standard 0.35 metre outlet pipes supplying each field. With this arrangement, which is similar to the layout in the Gezira and Managil schemes, there is no need for the double watercourse. The spacing of the minor canals is reduced with this layout to 1267 metres interval.

The minor canalization layout for the 50,000 feddans nett cultivable area served by the K 91.5 major canal has been designed in detail and is shown in Plate 13. at a reduced scale. On this plate, areas where the topography is less uniform and where the irrigation furrow length is shorter than the 150 metre standard length for the scheme are shown by shading.

Full details of the standard dimensions for the proposed layout, together with design criteria to be followed for the standard layout, or for a modified layout where the topography is less uniform, are given in Appendix I.

3.8 NIGHT STORAGE CAPACITY OF MINOR CANALS

In Section 3.4 of this chapter it was stated that the night storage system of watering is recommended for the Project. Storage is achieved by storing the flow during the night in the minor canals, the outlets to the watercourses being closed at sundown and opened again at sunrise on the following day.

The storage is obtained by providing highter banks on the minor canals. For this Project the storage depth needed is 30 cm. at the down-stream regulator. The effective depth of storage decreases with distance upstream of the regulator. This is due to the normal flow water surface slope of five cm/kilometre which converges towards the night storage slope which is normally assumed at one cm. per kilometre. The length of reach between regulators normally varies between one and four kilometres according to the ground

slope along the canal line. The intermediate regulators which divide the minor canal reaches are night storage weirs. These consist of a pipe regulator with sliding steel door at the upstream end and a circular weir built either in brickwork or concrete. The sill of the weir is built to the level which allows the full canal flow to pass over the weir when the water level upstream of the regulator is at the night storage level.

For the median year condition, peak factor of 17.5 at minor canal head, night storage can be obtained for 12 hours in the minor canals. Eight hours storage can be obtained in the carrier canal adjacent to the minor canal for the fields served by the first double watercourse. For the ten per cent dry year condition, peak factor 20.5 at minor canal head, night storage can be obtained for ten hours in the minor canals and about seven hours in the carrier canal.

For the parts of the Project with flatter ground slopes where there are normal offtakes supplying the fields direct from the minor canals the night storage capacity is easier to obtain. In some cases it will be possible to obtain the full twelve hours storage with 25 cm. night storage depth at the downstream regulator.

3.9 MAJOR CANALS

The major canals offtake from regulator groups on the Project Main Canal and serve areas of land between 12 and 15 kilometres in width, see Plate 11. As has been stated earlier, the majors are aligned across the contours and therefore follow the steepest ground slope. Regulated falls or cross regulators divide the majors into reaches about three kilometres in length. This distance corresponds to the spacing between alternate minor canals. The minor canal offtakes are normally grouped together at the major regulators and measured discharges can be passed into the minors through the movable weirs provided at the head of each canal. The supply for alternate minor canals is conveyed in a carrier canal known locally as "Gannabia" parallel to the major from the regulator group to the head of the minor.

There are nine major canals which supply the whole Project canalization. The majors vary in length from eight to twenty-two kilometres and the largest has a head capacity of 18.5 cumecs.

3.10 PROJECT MAIN CANAL

The Main Canal is designed to supply the 430,000 feddans net cultivable area. It has a head design capacity of 110 cumecs and extends for 164 kilometres northwards from the Rahad Barrage at Malek, (see Plates 11 and 12). For 22 kilometres from Malek to Tuneidba the canal headreach

FIGURE 3.2

CANALIZATION LAYOUT

WATERCOURSES NORMAL TO MINOR CANALS

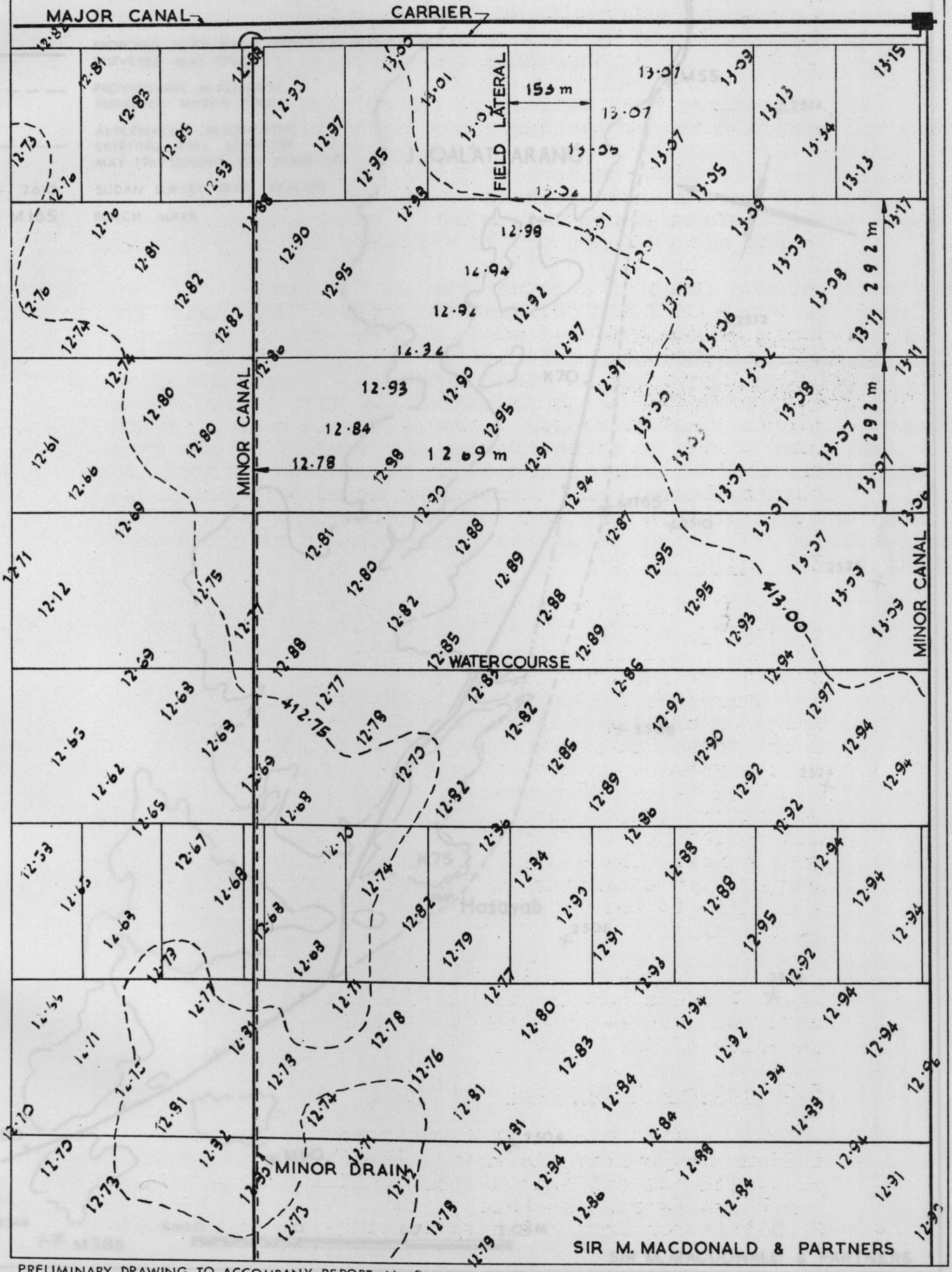


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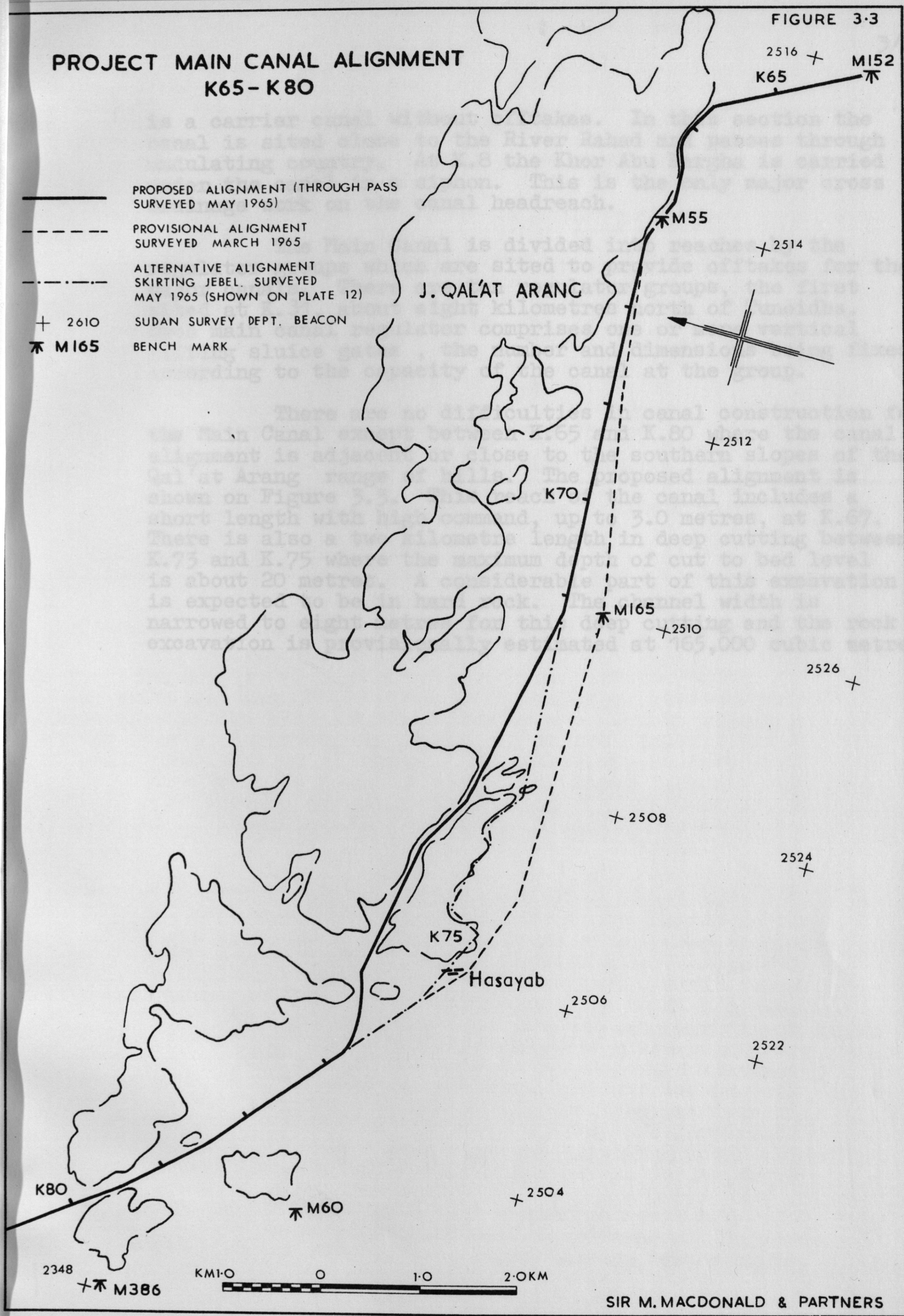
FIGURE 3·3

PROJECT MAIN CANAL ALIGNMENT K65 – K80



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is a carrier canal without offtakes. In this section the canal is sited close to the River Rahad and passes through undulating country. At K.8 the Khor Abu Fargha is carried under the canal in a siphon. This is the only major cross drainage work on the canal headreach.

The Main Canal is divided into reaches by the regulator groups which are sited to provide offtakes for the major canals. There are ten regulator groups, the first sited at K.31, about eight kilometres north of Tuneidba. Each main canal regulator comprises one or more vertical lifting sluice gates , the number and dimensions being fixed according to the capacity of the canal at the group.

There are no difficulties in canal construction for the Main Canal except between K.65 and K.80 where the canal alignment is adjacent or close to the southern slopes of the Qal'at Arang range of hills. The proposed alignment is shown on Figure 3.3. This reach of the canal includes a short length with high command, up to 3.0 metres, at K.67. There is also a two kilometre length in deep cutting between K.73 and K.75 where the maximum depth of cut to bed level is about 20 metres. A considerable part of this excavation is expected to be in hard rock. The channel width is narrowed to eight metres for this deep cutting and the rock excavation is provisionally estimated at 165,000 cubic metres.

CHAPTER 4

DRAINAGE AND ESCAPES

4.1 INTRODUCTION

The Project Area consists of a cracking clay plain with soils which are uniformly of high clay content, mostly in the range 65% to 80%. The soil when wetted becomes very impermeable and so seepage and percolation losses from canals are very low.

The existing depth to groundwater in the Project Area is in the range from 15 - 60 metres and possibly deeper in the south. As seepage losses are so low there is consequently very little danger of a rising water table causing the need for a sub-soil drainage system in the Project Area. Similarly, the irrigation supplies to the fields are planned to be carefully controlled and no surplus irrigation water will percolate to the water table due to the impermeable nature of the soil. There is thus no need for a system of deep drains to be established nor could such drains be effective in such impermeable soils.

4.2 STORM WATER DRAINS

The rainfall in the Project Area is predominantly of thunderstorm type and falls of up to 100 mm. may occur in a single storm. Due to the impermeability of the clay soil heavy rainfall cannot be quickly absorbed and it will therefore pond on the fields and especially on the lower lands in the scheme. Crops in the early stages of growth are liable to be drowned by flooding. In order to prevent this damage to crops occurring, a system of surface drains is included in the layout of the scheme.

The drainage system consists of minor drains which are sited adjacent to each minor canal. Drainage from the fields can pass to the minor drains along the space provided for access roads between each standard 80-feddan plot. The minor drains, (are designed to discharge into larger channels known as major drains) which follow the natural drainage lines. The major drains normally form the irrigation boundary between adjacent major canal systems. As the channels approach the western boundary of the Project Area the natural drainage lines become deeper and in some cases the natural section will be adequate without need of additional excavation. Between the Project boundary and the River Rahad the drainage passes through the "kerrib" which varies in width from 0.5 to 3.0 kilometres.

The gross catchment area served by each drainage channel is determined from the canalization layout plan. The drain capacity is provided according to the relationship

$$Q = 150\ A^{2/3}$$

where Q is discharge in cubic metres per day

A is catchment area in feddans

In this project, as the intensity of rainfall is equivalent to the southern Gezira in the central part of the area and somewhat heavier in the south the drain capacity is computed on the gross catchment area. The capacity of drain for various areas is given in Table 4.1 together with the equivalent run-off in metres per feddan per day.

Table 4.1 Design Capacity of Stormwater Drains

Catchment Area (Feddans)	Drain Capacity (Cumecs)	Equivalent Run-off (M3/Fed./Day)
1,000	0.174	15
2,000	0.270	12
5,000	0.521	9
10,000	0.810	7
50,000	2.315	4
100,000	3.819	3.3

The capacity provided is adequate to drain ten per cent run-off from a 100 mm. storm on 10,000 feddans in six days. In view of the local nature of individual storms, the drains will seldom operate at the design condition. After a heavy storm the water levels may be well above the design for a short period but even during the rainy season there will be many periods when there is no flow in the drains.

The design water level should as far as possible be below ground level. The design water surface slope should be the maximum possible without causing excessive excavation over any reach of the drain.

4.3 PROVISION OF MAJOR AND MINOR DRAINS

As the land surface in the Project Area is generally very uniform with a gentle slope downwards towards the river, it is not considered necessary to construct all the drainage channels for which provision has been made in the layout plan. Where the topography is sufficiently regular to enable the minor canals to be set out so that they do not

cross any low areas then the minor drains need not be excavated. The surface run-off will be able to flow along the drainage line adjacent to the minor canal and then along the major drainage line towards the River Rahad. Nor is it considered necessary to construct the catch drains adjacent to the double watercourses as these channels are only included in the layout when the ground slope exceeds 0.40 metre per kilometre. Thus, there will be no difficulty in obtaining surface run-off along the drainage lines adjacent to these small channels.

It should be stressed that the provision of drainage channels becomes a costly item if these are constructed throughout the Project Area. A large number of surface inlets would be required in addition to road bridges where access is necessary between adjacent canal systems. The drainage channels and structures are expensive to maintain and it is therefore desirable to omit them until the need for a particular channel is proved.

A detailed preliminary layout plan has been prepared for the canalization and drainage of 50,000 feddans which is served by the K. 91.5 Major Canal. The area served by this is in the centre of the Project lands and this layout is considered representative of the Project as a whole. On the basis of this plan we consider that provision should be made in the estimates for construction of major and minor drains as follows:-

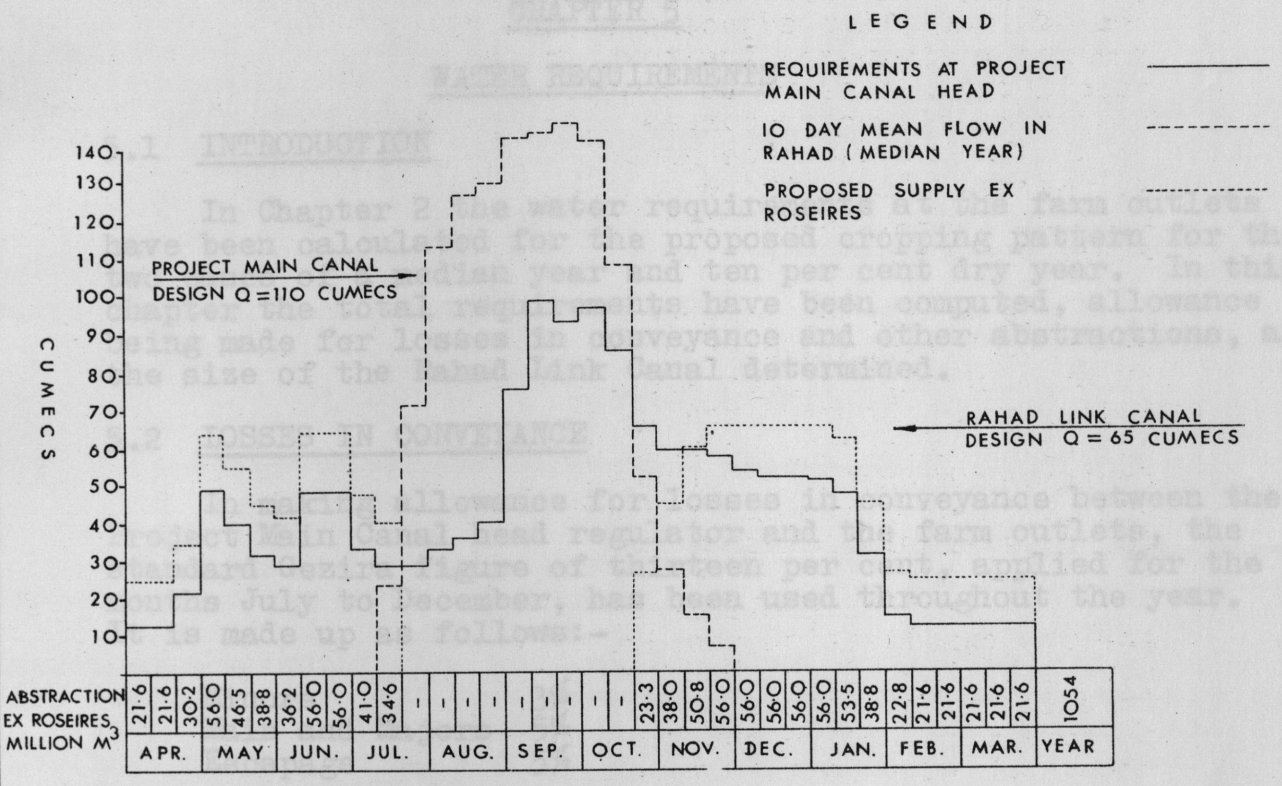
Major Drains - Allow for 33 per cent of total length of Major Canals

Minor Drains - Allow for 20 per cent of total length of Minor Canals

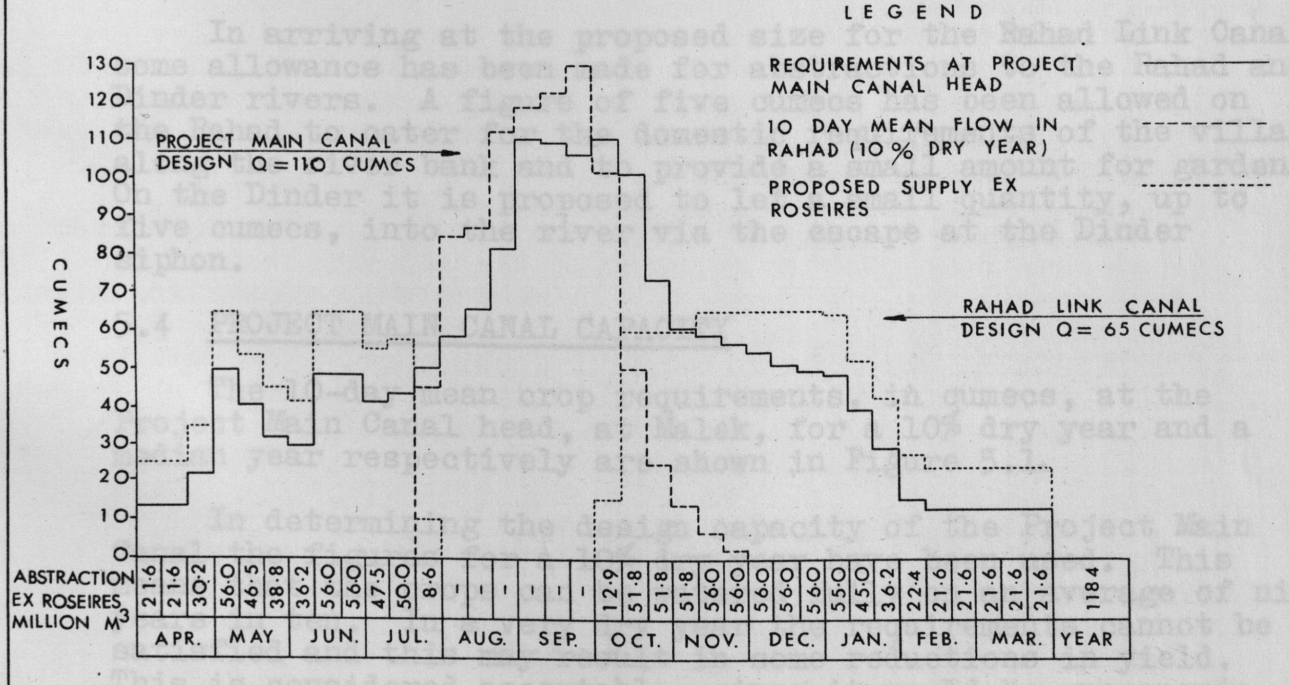
4.4 CANAL ESCAPES

After a heavy rainstorm occurs over the whole or a substantial part of the Project Area, there will be a sudden reduction in irrigation demand for the watering of crops. In order to dispose of the excess water in the Main Canal, three escape channels are provided which lead back to the River Rahad.

These escapes are sited on the main canal at K. 22, K. 75, and K. 150. The escape at K. 22 has a discharging capacity of ten cumecs. The escape channel is about one kilometre in length and discharges into the River Rahad at Tuneidba. The second escape, also of ten cumecs. capacity, is sited on the main canal about midway along the section which is adjacent to the southern side of the Qal'at Arang hills. The escape channel is about 17 kilometres in length and follows the natural drainage line between the K. 57 and the K. 80 major systems. The third escape at K. 150 is near the tail of the main canal and has a capacity of five cumecs. This channel also follows the drainage line between the K. 138 and K. 154 majors and is 12 kilometres in length.



PROPOSED SUPPLY ; MEDIAN YEAR



PROPOSED SUPPLY ; 10 % DRY YEAR

CHAPTER 5

WATER REQUIREMENTS

5.1 INTRODUCTION

In Chapter 2 the water requirements at the farm outlets have been calculated for the proposed cropping pattern for the two cases of a median year and ten per cent dry year. In this chapter the total requirements have been computed, allowance being made for losses in conveyance and other abstractions, and the size of the Rahad Link Canal determined.

5.2 LOSSES IN CONVEYANCE

In making allowance for losses in conveyance between the Project Main Canal head regulator and the farm outlets, the standard Gezira figure of thirteen per cent, applied for the months July to December, has been used throughout the year. It is made up as follows:-

Minors	3%
Main and Majors	5%
Escapage	5%

The suppply route from Roseires reservoir to the Project Area is a very long one, the water being conveyed for 191 kilometres in the Rahad Link Canal, then for 175 kilometres in the Rahad river channel. A factor of 10% has been adopted to allow for seepage, evaporation and escapage losses in this route.

5.3 ABSTRACTIONS TO THE RAHAD AND DINDER

In arriving at the proposed size for the Rahad Link Canal some allowance has been made for abstractions to the Rahad and Dinder rivers. A figure of five cumecs has been allowed on the Rahad to cater for the domestic requirements of the villages along the river bank and to provide a small amount for gardens. On the Dinder it is proposed to let a small quantity, up to five cumecs, into the river via the escape at the Dinder siphon.

5.4 PROJECT MAIN CANAL CAPACITY

The 10-day mean crop requirements, in cumecs, at the Project Main Canal head, at Malek, for a 10% dry year and a median year respectively are shown in Figure 5.1.

In determining the design capacity of the Project Main Canal the figures for a 10% dry year have been used. This means that the crops can be watered fully on an average of nine years in ten. In a very dry year the requirements cannot be satisfied and this may result in some reductions in yield. This is considered acceptable, since it would be uneconomic

to design for a full supply under all conditions.

The peak requirement occurs in September and October and is 110 cumecs. This has been taken as the design capacity of the Project Main Canal and corresponds to a gross crop factor of 22.1 cubic metres per feddan per day on the net cultivable area of 430,000 feddans.

5.5 WATER AVAILABILITY

Water is available from two sources to meet the irrigation requirements:

(a) From the Rahad
(b) From Roseires reservoir

As the Rahad flows during the period from July to November, it is only able to supply a part of the irrigation requirement. The balance has to be brought from Roseires. The 10-day mean flows for median and 10% dry years on the Rahad are shown in Figure 5.2. These have been derived from the gauge records at Abu Haraz, which is the only gauging station on the Rahad where a fairly continuous record of gauging and discharge measurement is available. It has been assumed that the same discharge will be passing Malek, the site of the canal headworks, because there is little spill or inflow between Malek and the confluence.

The ten-day mean discharges in Figure 5.2 have been derived as follows:-

(a) July to October: Based on the records for the period 1922 - 1951 (30 years). Although the gauge was established in 1908 the records prior to 1922 are incomplete and inconsistent, and have been rejected. Since 1951 the gauge has not been read continuously.

(b) November: Based on the records for the period 1937 to 1960 (24 Years). Prior to 1937 the gauge was not always read throughout November. Since 1937 discharges have been recorded for November and December.

In Figure 5.1 the 10% dry year discharges for the River Rahad have been plotted along with the 10% dry year crop requirements for the Project. In making this comparison it has been assumed that a year of low flow coincides with a year of low rainfall, which is an unusual occurrence. The catchment area for the River Rahad is in Ethiopia and there is no reason to assume close correlation between the rainfalls in the catchment and the Rahad Project Area.

Figure 5.1 shows that there will be adequate water in August and September to meet the irrigation requirements, but that there will be a deficit in October, which will have to be met from Roseires. Considering the median year flow, also shown on Figure 5.1, it appears that this will only occur during the last ten days of October.

RIVER RAHAD

TEN DAY DISCHARGES FOR MEDIAN AND 10% DRY YEARS

MONTHS JULY TO OCTOBER : PERIOD 1922 – 1952

MONTH OF NOVEMBER : PERIOD 1937 – 1960

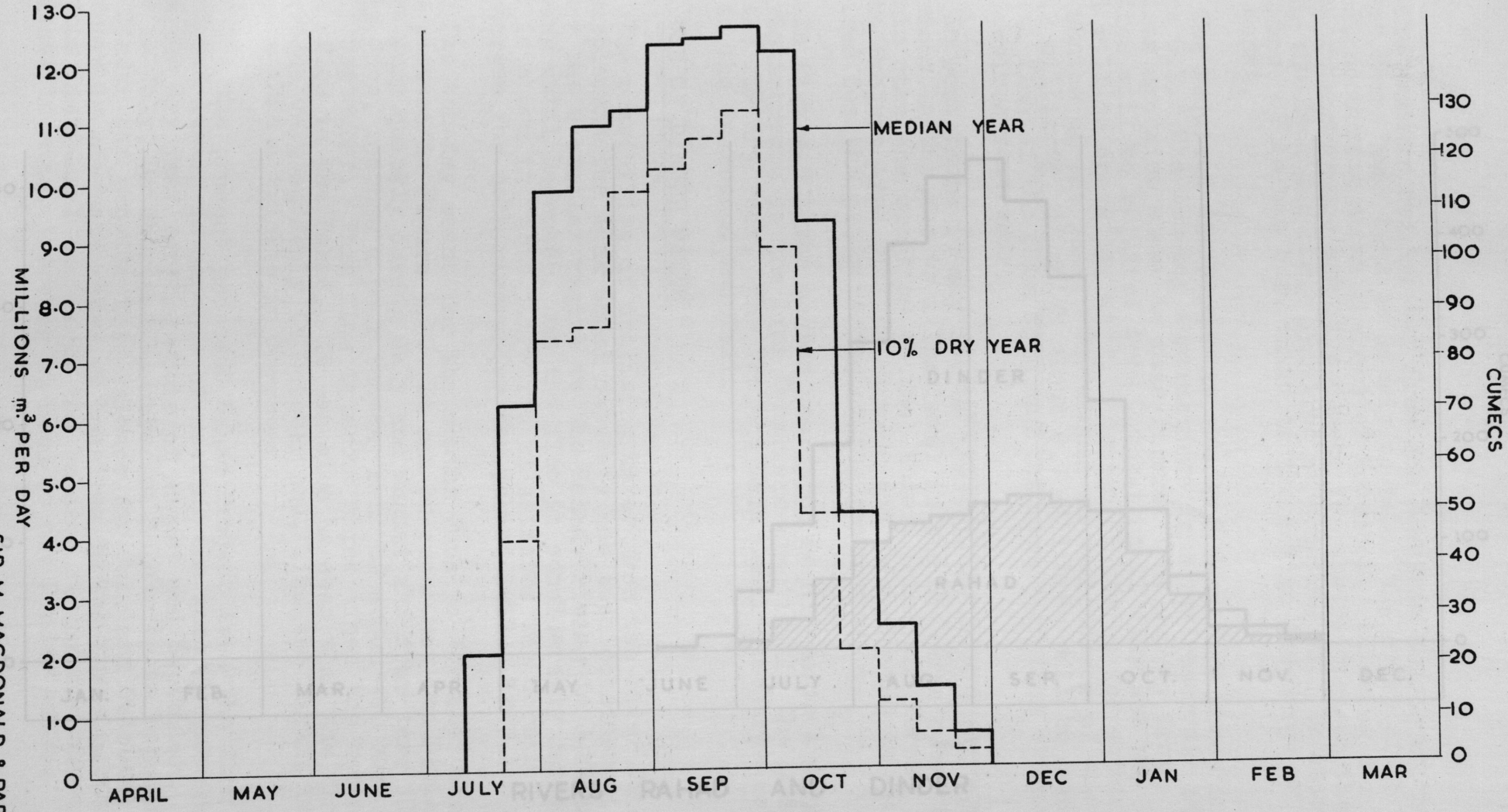


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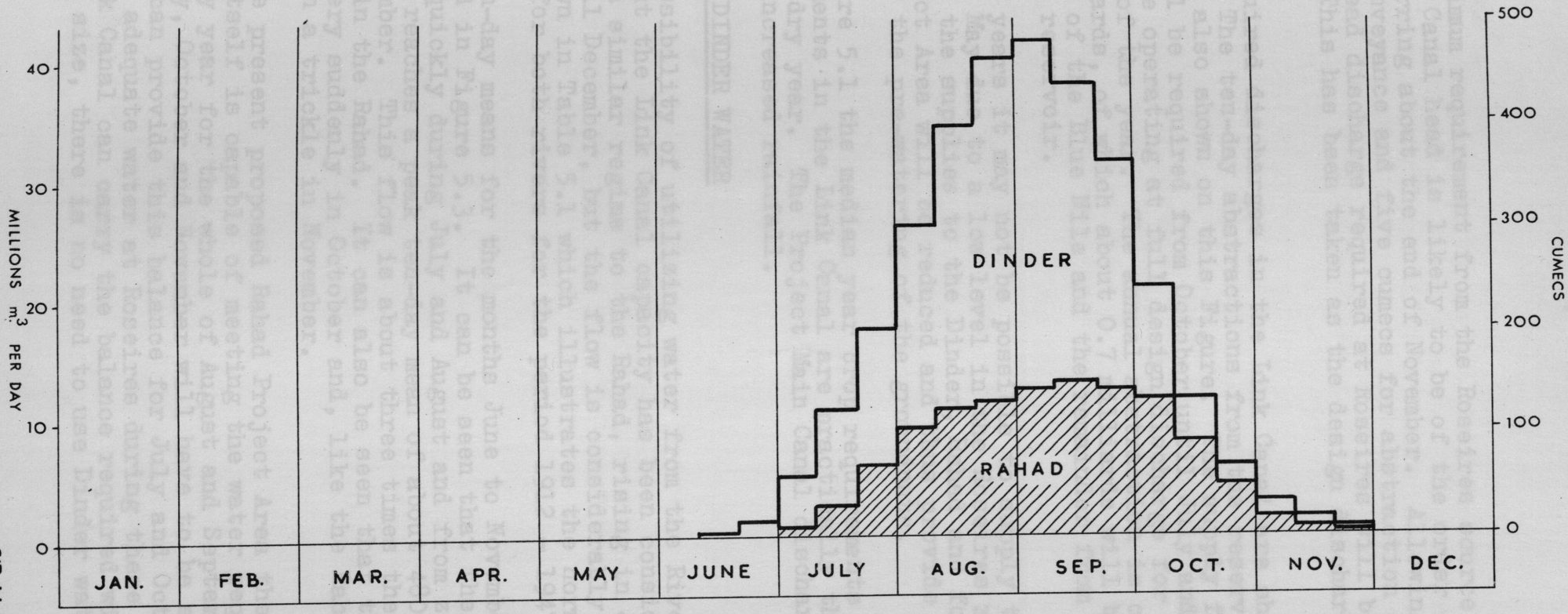
FIGURE 5·2



RIVERS RAHAD AND DINDER

10 DAY NORMAL DISCHARGES FOR THE PERIOD 1912 — 1947

FIGURE 5.3

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The maximum requirement from the Roseires source at the Project Main Canal head is likely to be of the order of 55 cumecs, occurring about the end of November. Allowing for 10% losses in conveyance and five cumecs for abstraction on the Rahad, the head discharge required at Roseires will be about 65 cumecs. This has been taken as the design discharge of the Link Canal.

The required discharges in the Link Canal are shown in Figure 5.1. The ten-day abstractions from the reservoir at Roseires are also shown on this Figure. The supply from Roseires will be required from October until July and the Link Canal will be operating at full design discharge for about four months of the year. The annual abstraction is of the order of 1.2 milliards, of which about 0.7 milliards will be from natural flow of the Blue Nile and the remainder from storage in the Roseires reservoir.

In some years it may not be possible to supply the full 65 cumecs in May due to a low level in the Roseires reservoir. In this case the supplies to the Dinder, Rahad and forest plots in the Project Area will be reduced and thus provide the water required for the pre-watering of the groundnuts.

In Figure 5.1 the median year crop requirements are shown. The requirements in the Link Canal are practically the same as for the 10% dry year. The Project Main Canal discharge is lower due to the increased rainfall.

5.6 USE OF DINDER WATER

The possibility of utilizing water from the River Dinder to supplement the Link Canal capacity has been considered. The Dinder has a similar regime to the Rahad, rising in June and flowing until December, but the flow is considerably larger. This is shown in Table 5.1 which illustrates the normal discharges for both rivers for the period 1912 - 1947.

The ten-day means for the months June to November have been plotted in Figure 5.3. It can be seen that the Dinder rises very quickly during July and August and from zero flow in early June, reaches a peak ten-day mean of about 480 cumecs in early September. This flow is about three times the normal peak flow in the Rahad. It can also be seen that the flow decreases very suddenly in October and, like the Rahad, becomes no more than a trickle in November.

For the present proposed Rahad Project Area the flow in the Rahad itself is capable of meeting the water requirements in a 10% dry year for the whole of August and September. The flow in July, October and November will have to be supplemented. The Dinder can provide this balance for July and October, but, as there is adequate water at Roseires during these periods and the Link Canal can carry the balance required without any increase in size, there is no need to use Dinder water.

If Dinder water were to be used, a barrage would be necessary on the river, but, in view of the remoteness of the site, control would be a major problem, and there is a strong argument in favour of building a siphon, which would be able to operate with the minimum of attention.

Table 5.1: Rivers Rahad and Dinder; Normal discharges for the period 1912-1947

Ten day and monthly means in millions of cubic metres per day.
Totals in millions of cubic metres.

River	Period	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year (Mill. M3)
Rahad	1-10	-	-	-	-	-	0.0	0.8	9.2	12.3	11.4	1.5	0.1	
	11-20	-	-	-	-	-	0.0	2.7	10.6	12.9	7.8	0.7	0.0	
	21-end	-	-	-	-	-	0.1	6.0	11.3	12.4	4.1	0.3	0.0	
	Mean	-	-	-	-	-	-	3.3	10.5	12.5	7.6	0.8	0.1	
	TOTAL	-	-	-	-	-	-	102	324	375	236	25.2	1.9	1,060
Dinder	1-10	-	-	-	-	-	0.1	5.1	26.1	41.3	21.0	2.9	0.3	
	11-20	-	-	-	-	-	0.3	10.7	34.4	37.7	11.4	1.5	0.3	
	21-end	-	-	-	-	-	1.4	17.6	39.8	31.5	6.0	0.7	0.1	
	Mean	-	-	-	-	-	-	11.4	33.6	36.8	12.6	1.6	0.2	
	TOTAL	-	-	-	-	-	-	353	1,040	1,100	390	49.7	7.0	2,960

CHAPTER 6

SUPPLY ROUTES

6.1 ALTERNATIVES CONSIDERED EX SENNAR OR ROSEIRES RESERVOIRS

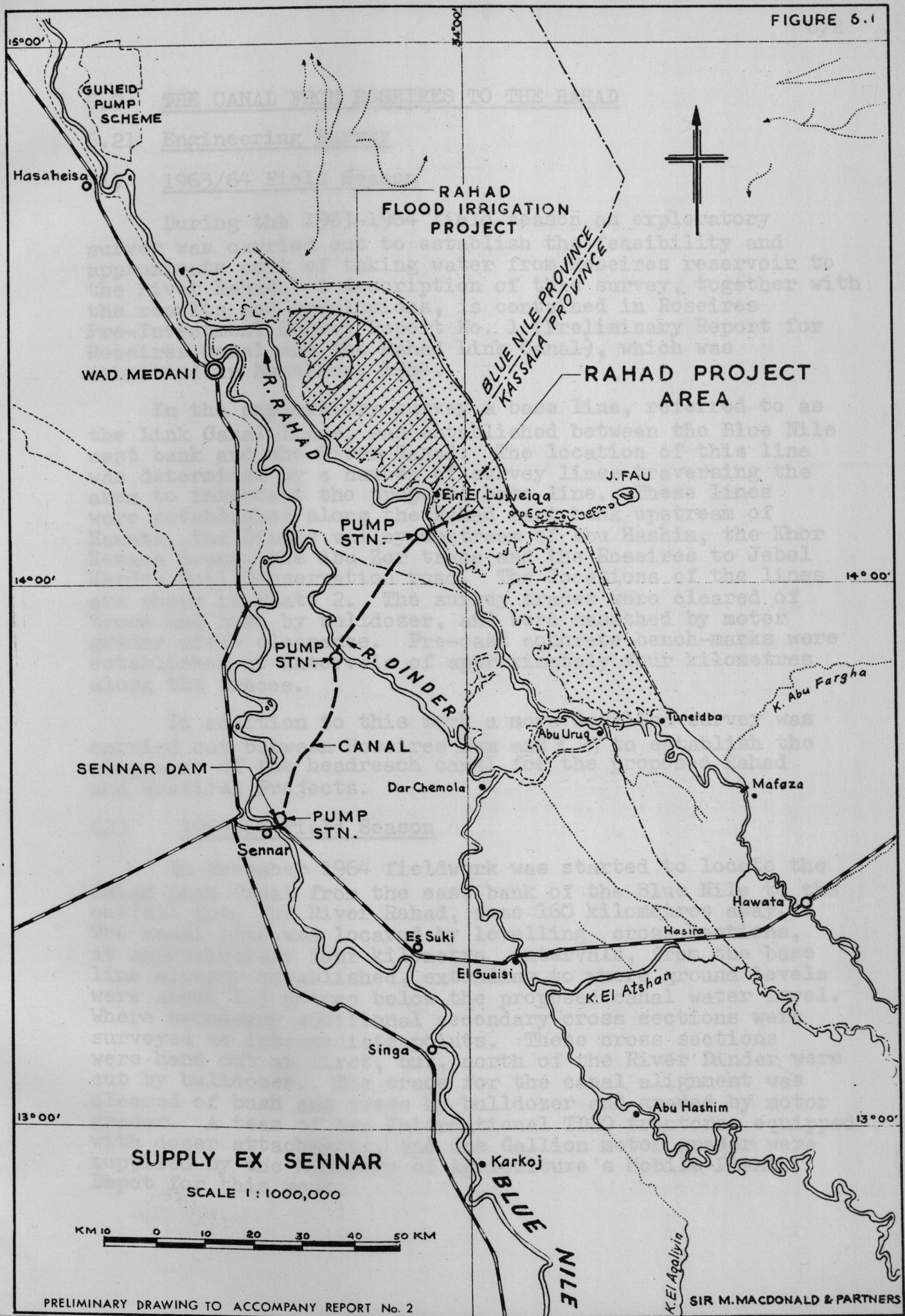
The possibility of obtaining an irrigation supply from the Blue Nile at Sennar was studied for the Rahad Flood Irrigation Project. It was shown to be feasible to provide a pumped irrigation supply from the Sennar reservoir, top water level 421.7 metres, for the proposed 150,000 feddans Project Area, see Figure 6.1, which extends northwards from Kumar Hag es Sid (lat. 14°0 N). To obtain this supply however pumping would be necessary at the Blue Nile and again at the River Rahad. Lifts of 2.5 metres and 5 metres respectively are necessary for the low river condition. Crossings of the Dinder and Rahad would be effected by siphoning the canal underneath these rivers, and it would be preferable to have booster pumps installed at the Dinder to economise on the cost of the siphon. The supply route considered is shown on Figure 6.1.

The possibility of arranging a pumped supply for the full Rahad East Bank Project Area was also studied. It is not possible to command any of the southern part of the Project Area from the supply route shown in Figure 6.1 and it is considered that the 150,000 feddans north of Kumar Hag es Sid is the limit of the area which can be supplied by pumping from the Sennar reservoir.

The alternative method of supply by gravity canal from the Roseires Dam was therefore considered and this supply route has been studied in detail. The route is a long one, the distance from Roseires Dam to the Rahad Barrage at Malek being 366 kilometres. Of this length the first 191 kilometres comprises a carrier canal from the dam to the River Rahad, then the supply is conveyed in the river channel for 175 kilometres to the diversion site at Malek. Between Roseires and the Rahad the carrier canal crosses the River Dinder and the Khor el Atshan, both major crossings which require the canal to be siphoned underneath.

A description of the engineering surveys carried out, the canal alignment and structures which are required for the proposed canal from the Roseires Dam to the Rahad, is given in the next section of this chapter. Following this, section 6.3 deals with the River Rahad as a supply channel from the canal outfall at Wad Miskin to the proposed diversion at Malek 175 kilometres downstream. In the same section the spilling which takes place from the River Rahad is discussed and also the possibility of flood control.

FIGURE 6.1



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6.2 THE CANAL FROM ROSEIRES TO THE RAHAD

6.21 Engineering Survey

(1) 1963/64 Field Season

During the 1963-1964 field season an exploratory survey was carried out to establish the feasibility and approximate cost of taking water from Roseires reservoir to the River Rahad. A description of this survey, together with the results and conclusions, is contained in Roseires Pre-Investment Survey Report No. 1 (Preliminary Report for Roseires Canal and the Rahad Link Canal), which was submitted in November, 1964.

In the exploratory survey a base line, referred to as the Link Canal Trace, was established between the Blue Nile east bank and the River Rahad. The location of this line was determined by a number of survey lines traversing the area to intercept the proposed base line. These lines were established along the Rahad east bank upstream of Hawata, the Dinder valley upstream of Abu Hashim, the Khor Kenana trace, the Abu Zor trace and the Roseires to Jebel Kardos Soil Conservation road. The locations of the lines are shown in Plate 2. The survey traces were cleared of trees and bush by bulldozer, and were smoothed by motor grader after clearance. Pre-cast concrete bench-marks were established at intervals of approximately four kilometres along the traces.

In addition to this work a more detailed survey was carried out between Roseires Dam and K.27 to establish the alignment of the headreach canal for the proposed Rahad and Roseires Projects.

(2) 1964/65 Field Season

In November 1964 fieldwork was started to locate the Rahad Link Canal from the east bank of the Blue Nile to the outfall into the River Rahad, some 160 kilometres away. The canal line was located by levelling cross sections, at approximately four kilometre intervals, from the base line already established, extending to where ground levels were about 1.5 metres below the proposed canal water level. Where necessary additional secondary cross sections were surveyed at intermediate points. These cross sections were hand cut at first, but, north of the River Dinder were cut by bulldozer. The trace for the canal alignment was cleared of bush and trees by bulldozer and graded by motor grader. A team of two International TD20 tractors, equipped with dozer attachments, and one Gallion motor grader were supplied by the Ministry of Agriculture's Mobile Plant Depot for this work.

6.22 Canal Alignment

The canal alignment is shown at scale 1:250,000 in Plate 3 and at scale 1:100,000 in Plates 4,5,6,7 and 8.

From the headworks, located adjacent to the east transitional buttress of the dam, the canal swings eastwards across the "kerrib" lands towards the more uniform clay plain which is reached at K.1.8. Between K.1.8 and K.6.0, where the canal regains low ground again, there is a deep cut of maximum depth 17.5 metres to canal bed level. From K.6.0 to K.10.5 the canal route utilises a trough of low ground, once the former course of a khor, which lies to the east of Roseires town. From K.10.2 the canal again runs in deep cut, fifteen metres to bed level at K.10.6 decreasing to about eight and a half metres at the K.27 regulator group.

It is anticipated that excavation in the headreach of the canal will be in clays with sandy loams in the lower strata. It is likely that should rock be present it will only be as isolated outcrops in the bed of the canal between K.0 and K.12. At K.8, where the canal bed level is about 462.0. outcrops have a reduced level of approximately 464.0.

The regulator group for the bifurcation of the Roseires canal and the Rahad Link Canal has been located at K.27 since this is the most convenient point for the Link Canal to swing eastwards away from the Blue Nile and cross the Khor Aqaliyin and Khor Abu Muhar (see Plates No. 3 & 4).

The size of the khors and depressions which drain the lands between the Blue Nile and the Dinder do not conform with present hydrological conditions and it is likely that they are old river valleys, long since filled by deposits of clay. This is confirmed by the location of lenses of gravel and kanker some five metres below the clay infill at Khor Kenana.

The alignment of the canal between K.27 and Khor Kenana is rather tortuous as a result of the undulating topography. From K.27 the canal is routed to a suitable crossing site on Khor el Aqaliyin near Shamphur village (Plate 5). The flow in Khor el Aqaliyin is estimated to be five cumecs and a combined underpass and inlet structure is planned to cope with this flow.

Five kilometres downstream of the Aqaliyin crossing the canal first gains command when it cuts into a broad depression which drains eastwards to Khor Abu Muhar. The canal follows the southern edge of this low ground for five kilometres before turning southwards towards the Khor Abu Muhar crossing site. The Khor is rather more incised than either Khor el Aqaliyin or Khor Kenana and to limit the canal water level to a maximum command of 2.5 metres above ground level, it has been necessary to divert the canal route five kilometres

south from the original base line.

From here the topography is flat and the canal follows a fairly straight alignment to within one kilometre of the Abu Zor trace (Plate 6). Between this point and Khor Kenana the country is undulating and it was not possible to locate a route to give the optimum excavation without numerous bends, which are not acceptable for a main canal. Between K.93.5 and K.95.5 the canal is in deeper cut where it crosses a ridge of high ground running towards the confluence of the Khor el Aqaliyin and the Khor Kenana.

On the eastern side of the ridge the wide depression associated with Khor Kenana necessitated running the canal southwards for six kilometres so that it could be taken across the depression without excessive command.

From Khor Kenana to the River Dinder the ground slopes are flatter and more uniform, and the canal can be aligned in fairly long straights (Plate 7). The Dinder is reached at K.136.5.

The river is different in character from its lower reaches and is not incised deeply into the clay plain. The section is fairly wide (200m) and shallow (4m) with a sandy bed and a fairly wide meander plain has been formed, which is subject to flooding during high river flow. This meander plain makes it difficult to find a very suitable site for a crossing point. The prime considerations in choosing a site have been to keep the canal water level as near ground level as possible to prevent excessive embankments, and to cross the meander plain in as short a distance as possible. At the site chosen the clay plain extends almost up to the river on the west bank, but on the east the flood plain extends for about two kilometres. The site, although not ideal, is considered to be the best available on this section of the river for the levels required in the canal (see Plate 7).

There are two pronounced meanders upstream of the siphon site, the main river channel, however, appears to be stable with a uniform bed and there is no evidence of excessive scour. At peak flows the flood plain on the right bank is subjected to sheet flooding to a depth of about one metre, and it will be necessary to protect the canal bank from scour. The extent to which flow takes place within the flood plain is difficult to estimate. After the construction of the siphon, the canal bank on the right flank will prevent any of the cross flow in the flood plain, this could increase cross spill parallel to the axis of the canal, which in turn may cut the meander loop immediately upstream of the siphon site and upset the course of the river in this vicinity. In order to counter the possibility of this occurrence we recommend that a small cut-off channel should be excavated across the second

meander loop upstream of the proposed siphon. This channel will help to divert the flood water and may in time divert the main river channel. This measure would tend to stabilise the approach condition upstream of the siphon site and divert the flow away from the canal banks.

During the flood, water is diverted into the khor running parallel to the east bank. A small flood bank at the junction of this khor with the river would shut this off and prevent a by-pass channel forming. No accurate estimate of the flow in the Dinder is possible due to lack of hydrological information. However, a rough estimate, using a water slope determined from the water levels observed on trees, gives a maximum flow of the order of 500 cumecs. This compares with a maximum recorded flow at Hilat Idris gauge, at the confluence with the Blue Nile, of 640 cumecs in 1946, but some of the discrepancy can be attributed to inflow from the Khor el Atshan. Due to the uncertainty of flow in the river, a siphon is considered to be the best type of structure for this crossing. The alternative, a barrage, would, in any case, be much more expensive.

From K.139 the canal is aligned along the edge of the high clay plain for some twelve kilometres before gaining command at K.153. Siting the crossing lower down the Dinder valley would have reduced the volume of cut on the west bank of the Dinder but the meander plain increases in width downstream of the selected site. In following the edge of the clay plain the canal alignment crosses a number of depressions, but, with the exception of the valley at K.140.4, which is a by-pass channel for the River Dinder at high discharges, it seems unlikely that the depressions carry water apart from occasional spilling. The maximum depth of cut between K.139 and K.151 is about 6.5 metres to canal bed level.

From K.152 to the Khor el Atshan crossing at K.177.6 the topography is suitable, although there are several minor undulations with depressions up to one metre below the ground level of plain (see Plate 8). There is a deeper depression at K.153.4 but this is an old valley from the Dinder "kerrib" lands and appears to be above the flood levels. If necessary this depression could be avoided by routing the canal further to the east, although this would increase the earthworks. The selection of a site for the canal crossing at Khor el Atshan was guided by the necessity to choose a location free from sheet flooding and where the flood waters would be concentrated into a single channel. The site selected is one kilometre downstream of the confluence of Khor el Suffera and Khor el Atshan and was first noted during the reconnaissance of the Rahad flooding in October, The command in the canal adjacent to the crossing site is two metres, which is not excessive. The khor itself is a sluggish, meandering channel, with a

grassy bed which is fairly thickly wooded. The width at the crossing point is 100 metres and depth four metres. The maximum flow has been estimated as approximately 70 cumecs, and is discussed in more detail in section 6.35. A siphon is considered to be the best type of structure for this crossing.

Between the Khor el Atshan and the Rahad, the canal has to cross areas which are sometimes subject to flooding, particularly over the first kilometre, where the average depth of flooding is about one metre. At K.188.5 the canal crosses the Wadi Wad Nurein, which drains water back from the Khor el Atshan into the Rahad. The flow in the Khor during the flood, could either be let into the canal at this point, or alternatively, be diverted by digging a channel as shown in Plate 8. The latter solution is considered preferable. The flow in the Khor is indeterminate, and the construction of this diversion channel would probably help to keep the canal bank free of floodwater in this reach.

At K.191 the canal intersects the River Rahad at Wad Miskin.

In choosing a suitable outfall site the following requirements have been considered:-

(a) The canal to have a suitable alignment between Khor el Atshan and the Rahad.

(b) The river to be stable in the vicinity of the outfall.

(c) The site of the outfall structure to be free from flooding.

(d) The ability of the canal to discharge into the Rahad at a river flow of 150 cumecs.

The selected canal alignment has already been described. An alignment further to the south would have involved heavier earthworks and would not have been able to satisfy requirement (d) easily. To the north there is extensive flooding during high river flow, and any economies possible in canal construction would be offset by the increased cost of protection and drainage works.

The river at Wad Miskin is unusual in that there is a long straight reach of about two kilometres. Although this is a little out of character for the Rahad, there is no evidence that the reach is unstable, and the silt berms are well formed. The higher ground on the east bank will probably prevent the river from cutting through from upstream. There may be a tendency, however, for the channel to swing to the right downstream of the outfall, with the Link Canal in operation.

In general the ground levels are 80 cm. to 90 cm. above the 1964 high flood, which are as high as can be expected. The presence of a village and rainland cultivation are also good indications that the site is always free from flooding.

From gauge and discharge measurements taken during the 1964 flood at Wad Abu Nahl, eight kilometres upstream of the proposed site (discussed in section 6.3), it has been estimated that there will be a drop of about 0.8 metres from canal design water level to river water level at a river discharge of 150 cumecs. This is considered satisfactory.

6.23 Canal Design and Levels

Canal dimensions and levels are shown on Plates 3 to 8.

The dimensions are based on a section designed according to revised Lacey regime equations. The design has then been checked and the channel dimensions adjusted so that the required discharge can be passed with Manning's $^{1}/_{n} = 45$. The method used is therefore generally in accordance with the design procedure described by Matthews and Morrice in their note "Investigation of Stable Channels in the Gezira Canalisation Scheme" (S.I.D. Technical Note No. 3/52).

Design water levels for the canal are shown in Table 6.1. below:-

Table 6.1: Rahad Link Canal - Design Water Levels

Km.	Structure	Design Water Level
0	D.S. Headworks	446.50
27	K.27 Regulator Group	(464.37 (464.18
136.5	Dinder Siphon	(454.77 (453.37
177.6	Khor el Atshan Siphon	(449.83 (448.83
191.0	Rahad Outfall	447.69

6.24 Canal Structures

The structures on the canal are as follows:-

i) Headworks; K.0; integral part of Roseires Dam.
ii) Cross regulator; K.27.
iii) Dinder siphon; K.136.5
iv) Khor el Atshan siphon; K.177.6

v) Outfall into the River Rahad at Wad Miskin; K.191
vi) Cross drainage works:
(a) Culverts or siphons; 62 No.
(b) Inlet weirs; 5 No.
vii) 4.0m road bridges; 9 No.
viii) Footbridges; 5 No.
ix) Animal ramps; 19 No.

The regulator group at K.27 is sited at the bifurcation of the Roseires and Rahad Link Canals. A fall of 0.19m has been allowed for from the headreach canal into the Link Canal. An escape, of 10 cumecs capacity, has been provided at this point to discharge into the Blue Nile. Topographically the site presents no problems as the ground is flat. The structure will be founded in medium-coarse sand, which underlies the top layer of clay.

Siphons have been provided at both the Dinder and Khor el Atshan, due mainly to the size of these channels and uncertainty of their capacity. The siphons have been designed for a peak capacity of 83 cumecs. In the case of the Dinder siphon it is necessary to restrict the dimension of the inlet bay to ensure that the velocities in the approach canal at low canal flows do not exceed 1.0 metre per second. An escape of 10 cumecs has been provided at both the Dinder, and the Khor el Atshan. The escapes will discharge water into the river channels during periods of low demand in the Project Area. A 4.0 metre road bridge has been provided at both crossings for access along the canal. Foundations at the Dinder will be in sand and at the Atshan in silty clay, with lenses of sand.

In the estimate a reinforced concrete bridge deck has been provided, with 7.5 metre clear spans resting on 0.5 metre wide reinforced concrete piers founded on the reinforced concrete siphon barrels. Although a certain amount of scour will take place at the piers it is not considered that it will be sufficient to endanger the structure, as the foundation level of the siphon is 4.0 metres below the existing river bed, and, from preliminary information, the maximum velocity in the river will not exceed 1.0 metre per second. The width of the river at this point is more than adequate for the peak floods likely to occur.

The outfall structure into the Rahad at Wad Miskin will take the form of a 3.0 metre regulated fall, the structure being provided with 4.0 metre span lifting gates. A considerable amount of protection will be necessary both downstream of the structure and at the junction with the Rahad to ensure stability under the widely varying conditions of flow to be expected. The foundations of the structure at this site will be in clay.

A large number of cross drainage works are necessary on the canal. The canal is to be siphoned under the two main

obstacles on the route, the River Dinder and the Khor el Atshan, and the remaining cross drainage will either be passed under the canal in siphons or culverts or be let into the canal through surface inlets. The largest of these, at Khor Kenana, will be a 15 cumec capacity siphon passing under the canal with an emergency inflow section and a canal overflow. At the other main cross drainage points, Khor el Aqaliyin, Khor Abu Muhar and K.140.5 on the Dinder east bank, 6 cumec culverts have been provided under the canal, supplemented by emergency inflow and overflow structures.

On the alignment there are five surface inlets which will discharge surface run-off into the canal by means of a weir and culvert.

Culverts have been provided at all other cross drainage points and, in addition, a nominal number has been allowed for on other reaches of the canal.

4.0 metre roadbridges have been provided on all major existing routes crossing the canal line and at intermediate points such that there is a bridge at approximately 20 kilometre intervals. This is particularly important between K.27 and the Dinder, where crossings are required for animal migration to and from the Game Reserve.

6.3 THE RIVER RAHAD

The supply route from Roseires dam to the Rahad Irrigation Project utilises some 175 kilometres of the Rahad channel from the Link Canal outfall at Wad Miskin to Malek barrage where the headworks for the Project Main Canal are located.

The alternative of extending the Link Canal for 80 kilometres along either the left or right bank does not present an easier solution since a left bank route would cross extensive areas subject to flooding and a right bank routed requires a suitable structure to cross the Rahad and then would be in cut for some distance downstream.

The purpose of the Rahad spill studies was to examine the Rahad channel under flood conditions between the Link Canal outfall and Malek barrage and investigate whether the Rahad would convey the maximum demand required for the Rahad Irrigation Project.

A general picture of the Rahad floods was obtained from a flight along the Rahad and Dinder valleys on October 5th, 1964, just four days after the peak discharge in the Rahad had passed Mafaza gauge. This was followed up by a series of discharge measurements during October at Mafaza and Wad Abu Nahl and observations of water surface slopes between Wad Abu Nahl and Tuneidba (see Plate 1).

General enquiries and reconnaissance levelling were carried out in the spill areas during February and March, 1965.

6.31 Description of the River Rahad

The source of the Rahad is twenty kilometres to the north-west of Laka Tana. The river flows westwards to cross into the Sudan at Fadl Ingliz, 150 kilometres southwest of El Hawata. The principal catchment areas are in the uplands of Ethiopia, the only tributaries in the Sudan being Khor Sim Sim and Khor Abu Fargha which carry spates after heavy rains and do not make any appreciable contribution to the flow in the Rahad.

The Rahad channel is generally between 40 and 50 metres wide and when full, is nearly six metres deep. The river carries a high silt load and has formed a well-defined meander pattern along the whole length of its course. From the Ethiopian frontier the river slope is fairly constant at 10 to 12 cms. per kilometre with the channel below the general country level in its upper reaches. Downstream of Mafaza, where retrogression from the Blue Nile valley has cut down the bed level of the channel the valley is more marked with a strip of eroded gullied lands on each side of the river. The river flows generally parallel to the contours in a north-westerly direction and not down the steepest slope as might be expected.

The lower level of the clay plain on the left bank of the Rahad has resulted in extensive spilling towards the River Dinder over a distance of 160 kilometres from the Game Reserve boundary to Abu Uruq (Plate 1); however a lowering of the channel bed level, together with the increase in spilling from the upstream reaches, means that there is now no spill north of Hawata.

From Hawata to the south, as far as the Game Reserve boundary, the Khor el Atshan has developed as a collector channel for the numerous spill areas and khors which run westwards from the Rahad. The reason for the khor developing in this way is not altogether clear, but it may, at one time, have been a course of the Rahad which has silted heavily in the upper reaches and resulted in the Rahad waters forming a new channel along the lowerreaches of Khor Sim Sim, in the same manner as the cut-off channel between Malek and Tuneidba developed along the lower reaches of Khor Abu Fargha.

6.32 Existing Hydrological Data

There are three gauges on the River Rahad which are observed at regular intervals. These are sited at Abu Haraz, immediately upstream of the Blue Nile confluence, at Mafaza some 256 kilometres upstream and at Matama in Ethiopia. In addition to these gauges, a gauge was established in June 1964 at Wad Abu Nahl, some 50 kilometres south of El Hawata, and eight kilometres upstream of the outfall of

the canal from Roseires. The gauges at Abu Haraz and Mafaza have been in existence for more than 50 years; the Matama gauge was only established in 1962.

The Abu Haraz gauge is close to the Blue Nile confluence, and at higher discharges of the Blue Nile, is affected by the backwater so that it is not possible to construct a reliable stage discharge curve.

The river channel at Mafaza has been subject to considerable retrogression following the formation of a by-pass channel between Malek and Tuneidba. However, the retrogression taking place at present is very small and the stage discharge relationship for Mafaza gauge is probably now stabilised.

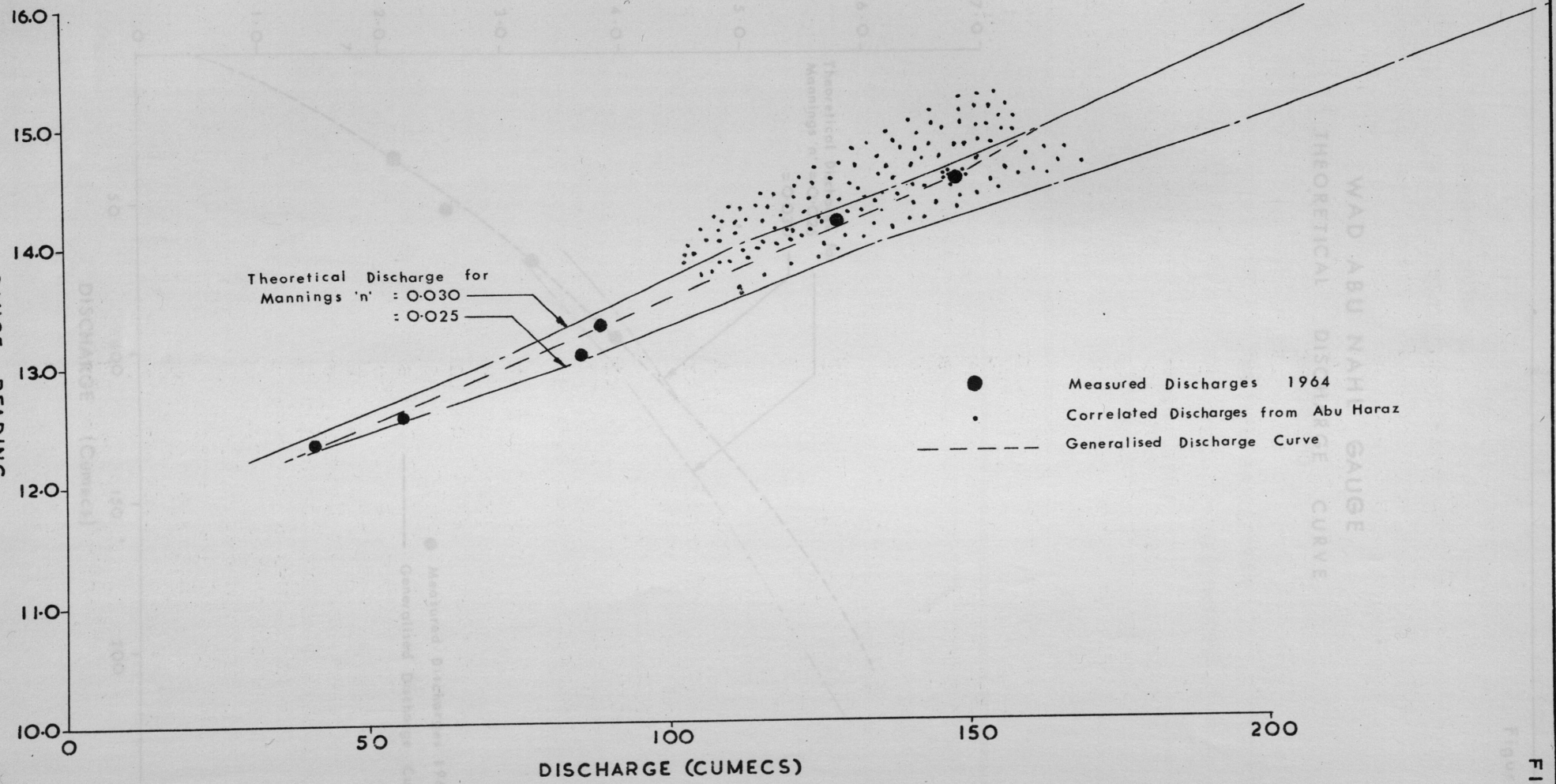
In October 1964, as part of the reconnaissance for the study of the Rahad flooding, a series of discharge measurements was made at Malek, four kilometres downstream of Mafaza, and from these measurements, together with a correlation of the discharge measurements at Abu Haraz between 1945 and 1964, a stage discharge curve has been produced for Mafaza, as shown in Figure 6.2. It should be noted that the measurements at Abu Haraz have not been adjusted for run-off between Mafaza and Abu Harez nor has any differentiation been made between a rising or falling river.

The gauge at Wad Abu Nahl was established in order to obtain information regarding water levels and discharges in the Rahad in the region where the outfall of the Rahad Link Canal might be located. The gauge was read from the beginning of the 1964 river flow and, from discharge measurements taken in October, an approximate stage discharge relationship was obtained and is shown in Figure 6.3.

The lack of long-term discharge records of the Rahad and the complexity of the spill areas and channels make it an impossible task to define the precise mechanism of spilling. The river usually begins to flow in late June, building up rapidly in July before a more gradual rise to a peak discharge in the second half of September. The discharge falls rapidly in October and the flow very rarely lasts beyond December. At Matama, peak discharges as high as 650 cumecs have been recorded but these were of very short duration and the mean maximum discharge is of the order of 350 cumecs. This corresponds to an estimated discharge at Wad Abu Nahl of 260 cumecs, whilst the maximum discharge at Mafaza does not exceed 180 cumecs. A small proportion of these losses can be accounted for in damping due to valley storage but much of the water must be lost to the spill areas and channels.

6.33 Capacity of Rahad Channel

The determination of the safe carrying capacity of the



MAFAZA GAUGE
STAGE DISCHARGE CURVE

FIGURE 6·2

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Figure 6·3

WAD ABU NAHL GAUGE
THEORETICAL DISCHARGE CURVE

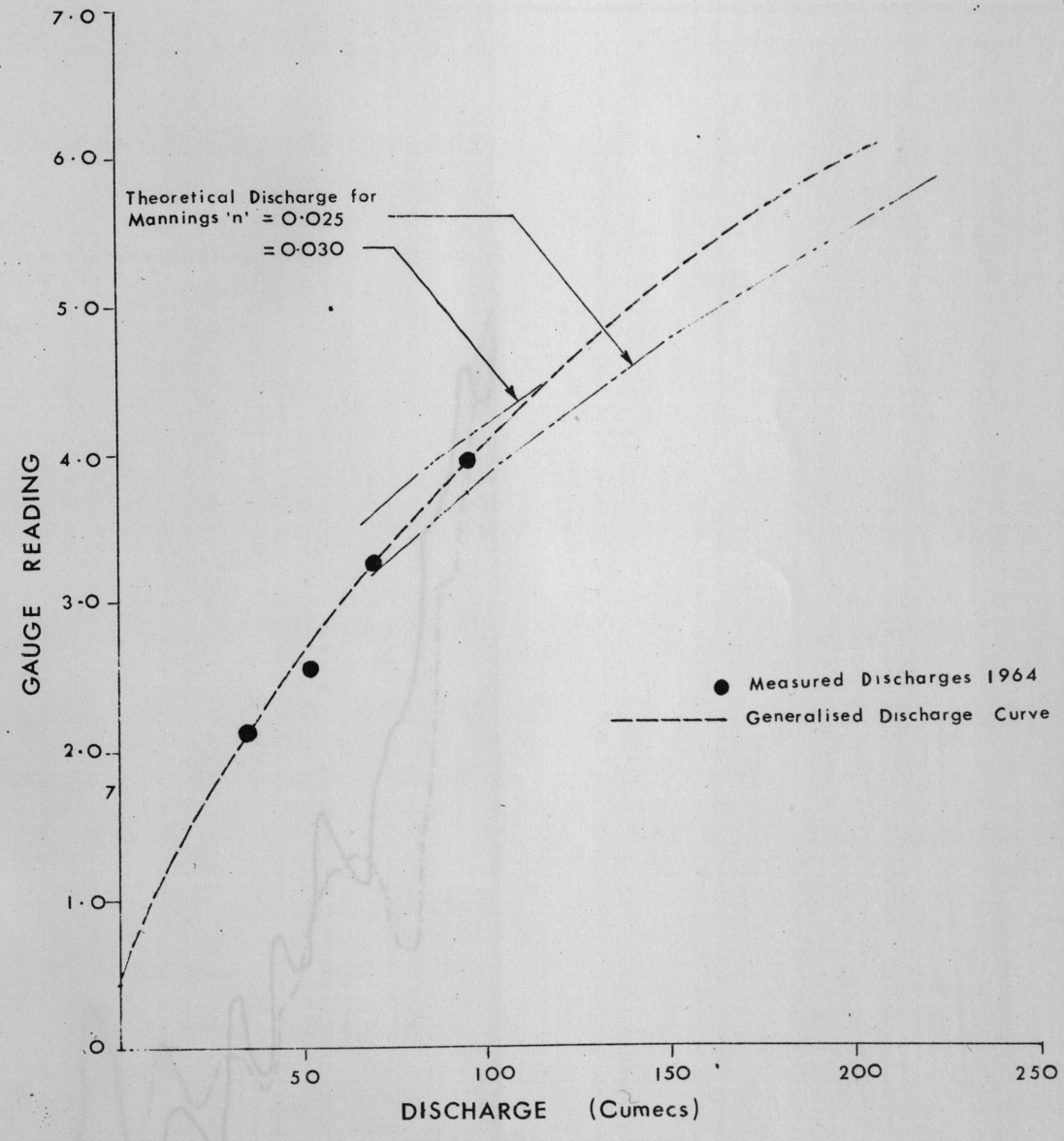
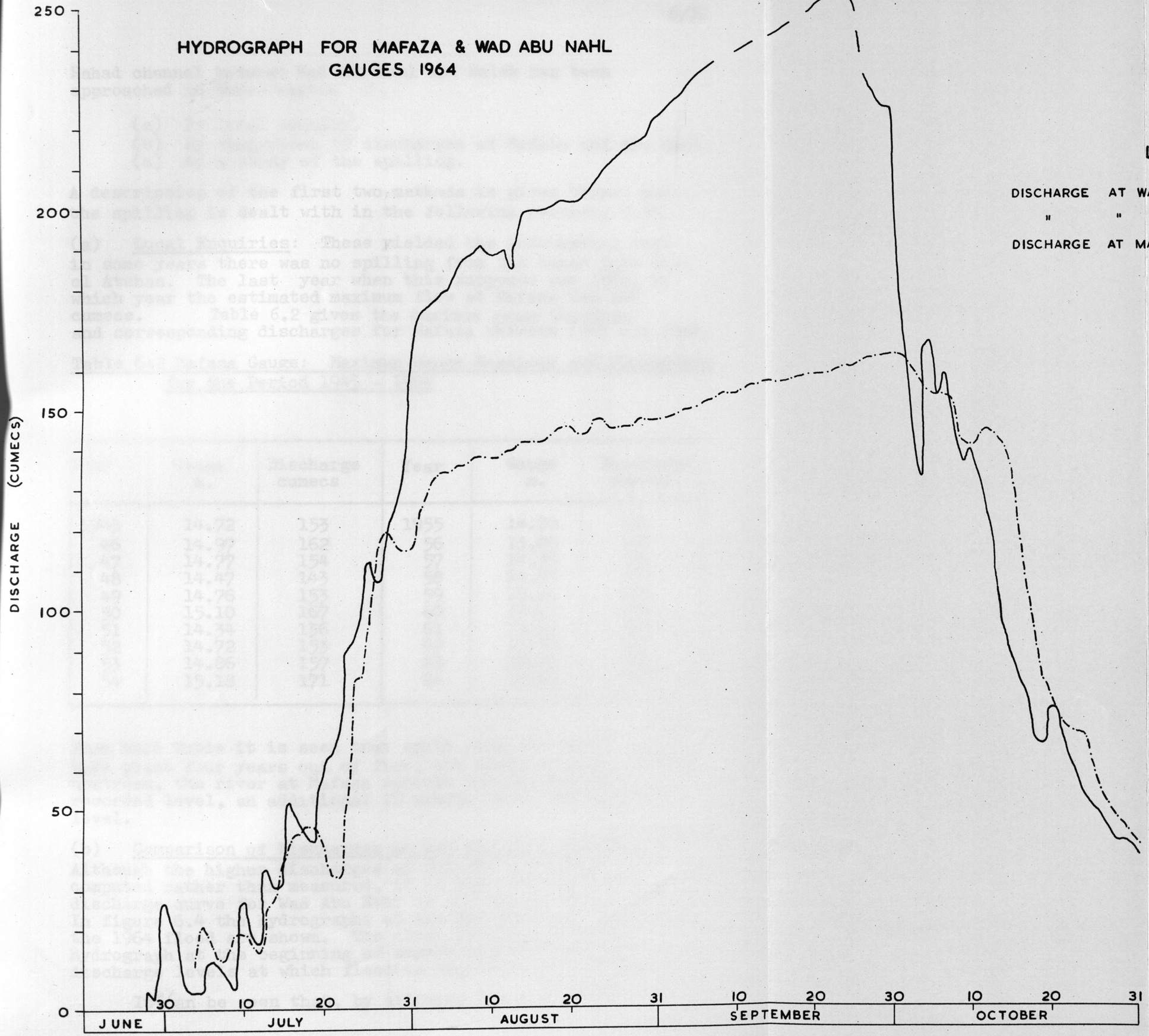


FIGURE 6·4

HYDROGRAPH FOR MAFAZA & WAD ABU NAHL GAUGES 1964



LEGEND

DISCHARGE AT WAD ABU NAHL, 1964 ——————

" " " " " (ESTIMATED) — — —

DISCHARGE AT MAFAZA, 1964 —·—·—·—

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Rahad channel between Wad Abu Nahl and Malek has been approached in three ways:-

(a) By local enquiry.
(b) By comparison of discharges at Mafaza and Abu Nahl.
(c) By a study of the spilling.

A description of the first two methods is given below, and the spilling is dealt with in the following section, 6.34.

(a) Local Enquiries: These yielded the information that in some years there was no spilling from the Rahad into Khor el Atshan. The last year when this happened was 1960, in which year the estimated maximum flow at Mafaza was 148 cumecs. Table 6.2 gives the maximum gauge readings and corresponding discharges for Mafaza between 1945 and 1964.

Table 6:2 Mafaza Gauge: Maximum Gauge Readings and Discharges for the Period 1945 - 1964

Year	Gauge m.	Discharge cumecs	Year	Gauge m.	Discharge cumecs
1945	14.72	153	1955	14.80	155
46	14.97	162	56	15.09	167
47	14.77	154	57	14.39	138
48	14.47	143	58	14.85	157
49	14.76	153	59	15.24	174
50	15.10	167	60	14.62	148
51	14.34	136	61	15.13	168
52	14.72	153	62	15.00	163
53	14.86	157	63	14.75	153
54	15.18	171	64	15.02	163

From this table it is seen that spill from the Rahad could take place four years out of five, but that, despite spilling upstream, the river at Mafaza conveys for the maximum recorded level, an additional 25 cumecs above the spilling level.

(b) Comparison of Discharges at Wad Abu Nahl and Mafaza: Although the higher discharges at Wad Abu Nahl have been computed rather than measured, it is expected that the discharge curve for Wad Abu Nahl is correct to within 10%. In figure 6.4 the hydrographs at Wad Abu Nahl and Mafaza for the 1964 flood are shown. The clear divergence of the hydrograph at the beginning of August demonstrates the discharge levels at which flooding begins to take place.

It can be seen that, by allowing for a three-day time

lag from Wad Abu Nahl to Mafaza, the initial divergence point occurs at 135 cumecs, when the mayas and meanders begin to fill, and by 140 cumecs the divergence is well defined. The initial level at which spilling of the Rahad takes place towards Khor el Atshan corresponds to a reduced water surface level at Wad Abu Nahl of 447.2 metres.

6.34 River Rahad Spillways

Field studies have been restricted to the sector of the Rahad between the Link Canal outfall and Malek. From reports that Khor el Atshan normally flowed before Khor Abu Shawish it appears almost certain that spilling upstream of Wad Miskin occurs at discharges above the discharge levels which cause spilling below Wad Miskin. A length of at least 40 kilometres between Wad Miskin and El Hawata requires study. Since spilling often takes place from old cut-off channels and mayas rather than directly from the river, the effective width of the "river channel" from which spilling may occur could be as much as two kilometres. Moreover, the area is inaccessible during the rainy season and for the rest of the year movement is hampered by heavy bush and thick acacia forests. The fieldwork was therefore limited to opening up and levelling of a trace along the Rahad west bank together with the survey of a number of cross-sections of the river channel between Wad Miskin and El Hawata. The locations of the survey lines are shown on Plates 9 and 10.

From the ground survey the areas subject to flooding have been placed into three groups:-

(a) From Wad Miskin to El Greigrib (Plate 9). This area is generally known as Mayaat Keisalu, although the name Keisalu is applied locally to old river cut-offs at Hillet Omer and El Greigrib. Floodwaters spill from the old cut-off channels, and also, to a lesser degree, from the tail of Wadi Wad Nurein, and flow westwards to form Khor Id El Tamar which runs parallel to the graded road from El Greigrib towards Abu Hashim. The confluence of Id el Tamar with the Atshan is near Aboda village. The road from El Greigrib to Aboda is aligned along high ground between the Rahad and the Khor el Atshan which forms an effective barrier to flood waters moving parallel to the Rahad.

(b) The second spill area is that which covers spill draining into Khor Abu Shawish (Plate 9). The flooding begins below Wad Gamzuz and is continuous for 16 kilometres as far north as Kataku. The flood waters immediately downstream of Wad Gamzuz drain into a Khor known as Id El Joda, which conveys water parallel to the Rahad for eight kilometres before joining Khor Abu Shawish which flows westwards from an extensive spill area situated around the large river loop near Meshra el Medeika. It also appears that Khor Abu Shawish receives water flowing

southwards from spill at Kataku along Wadi esh Sherif, although flooding at Kataku also contributes to sheet flooding in Mayat Umm Kogra. From latitude 13° 17 N, Khor Abu Shawish becomes more incised into the clay plain and flows westwards for 25 kilometres to join Khor el Atshan near Wad Kabusa.

(c) The northern spill area differs from the other two in that the floodwaters also drain back to the Rahad. The spilling takes place mainly between Kataku (Plate 10), Es Sharma and Meshra Deilagu, with the spill draining into a well-defined Khor near Es Sharma which rejoins the River Rahad at Jarmai, although it does appear that some of this water moves westwards into Mayat Umm Kogra. A small volume of water moves northwards from Umm Kogra across the railway some seven kilometres from Hawata but, except in years of very high flood, this volume of water is very small.

From Wad es Shair northwards, although the country is broken up by old spill channels, the spilling now appears to be negligible and the large number of villages with extensive rainland cultivation confirm this assumption.

The conclusions drawn from the ground survey are that ground levels fall away very rapidly from the river banks. often at slopes steeper than one metre per kilometre, but away from the river the general ground slopes are 30 -40 cms. per kilometre. However, the bed levels of khors and depressions are often two to three metres below high river levels at distances of only a kilometre or two away from the river. The fact that the spill waters have not eroded the river banks down to the levels of the khors may be due to the resistance to erosion of the clay soils and that silt berms are being deposited close to the river banks. Also, with the floodwaters often flowing parallel to the river for some distance, the water surface slopes are less than the ground slopes from the Rahad towards Khor el Atshan.

6.35 River Rahad Flood Control

At present the Rahad flood affects approximately 150,000 feddans along the west bank of the Rahad together with a few small areas on the east bank. The area affected is almost all between El Hawata and the boundary of the Game Reserve, some eighty kilometres away. Whilst the flooding is a serious handicap to development of lands along the west bank south of the railway, the floodwaters are essential to the growth of sunt (acacia arabica) forests and provide useful pasture lands as the floodwaters subside.

For the proposed peak water demand of 110 cumecs for the Rahad Irrigation Project, of 430,000 feddans, the river channel between Wad Miskin and Malek can carry the required discharge without spilling, and it is also probable that the channel can carry the water required for the Guneid Extension area. Further study is needed to assess the actual

capacity and the ability to serve areas additional to those mentioned above. These investigations should consider the alternative of construction of levees for the river or a feeder canal for the alternative supplies. Whilst the Rahad channel at Mafaza will carry 175 cumecs or more without spilling in that sector, the Wad Miskin - Hawata channel cannot pass this discharge without widespread flooding. The construction of levees would stop the natural spilling, which is to some extent beneficial, in the area south of Hawata. Flood storage reservoirs cannot be provided because there are no suitable sites.

The improvement of the river channel to carry peak floods would be very costly, requiring a 300 cumec channel for 100 kilometres. The most suitable arrangement for flood control would appear to be the use of Khor el Atshan as a flood spillway. From studies for the Link Canal crossing site on the Atshan it seems unlikely that the khor will now carry much more than the estimated 1964 flow of 70 cumecs. Allowing for storage in the upper Atshan depressions the 70 cumec flow at the crossing site agrees fairly well with the difference between the average high flow at Matama of 350 cumecs and the 260 cumecs estimated as the approximate peak discharge at Wad Abu Nahl, although further downstream the khor is incised well below the level of the clay plain and it is probable that these lower reaches have adequate capacity to act as a flood spillway.

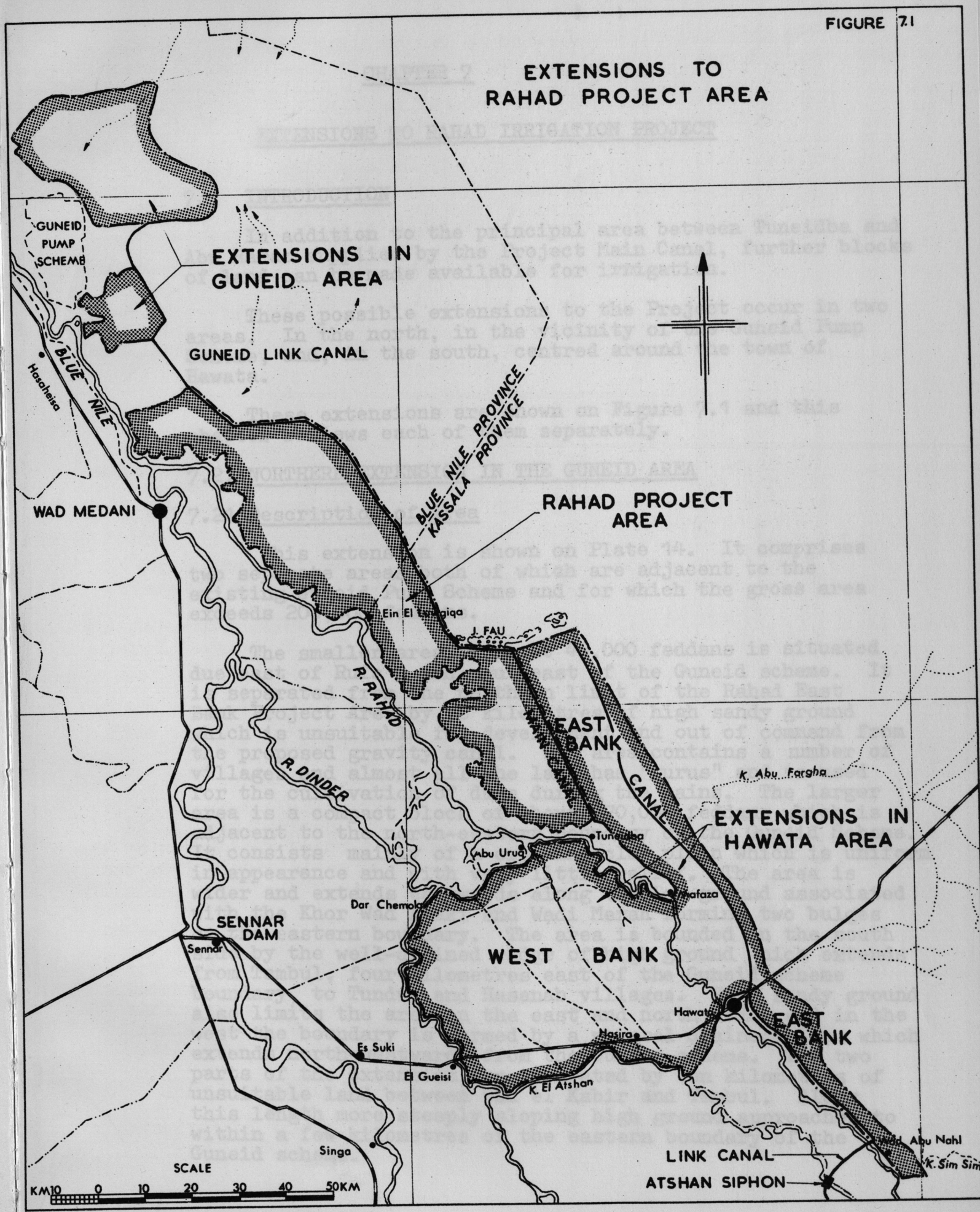
6.36 Conclusions

The safe capacity of the River Rahad channel between Wad Miskin and Malek is in the range 135 - 140 cumecs. Above this level, considerable spilling takes place towards Khor el Atshan.

For the present development envisaged for the Rahad Irrigation Project this capacity is adequate. There does not appear to be any possibility of increasing the safe capacity of the channel by the construction of levees without destroying the natural protection afforded to lands north of Hawata by means of the present spilling.

Subject to further investigation, a suitable form of flood control of the River Rahad would appear to be the construction of a flood relief channel located near El Greigrib from the Rahad to Khor el Atshan. The construction of a relief channel will not, however, be necessary until such time as development is considered for the areas south of El Hawata which are now affected by flooding.

FIGURE 7.1



PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

On Plate 14 the results of the semi-detailed soil survey carried out during 1963/64 are shown. The land classification covers 18,000 feddans in the southern and 78,000 feddans in the northern area. Of these areas 16,000 and 68,000 feddans in the southern and northern areas were classified as usable irrigable lands (Class 2, 3 and 4 lands). The remainder of the extension areas, 27,000 and 93,000 feddans respectively in south and north are being covered by semi-detailed soil survey which started in April 1965 and will be completed after the commencement of the 1965/66 season in October 1965.

Assuming that the additional area surveyed is not greatly inferior to the parts for which the results are already available the gross area of usable irrigable land in the extension will be of the order of 150,000 feddans. This is expected to provide a project extension covering about 120,000 feddans net cultivable area.

7.22 EXPLORATORY ENGINEERING SURVEY

To demarcate the extent of any suitable land to the northeast of the Guneid Pump Scheme, a number of reconnaissance sections were surveyed, using as a starting point the Bench Mark No. 6 established by the Sudan Surveys Department near the village of Haddaf.

These lines of levels extended northwards through Abu Sham to Abu Horira and to Hasanab and El Hawalda in the east.

In addition, the data from a line of levelling carried out in 1962 by the Ministry of Irrigation and H.E.P. between Tambul, Tundub and Abu Sham was available.

The extent of the levelling is shown on Plate 14 on which are also plotted five metre contours as deduced from this work and also from a previous contour plan prepared by the Sudan Survey Department.

In determining the extent of any possible extension southeast of the Guneid Pump Scheme it was decided to use the reconnaissance contours already available which were drawn by the Sudan Survey Department. Consequently no additional survey was carried out in this area.

To check the proposed route of the link canal which takes off the Project main canal at K. 162, near Wad Harras lat. 14° 37'N long 33°37'E, levelling along the alignment was done for about sixteen kilometres to reach the southern extension near Rufa'a. Sections were taken at each kilometre to ensure that the line followed was the most economical. The longitudinal section obtained from this field work is shown on Plate 14A.

7.23 POSSIBILITY OF GRAVITY SUPPLY TO GUNEID SUGAR SCHEME

At the present time the Guneid Sugar Scheme is irrigated by pumping from the Blue Nile. The two pump stations are

located near the village of Guneid at the south-western corner of the scheme. One pump station built in 1954, comprises four diesel powered units and the other, built in 1962, three electric units. If a gravity water supply can be made available to the scheme from the canal built to supply the Guneid extensions a considerable reduction in the yearly operating expenses can be effected.

The total area of the scheme, including the planned extension which is not yet completed, is 53,000 feddans with a net cultivable area of about 43,000 feddans. During the year ending March 31st 1965, the net cultivable area was 36,000 feddans and the area cropped was reported to comprise:-

Sugar	18,847	feddans
Groundnuts Other crops (Lubia)	3,000	"
Total	21,847	feddans

The water pumped during the period April 1st, 1964, to March 31st, 1965, inclusive is summarised in Table 7.1.

It is considered that a supply canal with a capacity of 18 cumecs would be adequate to meet the requirements of the Guneid Sugar Scheme. This canal could be built taking off the canal serving the other extensions in the Guneid area, and joining the existing pump canal in its head reach.

Table 7.1: Ten-day Mean and Monthly Totals of Water Pumped - Period April 1964 - March 1965

Period	Water Pumped to Canal Head Ten Day Means - cumecs Monthly Totals - Million Cubic Metres											
	Apr. 64	May 64	June 64	July 64	Aug. 64	Sept. 64	Oct. 64	Nov. 64	Dec. 64	Jan. 65	Feb. 65	Mar. 65
1-10	5.2	7.3	7.2	5.7	1.3	1.5	8.0	6.2	6.1	4.3	3.6	6.5
11-20	4.4	7.4	7.4	2.5	1.3	5.2	8.5	7.9	5.8	4.4	5.3	6.4
21-end	5.0	6.7	6.7	1.4	0.1	8.1	4.3	7.5	4.5	4.8	5.6	6.4
Monthly Totals	12.6	18.5	18.4	8.3	2.3	12.8	18.0	18.7	14.2	11.7	12.5	16.7

Note: During the period 21/31 October 1964 pumping did not take place on the 29th or 30th.

7.24 Irrigation Supply Route to Guneid

The canal to supply the extensions in the Guneid Area takes off the Rahad Project Main Canal at K. 162 just north

of Wad Harras, lat. 14° 37'N long. 33° 37'E. The intial section of the canal known as the Guneid Link Canal is sixteen kilometres long. The route traverses an area of cracking clay with occasional areas of sandy loam.

A sketch map of the link canal route and a longitudinal section are given on Plate 14A. The maximum cut at K. 9.2 on the link canal is approximately eleven metres. It is considered unlikely that much rock will be encountered in the excavation of the link canal.

From K.16 (water level 413.2) near the village of El La'ota, the supply canal follows the eastern perimeter of the southern Guneid extension, then the ridge of high ground, northward to the vicinity of Tambul (water level 410.7). Still following the high ground, the alignment here turns east to Tundub and Hasanab, proceeding thence around the boundary of the northern extension to Borida, Abu Sham and finally Abu Horira in the north (water level 405.0).

Between El La'ota and Tundub, e.g. where the alignment follows the top of the ridge, small isolated rock outcrops must be expected. These consist of soft or fragmented sandstones, of the type visible near the road south of Tambul village and which is excavated by hand for building purposes by the local inhabitants.

The total length of the canal from Wad Harras to Abu Horira is approximately 98 kilometres.

7.3 SOUTHERN EXTENSIONS IN THE HAWATA AREA

7.31 Description of East Bank Area

The land demarcated on the east bank of the River Rahad and shown on Plate 15 comprises two separate schemes:

1). An area of 240,000 feddans which can be commanded by a gravity canal on the east bank flowing from Wad Miskin to Jebel el Fau.

2). An area of 110,000 feddans between Wad Miskin and the Sennar-Gedaref railway line commanded by pumping water from the east bank canal.

The area south of Hawata which would be commanded by gravity is of little value, being a strip no more than five kms. wide and adjacent to the River Rahad. This land is undulating and dissected by numerous drainage channels and much of it is subject to periodic flooding from the Rahad. Considerable areas of Forest Reserve have been established between the road and the river and a pump scheme of 700 feddans is in existence five kilometres south of Hawata. For these reasons, this land cannot be considered for development. In order to facilitate development south of Hawata the pumping of

water from the east bank canal near Wad Miskin (water surface level 447.0) to the level of the 455.0 metre contour is considered to be feasible. The gross area commanded by pumping is estimated at 110,000 feddans.

North of the railway line, between Hawata and Jebel el Fau, the gravity canal can command a strip of suitable land generally about thirteen kilometres wide. This land is bounded on the west, between Hawata and Malek by the River Rahad and thence to Jebel el Fau by the East Bank Project Main Canal. The commanded area of 240,000 feddans is at present sparsely populated especially north of Tuneidba. It appears to be ideal for development as it slopes gently towards the river and is generally thinly vegetated. On Plate 15 the extent of the soil survey carried out during 1963/64 is shown and this covers part of the proposed extension area. The results of the soil survey classified the area as arable, mainly Class 2 and Class 3 lands, consisting of a cracking clay plain.

Much of the area between the River Rahad and the Hawata - Mafaza road cannot be considered for development as it is undulating and part has already been developed privately by pumping from the Rahad. The land to the west of the Project Main Canal between the Malek Barrage and Tuneidba has also been excluded.

Hawata, with its railway access, is the main centre on the Rahad east bank and would, with the development of the area, assume considerable importance, especially as an outlet for produce.

7.32 Description of West Bank Area

This area of 600,000 feddans gross, shown on Plate 15, is situated between the rivers Dinder and Rahad and is bounded in the south by the Khor el Atshan and in the north by the Khor el Zeraf. The land is generally flat at an elevation of between 425 and 435 metres but is dissected by numerous khors and drainage channels. The general slope of the land falls from the south-east near Hawata towards Dar Chemola in the northwest. Most of the area is sparsely populated, the majority of the villages being situated on the banks of either the Dinder or Rahad. There is, however, a certain amount of seasonal habitation which relies on rain-filled hafirs for water supply.

The whole plain is composed of clay with small thick Acacia forests. Elsewhere the country is more open and "Kitr" bush and scrub alternates with open grassland. The area is traversed by a graded earth road from El Hasira railway station to Umm Darraga and Dar Chemola, but this road is little used and in places is badly overgrown. In the north of the area there are few roads; a track from Allatifa to Dar Chemola and three rarely used tracks radiating from Umm

Darraga to Khor el Atsham station, El Gueisi and Allatifa. The main Sennar-Gedaref railway and the El Gueisi - Hawata road, cross the southern edge of the area.

7.33 Exploratory Engineering Survey

On the east bank between Wad Miskin and Jebel el Fau eight cross sections were levelled to determine the extent of the land that could be commanded by a canal supplied from a siphon at Wad Miskin. These sections are shown on Plate 15.

In the 1963/4 field season levelling was completed from Khor Sim Sim along the road to Tuneidba. From this longitudinal section of the road, cross sections of the River Rahad were completed in the same season. The bench marks set up during that survey proved invaluable in establishing six of the eight cross sections required on the east bank. The other two sections on the plain south of Jebel el Fau tied into the levelling carried out by the Sudan Survey Department in conjunction with the beaconing of the Project Area in 1964.

The five metre contour lines south of the Sennar-Gedaref railway line were obtained from the Sudan Railways plan of the area.

On the west bank, 150 kilometres of sections were levelled, the majority being along existing traces and roads. The only exception was the section across open country from Umm Darraga in an easterly direction to join the end of Cross Section 14, levelled during the 1963/4 season.

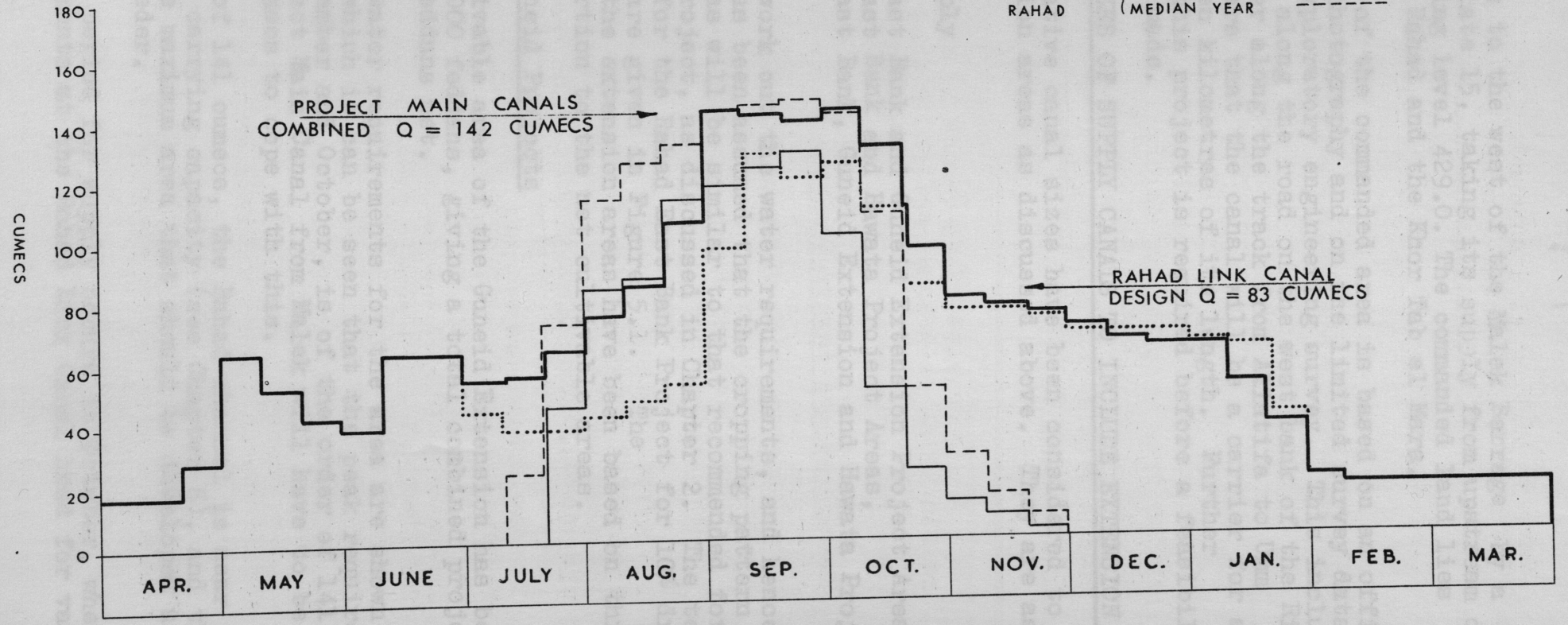
The levelling carried out on the west bank was restricted by the time available but is sufficient to give the general lie of the land and to indicate to a certain extent, whether irrigation development is feasible.

7.34 Irrigation Supply to Southern Extension Areas

The extensive flooding which occurs on the Rahad west bank between Wad Miskin and the railway at Hawata will make the construction of a canal on this bank difficult and expensive. It is considered preferable therefore to arrange for the irrigation supply for both east and west bank extensions to be siphoned across the River Rahad at Wad Miskin and then be carried northwards in a single carrier canal on the east bank. This canal will be about 40 kilometres in length and will divide immediately north of the railway line at Hawata. The west bank supply can then be carried to a second siphon under the River Rahad and onto the west bank.

The east bank extension canal continues northwards from Hawata for approximately 90 kilometres to Jebel el Fau, and commands a gross area of 240,000 feddans.

It is possible to command a gross area of between 20,000



RAHAD & GUNEID PROJECTS
WATER REQUIREMENTS

FIGURE 7·2

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

conditions are as follows:-

	Capacity of Rahad Link Canal (Cumecs)		
	October		
	1 - 10	11 - 20	21 - 31
(a) 10% dry year requirement 10% dry year on Rahad	45	89	82
(b) 10% dry year requirement median year on Rahad	-	26	52
(c) median year requirement 10% dry year on Rahad	27	66	67
(d) median year requirement median year on Rahad	-	3	38

A canal size of 83 cumecs is thought to be reasonable, providing an occasional deficit during mid-October is accepted. This may result in reduced irrigation supplies for the last watering of groundnuts.

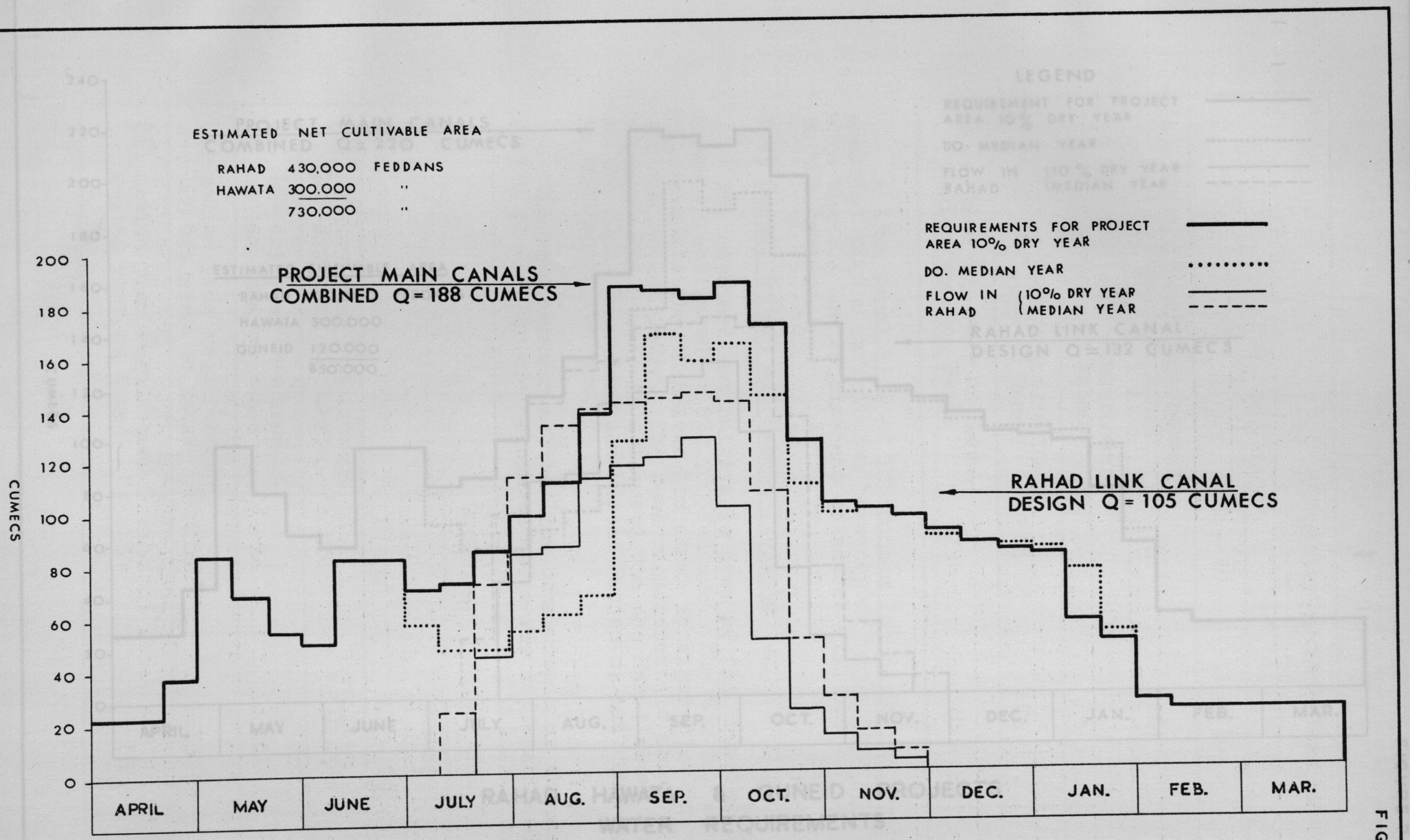
7.42 Rahad and Hawata Projects

The area which might be developed in the Hawata Project is tentatively forecast at about 300,000 feddans. The combined Rahad East Bank and Hawata Project Areas would thus be about 730,000 feddans net.

From Figure 7.3, which gives the 10% dry year and median year water requirements of the crops, it can be seen that the peak requirement in September and October will be about 188 cumecs. The Rahad channel will certainly not be able to carry this without spilling south of Hawata, and the canal for the Hawata Project will take off from the end of the Rahad Link Canal, at Wad Miskin. The best alignment for this canal will probably be along the right bank of the river between Wad Miskin and Hawata. Besides economising in earthworks, this alignment would avoid the difficulties likely to be encountered by a left bank canal in this area due to the spill which takes place between the Rahad and the Khor el Atshan.

A branch of this canal could be siphoned under the river near Hawata to serve the left bank area.

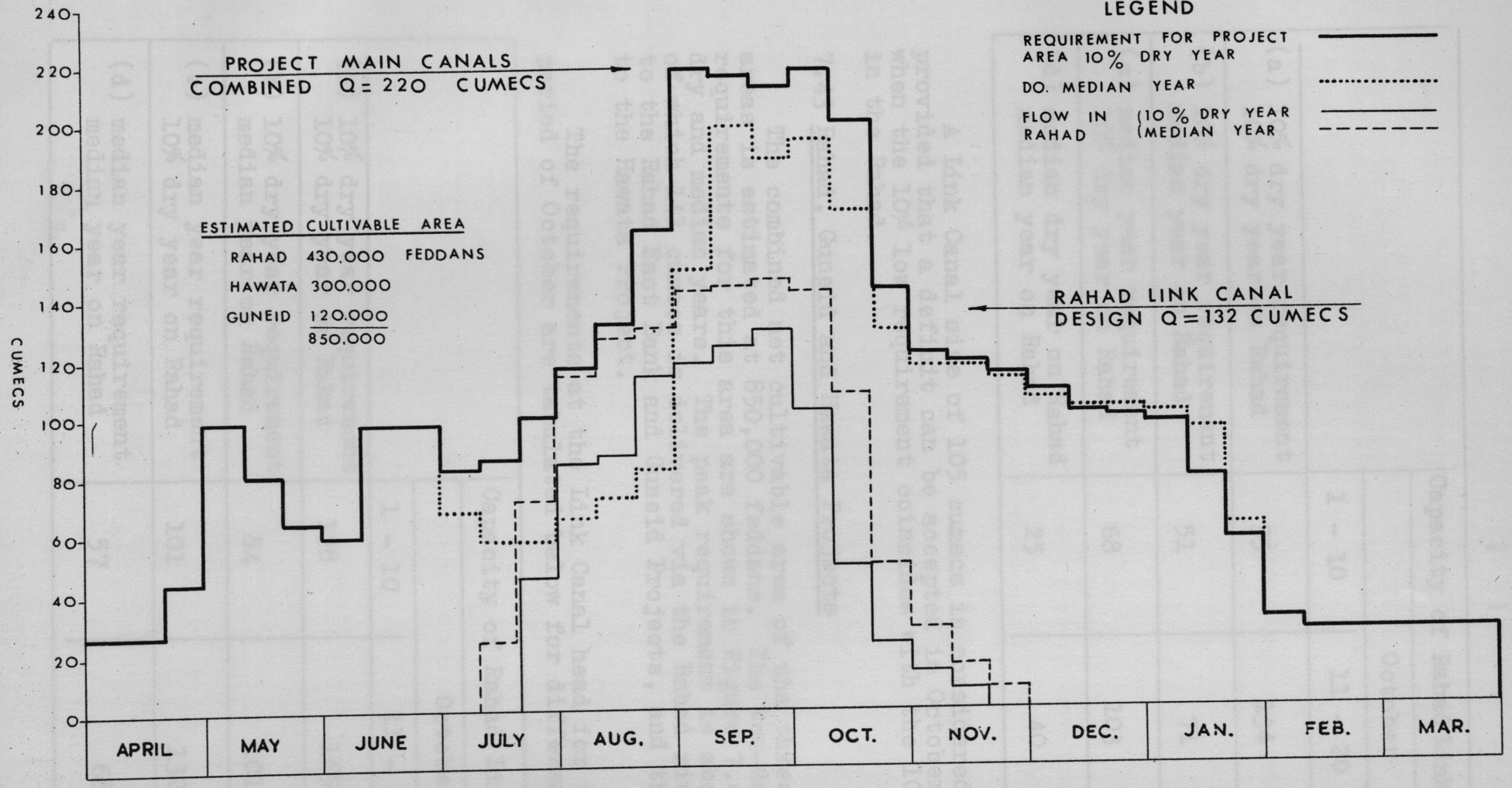
As with the Guneid Extension, the period of critical supply again occurs in October. The estimated requirements for this month at the Rahad Link Canal head are as follows:-



RAHAD & HAWATA PROJECTS
WATER REQUIREMENTS

FIGURE 7.3

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2



RAHAD, HAWATA & GUNEID PROJECTS
WATER REQUIREMENTS

FIGURE 7.4

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

	Capacity of Rahad Link Canal (Cumecs)		
	October		
	1 - 10	11 - 20	21 - 31
(a) 10% dry year requirement 10% dry year on Rahad	95	134	115
(b) 10% dry year requirement median year on Rahad	51	71	85
(c) median year requirement 10% dry year on Rahad	68	103	96
(d) median dry year on Rahad median year on Rahad	25	40	66

A Link Canal size of 105 cumecs is considered reasonable provided that a deficit can be accepted in October in years when the 10% low requirement coincides with the 10% low flow in the Rahad.

7.43 Rahad, Guneid and Hawata Projects

The combined net cultivable area of the three project areas is estimated at 850,000 feddans. The ten-day water requirements for this area are shown in Figure 7.4 for 10% dry and median years. The peak requirement is about 219 cumecs, of which 141 cumecs is delivered via the Rahad river channel to the Rahad East Bank and Guneid Projects, and the remainder to the Hawata Project.

The requirements at the Link Canal head for the critical period of October are tabulated below for different conditions:-

	Capacity of Rahad Link Canal (Cumecs)		
	October		
	1 - 10	11 - 20	21 -31
(a) 10% dry year requirement 10% dry year on Rahad	128	165	132
(b) 10% dry year requirement median year on Rahad	84	101	102
(c) median year requirement 10% dry year on Rahad	101	132	118
(d) median year requirement median year on Rahad	57	68	88

A capacity of 132 cumecs would satisfy condition (c) and would be adequate to provide a full supply for the remainder of the year. If, again, a deficit can be accepted in some years during October, this is considered to be the best canal size.

7.44 Summary

The estimated size of project areas, project canals and Rahad Link Canal for the different areas discussed are tabulated below:-

Project Area	N.C.A. (Feddans)	Project Main Canals combined capacities (cumecs)	Rahad Link Canal (cumecs)
1. Rahad East Bank	430,000	110	65
2. Rahad East Bank Guneid Extension	550,000	141	83
3. Rahad East Bank Hawata	730,000	188	105
4. Rahad East Bank Guneid Hawata	850,000	220	132

7.5 COST OF IRRIGATION SUPPLY TO PROJECT AND EXTENSION AREAS

A summary of the costs of providing an irrigation supply to the Project and extension areas discussed is given in Table 7.2. The different sizes of Rahad Link Canal have been costed and also the main canals within the project area. In the case of Guneid this estimate has been based on the alignment as shown in Plate 14A. For the Hawata project, for which no detailed levels are available for the main canal alignment, the same unit cost has been used as for the East Bank Project Main Canal, with an addition of 20% to allow for increased difficulties of alignment to be expected in the area, and also for the fact that the area is not so compact, requiring lengthier supply routes.

For the complete project of 850,000 feddans net cultivable area, two alternatives for the Rahad Link Canal have been costed. The first assumes a single canal of 132 cumecs throughout and the second a single canal of 132 cumecs for the headreach and twin canals, of 65 and 67 cumecs, from K.27 to K.191. This would be the case if the East Bank Project were implemented initially and the Guneid and Hawata Projects as a second stage.

Table 7.2: Cost of Irrigation Supply to Project and Extension Area.

Project Area	N.C.A. (Feddans)	Cost (LS.Million)	Cost/Fedden (LS.)
Rahad Project	430,000	12.2	28.4
(Rahad Project (Guneid Extension	550,000	15.2	27.6
(Rahad Project (Hawata	730,000	18.0	24.7
(Rahad Project (Guneid Extension (Hawata			
(a) Single Link Canal Q=132 cumecs	850,000	20.8	24.5
(b) Single canal Q=132 cumecs from K.0 to K.27 Twin canals Q=65 cumecs and Q=67 cumecs from K.27 to K.191	850,000	23.5	27.7

7.6 RECOMMENDED CAPACITY FOR HEADREACH CANAL K.0 TO K.27

In January 1964, the Ministry of Irrigation and H.E.P. requested the Roseires Dam Consultants, Messrs. Gibb, Coyne and Bellier to prepare designs for an irrigation outlet and headworks on the east bank with a discharging capacity of 360 cumecs. Subsequently, arrangements were made for the outlet, which comprises three separate orifices, to be incorporated in the east transitional buttresses of the dam. The orifices will discharge into penstocks which convey the irrigation supply to the canal head which is sited on higher ground. The estimated cost of construction for the complete headworks, including the alterations to the dam, is stated to be LS 2.4 millions.

The maximum discharging capacity of the headworks is 360 cumecs which required a minimum reservoir level of 470.9 metres. The relationship between reservoir level and discharging capacity of the headworks is stated by the Dam Consultants to be:-

Reservoir Level Metres	Headworks Capacity (Cumecs)
470.9	360
468.5	277
467.0	200

For the developments on the east bank which are currently being studied, an approximate estimate of the capacity of the gravity supply which will be needed in the headreach canal from K.0 to K.27 is given in Table 7.3. The irrigation supply has been estimated for all areas, assuming similar requirements to those which have been calculated for the Rahad East Bank

Project. This should be regarded therefore, as an approximate forecast only of the probable canal capacity which will be required when all the project areas are developed.

For the initial developments, we recommend that the headreach capacity is provided for 132 cumecs. This figure is about half the total capacity which will eventually be required. It is sufficient to provide for development of the various alternative combinations of projects:-

			Net Cultivable Area (Feddans)
1).	Rahad Project full development		850,000
2).	Rahad East Bank Project and	430,000	
	about half Roseires Project	260,000	690,000
3).	Roseires Project		500,000

If it is assumed that development of the new project areas is undertaken at the maximum rate which is considered possible by the Ministry of Irrigation and H.E.P.'s capacity for design and construction - a development rate of 200,000 feddans per annum was achieved in the Managil Extension of the Gezira scheme - then the alternative combinations described above could probably be brought under cultivation over a period of from three to five years.

The 430,000 feddans in the Rahad East Bank Project could be brought under cultivation in two successive seasons. It is probable that the 500,000 feddans in the Roseires Project could be brought under cultivation over a period of three successive seasons. In each case a minimum period of three years is needed for implementation of the initial phase of the development.

Table 7.3: Project Areas Supplied by Headreach Canal, KO -K27

Project Area	Net Cultivable Area (Feddans)	Canal Capacity (Cumecs)
Roseires:	500,000 *(1)	128
Rahad:		
East Bank	430,000	65
Guneid Extension	120,000 *(2)	17
Hawata	300,000 *(3)	40
Total	1,350,000	260

* These are forecasts of the probable size of the Project Areas.

(1)The semi-detailed soil survey was completed for the Roseires area in March 1965 and the Project Report on this area is scheduled to be completed in September 1965.

(2)The Guneid extension covers a gross area of about 200,000 feddans. Semi-detailed soil survey has been completed on 140,000 feddans and is due to be completed on the remainder by December 1965.

(3)Exploratory soil traverses were carried out in Hawata area during March - April 1965. It is planned to carry out semi-detailed soil surveys during the period November 1965 - April 1966 for this area.

7.7 RECOMMENDED CAPACITY FOR LINK CANAL K.27 to K.191

The Link Canal has been designed for a capacity of 65 cumecs with provision for enlargement in the future up to 83 cumecs. All structures on the canal are designed for a capacity of 83 cumecs so that no alteration to the structures will be necessary if the canal section is, in due course, enlarged. The 65 cumecs capacity is needed to supply the Rahad East Bank Project of 430,000 feddans. Enlargement of the canal section to carry 83 cumecs will permit an additional 120,000 feddans to be canalised so that the total area served by the canal is then 550,000 feddans.

In Table 7.2 it has been shown that the development cost per feddan would be more favourable if a single link canal is constructed to serve the total estimated area. Any economy, however, would depend on the rate of development, and a long period of development would tend to justify two smaller link canals rather than one large one.

It is recommended, therefore, that the Link Canal be constructed initially with a capacity of 65 cumecs which is sufficient to serve the 430,000 feddans in the Rahad East Bank Project. Further extensions to the Rahad Project can be supplied either by increasing the capacity of the Link Canal up to 83 cumecs, or, if a larger extension is planned, it is recommended that a second link canal be built of the required capacity. For the development of the full 850,000 feddans in the Rahad Project, as tentatively forecast at present, a second link canal of about 67 cumecs capacity would be required to provide the required irrigation supply to the Project.

CHAPTER 8

THE RAHAD BARRAGE

8.1 FACTORS INFLUENCING CHOICE OF BARRAGE SITE

The barrage should be sited as close as possible to the Project Area in order to minimise the length of headreach canal required. However, the closer the barrage is placed to the area to be commanded, the greater is the ponding up required in order to gain command and it is desirable that the pond level should not be above bank top level, or long closing embankments will be required. Also, a large difference in head between the upstream and downstream water levels will require expensive provision against seepage and uplift pressures. It is considered that the maximum head across the barrage should be limited to eight metres.

Having decided on the general location of the barrage it is necessary to choose a reasonably stable reach of the river where there is no likelihood of the river changing course at some time in the future and the structure being by-passed. A site where excessive scouring is occurring, or is likely to occur, in the river downstream should also be discarded to avoid any possibility of the structure being undercut.

From the point of view of the siting of the head regulator for the main canal, it is preferable to place the barrage so that the head regulator is on the outside of a bend. With this arrangement, silt-laden water tends to be drawn to the inside of the bend and the silt deposited there rather than being carried into the canal. Furthermore, the alignment of the headreach canal is usually simpler with this layout.

8.2 BARRAGE SITE AT MALEK

8.21 Description of River Rahad

During 1963 cross sections of the River Rahad were taken between Hawata and Kumar Hag Es Sid. This survey demonstrated that the nearest site capable of commanding the Project Area which is favourable for a barrage is at Malek. Further downstream recent changes in the river course render siting of a barrage unsuitable whilst a barrage upstream of Malek would require a longer supply canal with no compensating advantages.

At Malek the river is in a well established channel with no evidence of recent changes in the river course. The pond level will be below the existing bank top levels and no closing embankments will be required.

For the design of a barrage at this location however, the downstream conditions in the river need to be taken into

consideration. About 12 kilometres downstream of the proposed site the river has formed a by-pass channel some 12 kilometres long cutting off the originally highly meandering course. It is estimated that the river course has been shortened by about 31 kilometres. The resulting steeper river gradient, means that some degree of retrogression of the bed levels upstream will occur and this must be allowed for in the barrage design.

It has been deduced from the bed slopes in the by-pass channel and the original river channel, that the maximum retrogression that could develop at the upper end of the by-pass channel is of the order of 1.6 metres. However, since the new channel is some distance from the original course, the material of the section tends to be more resistant to erosion and retrogression will occur comparatively slowly.

Apart from direct retrogression of bed levels, adjustment of the slope may occur also by meanders developing and thus lengthening the channel. However, in such a straight channel as the by-pass section, meander development would take place very slowly compared with a section where meanders have already started to form. Moreover the homogenous nature of the clay in this plain will again retard meander development and also enable the channel to attain stability with a steeper bed slope than other reaches of the river, where the bed is in sandy material.

With the above considerations in mind a retrogression of 1.0 metres has been allowed for in the barrage design.

8.22 Alternative Structure Sites at Malek

At Malek the course of the river is such that it is possible to place the barrage either in the river bed or to construct it away from the river in the dry. There are several advantages to be gained by building the barrage away from the river. Diversion works are avoided and even though the Rahad is seasonal this could simplify timing in the event of construction delays. The soil characteristics are better away from the river channel and a more suitable alignment for the upstream and downstream channels for the structure can be planned. A site away from the river however, has the disadvantage of the extra excavation costs involved.

Estimates of construction costs for preliminary designs sited in the river bed and in the dry showed, (see Table 8.1) that the barrage site within the river bed was the cheaper and this site is the one selected.

8.23 Layout of Barrage and Head Regulator

The design of the barrage is shown in Plate 37. As both the river and the canal are likely at some stage to take a large proportion of the flow, it would have been desirable to offtake the respective channels at 45° to the upstream approach channel. The layout of the river is such that this is not possible. The barrage has been placed within the existing

river channel with the axis of the head regulator at 60° to that of the barrage. A training bund is provided on the left flank to protect the barrage in case emergency spill should occur on this side.

8.3 BARRAGE DESIGN

8.31 Foundation Conditions

Four boreholes were sunk at Malek on the site of the proposed barrage. Samples analysed from these bores show that the foundation material is almost wholly clay with occasional traces of coarser material which appear to be localised. The bedding of the clay also shows considerable variation with indications of a homogeneous clay layer within the profile. The cross section of the regime channel is regular with little evidence of any silt deposits and is fairly resistant to erosion.

It is considered that the clay foundation conditions will be satisfactory for the medium-head barrage that is required. The barrage design should however be monolithic to form a continuous raft foundation to avoid local settlement due to variations in the clay strata. Although clay is relatively impermeable and only limited seepage is likely to occur, we anticipate that full seepage pressures will develop. No danger from piping is likely to occur however. A cut-off is required at the downstream end for scour protection. In the preliminary design an exit gradient of one in five has been used. This provides for a downstream cut-off of reasonable proportions. The Rahad has much finer bed material than many alluvial rivers and although relatively impervious, there could be pervious strata within the bed material. Should the downstream cut-off intersect such strata there would be a danger of excessive pressure developing under the barrage floor. Filter drains with relief holes have been provided to counteract the danger from such an occurrence.

The type of barrage considered for the Rahad has a relatively small proportional relationship between the discharge and the operating head. The result of this is that the proportion, operation head to length of floor, is comparatively large, and with conventional design proportions for the barrage floor, this would result in a deep downstream cut-off and excessively thick floor downstream of the gates. To counteract this the concrete pavement upstream of the barrage gates has been extended, which has the effect of reducing the floor thickness, considerably. In the final design the inter-relationship between the various factors affecting the floor thickness will be considered in more detail.

8.32 Design Levels and Dimensions

The barrage width has been based on the width of the existing river channel. The pond level, fixed by the requirements

for the Rahad canal, is 429.0. This is equivalent to an anticipated flood level of 200 cusecs.

A downstream retrogression of 1.0 metres and 4.0 metres has been allowed for. Lifting gates are provided both in the barrage and head regulator. The use of 4.0 metre gates is recommended for the following reasons:-

(a) Gates of this size are already in use in the Sudan.

(b) In a remote area, maintenance and transport of larger gates to the site is more difficult.

(c) For bridging between piers a simple concrete slab deck can be used for the narrower gate bays. This simplifies construction and increases the freeboard for the same equivalent road level.

(d) The additional piers tend to spread the load to the foundations more evenly. The reduction in the waterway due to the additional piers should not have any significant effect.

8.4 BARRAGE AND CANAL HEADWORKS COSTS AND SITE RECOMMENDED

In section 8.22 the points in favour and against siting the barrage in the dry have been discussed. The estimated costs of the two alternatives for the barrage, built in the river bed or in the dry, are given in Table 8.1 below.

Table 8.1: Cost of Barrage and Canal Headworks at Alternative Sites

BARRAGE SITE	TOTAL COST LS.
In River Bed	371,800
In Dry (on right Bank)	473,200

As the estimated cost of building in the dry exceeds the cost of the structure in the river bed by more than LS.100,000 it is recommended that the barrage be sited in the river bed.

CHAPTER 9

IRRIGATION OPERATION

9.1. GENERAL

The area of the Rahad Project is 475,000 feddans of which 430,000 feddans are in the rotation and 45,000 feddans under gardens, forests and fodder plots. The area will make up a standard Irrigation Division in the charge of a Divisional Engineer and will be divided into three sub-divisions.

An Assistant Divisional Engineer has executive control of a sub-division (about 160,000 feddans). He is responsible for the maintenance of the canals, clearance of waterways, cleaning fixed weeds from the side banks or berms of the canals, clearing aquatic or floating weeds from the beds of the canals, and painting and repairs to regulator gates and structures.

In the southern part of the Gezira Scheme where there is heavier rainfall, surface water drains have been constructed and these require both silt clearance and repairs to the structures (stormwater inlets, bridges etc.) each year.

9.2 DISTRIBUTION OF IRRIGATION SUPPLIES

In addition to the maintenance of the works, the Assistant Divisional Engineer is also responsible for the distribution of the irrigation supplies. As described elsewhere in this report, the agricultural operations are organised by units or "Blocks" in the charge of a Block Inspector. A "Block" is generally about 30,000 feddans and an Irrigation Sub-Division will therefore serve five or six agricultural Blocks.

The water distribution from the minor canals (or distributaries) to the watercourses (or Abu Ishireens) which serve between 80 and 90 feddans is the charge of the Block Inspector who calculates his requirements on each minor canal and indents for this amount from the Sub-Divisional Engineer.

During the rainy season from July to November, these indents are accepted daily before 12 noon by the Engineer. From December and until the cessation of irrigation in February or March, changes in irrigation supplies can only be effected bi-weekly except in cases of emergency, and the distribution from the minor canals must be on a regular rotation.

The Assistant Divisional Engineer with his Senior Assistant Engineer, records the Block Inspector's indents.

These are totalled reach by reach of Major Canals and the discharge required at each regulator group in the Main Canal is summed up from the Major Canal totals. Before 1300 hours the first or downstream Assistant Divisional Engineer must inform his upstream neighbour of his requirement on the Main Canal - this process is repeated by each sub-division in turn along the Main Canal until finally the Resident Engineer on the Headworks is told of the diversion required from the river or reservoir. This change in discharge at the canal headwork is made at 1400 hours and passed down the Main Canal.

The changes of indent on the minor canals can only be made when the effect of the corresponding reduction or increase in supply has "travelled" along the Main Canal and major canals to the head of the distributory or minor concerned. The water control of distribution in the Gezira Scheme is by discharge and by level. The gate openings for the Headworks at Sennar, certain of the Main Canal cross regulators and the head regulators of the Major Canals are set to the opening required to pass the discharge. At the other end of the system, the discharge to the distributaries or minor canals is measured through standing wave movable weirs which can be set to give the discharge required by the Block Inspector. The gates of the intermediate regulators on the Main Canals and the Major canals are adjusted to maintain a constant water level in the upstream pool; and the gatemen watch the upstream gauge to time the changes in indent and also check that the gate opening is correct.

The change of indent within the Sub-Division is carried out by the Senior Assistant Engineer and the Section Engineers. The new requirements for the minor canal and Major regulators are distributed by telephone through the Sub-Division to the Section Engineers and from them to the gatemen who are told the opening required on each minor canal head regulator and the change of opening on each Major canal cross regulator and Head Regulator. The change is effected down the Main Canal from the Headworks and into the Major canals, as each regulator opening is altered, the gatemen controlling the downstream regulator are informed by telephone and so the new indent is satisfied. The whole operation in the Gezira Scheme may take 24 - 30 hours covering a system of nearly 1.7 million acres, with the tail canal 200 kilometres distant from the headworks.

During the rainy season this change of indent is a daily occurrence. On occasions of general rainfall, the irrigation engineers will be "inundated" by requests for urgent cuts in the supplies, an emergency indent will be put through to the Headworks during the evening and the changes required may take as much as two or three days to be executed - not because of delays in transmission but because of

restrictions in the rate at which the Main Canal and Major canal discharges can be reduced - limitations which have been imposed to protect the canals from slips on the side slopes.

9.3 CANAL GAUGES

In these paragraphs some attempt has been made to outline how the irrigation water is controlled. The Irrigation Staff have also to ensure that the canal system is operating to the correct water levels and that the minor canals are getting the correct supplies. Each regulator throughout the system has an upstream and downstream stick gauge to record the water level. These levels together with the gate openings are reported three times daily to the Section Engineer and Sub-Divisional Engineer's office (at 0600, 1200 and 1800 hours). The morning and evening gauges are studied to ensure that the system is operating correctly. The midday gauges are only required to check if a change has been effected and that the gatemen are on duty.

The canal gauges serve another purposes besides the day to day check on water distribution. They also indicate how the canal system is operating - a gradual increase in the water slope of a major canal reach will show that silt is depositing and in due course clearance may be required. A sudden rise in a gauge level may demonstrate that floating weeds are affecting the discharge, or that the control gate is not operating properly. In fact, the "Gauges" are the controls of the irrigation system.

9.4 ADVANTAGES OF STRICT IRRIGATION CONTROL

The system is simple to operate and has been well tested in the Sudan. The discharges are sizeable - the Main Canal Head Regulators at Sennar have capacities of 168 and 184 cumecs respectively and the Rahad Canal Head Regulator will discharge about 110 cumecs. The close control of the water distribution to the minor canals and to the fields means that all the water is used, no escapage is required from the tails of the distributaries and it is probable that this close control of irrigation supplies has done something to avoid waterlogging of the heavy clay soils. Some economies might be achieved by adopting a freer distribution of water and operating the minor canals on a constant discharge "rotation" system. This would certainly lead to serious flooding during the rains, and either breaches or escapage from the tails of the minor canals at all times. The Sudan Irrigation engineers and the agricultural inspectors are now well used to the system of close control of irrigation supplies and any relaxation would be a retrograde step. The great majority of the Gatemen will be

required whatever standards of irrigation control are adopted, and the advantages of close control throughout the year and in day to day indenting during the rainy season, justify the additional operating staff required.

The irrigation year begins in June or July and until the end of October the engineers are almost fully occupied with water control. This is also the season of maximum demand so that deficiencies in the canal system make themselves apparent and emergency measures must be taken to satisfy the irrigation demands.

9.5 CANAL AND DRAIN CLEARANCE

The activities of the staff of the Sub-Division continue throughout the year. From November to January the surface water drains are surveyed and cleared and then about one-third of the major and minor canals are also surveyed. The clearance and maintenance of the surface water drains should be started as soon as possible after the rains and completed in February or March. Concurrently with this work, the clearance of the canals by dragline may be started; this is also supervised by the engineers, and cross sections are taken to check the excavation, which is usually carried out in the wet while the canals are operating. A number of the smaller canals and carrier channels will be cleared by hand during the closure period, from March to June, when irrigation ceases.

9.6 CANAL WEED CLEARANCE

Throughout the system, fixed weeds - i.e. grasses - must be cleared from the sideslopes of the canals where these weeds are growing in standing water, to reduce mosquito breeding. This operation has to be carried out along the lengths of major and minor canals once or twice each year in December and January - later in the year grazing animals will keep the banks clear. A much greater menace to the canal system in the Sudan Gezira are the acquatic or "floating" weeds, such as "chara fragilis", "Potomogeton perfoliatus" and "Potomogeton nodosus". It is fortunate that during the period of maximum demand from July through November their growth is inhibited by the silt-laden water. They first appear during December and flourish in the warmer weather from January to March. The weeds are cleared by rake, hand cutters, camel and chain, or launch, depending on the variety and size of canal. A badly infected canal - and this probably includes as much as 50% of the canal system in the Gezira Scheme - must be cleaned every 14 days otherwise the water will cease to flow. Herbicides have been tried but, so far, either the effective dose will also be dangerous to humans, animals or crops, or the cost of the chemical treatment is excessive.

Experimental work continues but meanwhile the system is kept clean by comparatively simple and laborious methods which require the supervision of the Irrigation Staff if the work is to be effective and money not wasted. The work continues from December to the end of the irrigation season in February or March. During the "closure", when water is required only for domestic supplies or for the comparatively small area of gardens, fodder and other perennial crops, about 50% of the minor canals are dried off. The remainder and the major canals continue to require occasional weeding with a thorough clearance in June prior to the start of the new irrigation year.

9.7 MAINTENANCE OF CANAL STRUCTURES, BUILDINGS ETC.

The Ministry of Irrigation regulations require that all Main Canal and Major Canal Regulators are periodically examined, first by sounding the downstream protection and then, by drying out the regulator floor to check for piping and to carry out any repairs. This work is done early in the "closure" period. During this time a programme for painting all regulator gates and bridges should also be carried out. The "closure" period is also used for making minor repairs to canal banks, reforming ramps over regulators and bridges and extensive renewals and replacements of the "valves" which control the discharge from the minor canals through the "Field Outlet Pipes" to the watercourses.

The early policy of the Gezira Scheme was to incur the minimum capital expenditure on housing. Water control and unclassified irrigation staff were given a "Tukl" ("rondeval" - 4.0 metres diameter) either constructed with mud brick walls and a grass thatch roof, or of corrugated iron sheeting. The post war prosperity and national demand for improved working conditions has radically changed this policy and now every member of the staff is provided with a house built in red brick with a surrounding "hosh" wall. Fortunately, the maintenance of these permanent buildings is comparatively light, but there still remains a triennial programme of decoration and repairs to all the buildings in the Irrigation Division. This work is best carried out by the Divisional Building Foreman who can move round the Division during the year.

9.8 EXTENT OF IRRIGATION WORKS

The regular topography of the Sudan Gezira plain means that the length of canals and numbers of structures are approximately proportional to the irrigated area. To indicate the responsibilities of an irrigation sub-division, these are given overleaf for a typical sub-division in the Rahad Project:-

Table 9.1: The Engineering and Buildings In a Sub-Division (Area 160,000 feddans)

Description	Unit	Amount
Main Canal	kms	55
Major Canals	kms	55
Minor Canals	kms	530
" " Carrier	kms	75
Major Drains	kms	20
Minor Drains	kms	100
Main Canal Regulators	No.	4
Major Canal Regulators	No.	20
Minor Canal Regulators		
Head Regulators	No.	110
Cross Regulators	No.	220
Watercourse offtakes	No.	2050
Offices & Senior Staff Houses etc.	No.	9
Unclassified Staff Houses	No.	97

9.9 SUB-DIVISION ESTABLISHMENT

The Sub-Division administration consists of an Assistant Divisional Engineer's office with two Section Engineers' offices, thus dividing the area into three sections of about 55,000 feddans or 230 sq. kms. The establishment proposed for each sub-division is as follows:-

Table 9.2: Proposed Establishment For a Typical Sub-Division

Post	Total pay per annum LS.	A.D.E's Office	Section Engineer's Office (2 off)	Total	Housing Scale
Classified Staff					
Asst.Div.Engineer	1060	1	-	1	7A
Sen.Asst.Engineer	1010	1	-	1	7B
Asst.Engineer	730	1	2	3	3A
Eng.Assistant	290	1	-	1	3A
Clerk	333	1	-	1	3A
Tel.Operator/ typist	202	1	-	1	1A
Unclassified Staff					
Arabic Tel.Operator	199	2	2	4	1A
Labour Overseer	308	1	-	1	1A
Storeman	172	1	-	1	1
Car Drivers	199	3	2	5	1A
Head Chainman	265	2	2	4	1A
Mounted Chainman	155	2	2	4	1
Ord. Chainmen	155	4	4	8	1
Messenger	155	2	-	2	1
Gardener	125	2	2	4	1
Mason	265	1	-	1	1A
Fitter	265	1	-	1	1A
Labour Foreman	248	-	2	2	1A
Water Control Staff Irrigation(1) Agriculture(2)	164 to 219	17	34	51	1 or 1A
		-	-	125	1

Notes:-

(1) Water Control Staff (Irrigation) are the gatemen for operating the Main and Major Canal regulators and the Minor Canal Head regulators. The establishment for each group of regulators varies from four gatemen on a Main Canal regulator to one man on the smaller major canal groups.

(2) Water Control Staff (Agriculture) are the "ditch riders" who operate the minor canals and control the distribution to the watercourses which irrigate 80 - 90 feddans. One "ditch rider" is provided for each four kilometres of minor canal or 1200 feddans of irrigated area.

In addition to the Sub-Division Water Control Staff, gatemen will also be required for the Rahad Link Canal and the Rahad Barrage. The proposed establishment is as follows:-

Table 9.3: Proposed Establishment for Rahad Barrage

Staff	Total pay per annum LS	No	Housing Scale
Rahad Barrage			
Water Control Staff	164 - 285	6	1 or 1A
Rahad Link Canal			
Water Control Staff	164 to 285	4	1 or 1A
Kilo 27		4	" " "
Dinder Siphon		2	" " "
Khor Atshan Siphon		4	" " "
Rahad Outfall			

The arrangements for supervising these staff are detailed overleaf.

9.10 DIVISIONAL ENGINEERS ESTABLISHMENT

The Divisional Engineer coordinates the activities of the Sub-Division. He submits the annual budget to the Director of Irrigation, approves the quarterly budgets of the Sub-Divisions and generally exercises financial control of the maintenance operations. Personnel problems are usually referred to the Divisional Engineer, who will also establish labour rates and approve contracts for works other than "Petty Contracts". The programme of clearance of canals and drains will be subject to the Divisional Engineer's approval and he will take a part in any remodelling or clearance designs which may be required for major canals or drains.

The establishment at the Divisional Headquarters is generous so that staff are available to relieve in the Sub-Division during periods of leave or sickness. This is as follows:-

Table 9.4: Divisional Engineers Office Establishment

Post	Total pay per annum LS	No.	Housing Scale
Classified Staff			
Divisional Engineer	1360	1	7A
Asst. " "	1060	1	7A
Senior Asst. "	1010	1 *	7B
Assistant "	730	1	3A
Engineering Assistant	290	-	-
Head Clerk	590	1	3A
Clerk	333	3	1A
Accountant	532	1	3A
Asst. Bookkeeper	202	1	1A
Building Foreman	532	1	3A
Unclassified Staff			
Arabic Tel. Operator	199	4	1A
Car Drivers	199	3	1A
Mason	265	1	1A
Carpenter	265	1	1A
Storeman	172	1	1
Messengers	155	3	1
Gardeners	125	3	1
Watchmen	133	2	1
Labourers	125	6	1

* - For Rahad Link Canal

Provision has been made for a Divisional workshop to service the Irrigation mechanical plant in the Project. The staffing proposed is as follows:-

Table 9.5: Staffing for Divisional Workshop

Post	Total pay per annum LS	No	Housing Scale
Mechanic	265	2	1A
Fitter	199	4	1A
Storeman	172	1	1
Driver	199	2	1A
Labourer	125	8	1

9.11 RAHAD LINK CANAL AND RAHAD BARRAGE

The practice is to base a section engineer at a Major Group Regulator. The Rahad Barrage and Main Canal Head Regulator will require constant supervision during the flood season and this can be provided if one Section Engineer from the southern Sub-Division is based at the Barrage; the Sub-Divisional Engineer would control the barrage.

The Rahad Link Canal can best be supervised from Roseires. The Maintenance Division for the Roseires Dam will be adequately provided with supporting services. One Senior Assistant Engineer has, for accounting purposes, been provided in the Divisional Engineers establishment for the supervision of the Link Canal. He would be based at Roseires and be subordinate to the Resident Engineer. This arrangement should be reviewed when the Roseires Project is developed.

9.12 CONCLUSION

The staffing proposed for the operation of the Rahad Project Irrigation is similar to that used for the Gezira Scheme. In view of the areas involved and the close control of irrigation supplies, it is better to continue the established system. "Economy" or dilution will be obtained by substituting sub-professional and technical staff for the administrative and professional staff in the more senior posts.

CHAPTER 10

ANCILLARY SERVICES

10.1 COMMUNICATIONS - GENERAL SUMMARY

A detailed study has been made of the relative costs and merits of the different means of transport both within the Project Area and to link the Project Area with nearby centres and Port Sudan. The agricultural produce will have to be transported to Port Sudan for export overseas.

Two basic forms of transport have been considered, rail and road. The rail system within the Project Area could either be a comprehensive light railway network as in the Managil, or a combination of light railway and Sudan Railways 3' 6" gauge track as in the main Gezira, or a link of the Sudan Railways running through the centre of the area as at Kashm el Girba. Road transport would be by diesel lorries and trailers travelling on a network of roads within the Irrigation Scheme. It is the practice in all irrigation schemes for the roads to follow the lines of the canals. Theoretically the roads could be surfaced but to provide a close network of metalled roads in a large area of irrigated clay lands would involve enormous expense and must be rejected on economic considerations. Thus, the roads can be of clay shaped to a smooth formation by a motor grader and compacted by the traffic.

The earth roads in the Sudan provide a reasonably smooth, though dusty surface for traffic during the dry months. They are unreliable in the rainy season and, during and immediately after a heavy rainstorm, are impassable. In the Sudan nearly all the rain falls in the period July to October. Crops of cotton and groundnuts are all picked and processed before the start of the rains. In fact, it is important to transport the cotton crop to Port Sudan before the onset of the rains as sufficient undercover storage facilities are not available for such a bulky product. It is the practice in the Gezira Scheme to close all roads for 24-hours after a rainstorm. This prevents vehicles becoming bogged down in soft wet clay and in their efforts to extricate themselves making deep ruts in the road surface. When the roads dry out these ruts make the road surface very rough and necessitate repair work by both bulldozers and graders.

The conclusions reached for the different systems are detailed individually and the detailed cost analyses are shown in Appendix II. The outline proposal is that neither a Sudan Railways 3'6" gauge nor a light railway should be constructed but road transport should be used both within the Project Area and to transport the processed agricultural produce to Wad Medani. It can then be loaded onto railway wagons at Wad Medani and transported by Sudan Railways on existing tracks to Port Sudan. The route to Port Sudan from Wad Medani can either

be the direct one via Khartoum and Atbara or, if this line is unable to carry all this extra traffic, by the slightly longer route via Sennar and Gedaref.

The site proposed for the Project Administration Headquarters is on an area of higher land in the north of the Project Area, which is out of command by gravity water but where the gardens can be irrigated by pumping. This site is about ten kilometres north of Sherif Yacoub and twenty-five kilometres due east of Wad Medani. It is shown on Plate No.16.

It is recommended that a bridge be built across the Blue Nile near Wad Medani and that a surfaced road be constructed from Wad Medani to the main Project Administration Headquarters, a distance of 25 kilometres. The economy resulting from the omission of a 110 km. link railway line will balance the cost of the new bridge over the Blue Nile. The cost of the lorry fleet is less than the cost of building a light railway. It is considered that the Project will not justify the construction of a new airfield. The nearby existing Wad Medani airfield and a proposed new light aircraft strip in the southern part of the area will be adequate.

10.11 Sudan Railways 3' 6" Gauge Railway

The possibility of constructing a spur from the Sudan Railways 3' 6" track into the Rahad Project Area was considered. The most obvious route would be a new line to Hawata and then to Port Sudan via Gedaref on the existing track from Hawata to Port Sudan which has recently been strengthened to carry modern diesel locomotives. A rail link would be required to the centre of the area and to serve the Ginning Factory and groundnut stacking yard. If the main route out of the area is by rail, then the Ginning Factory could be located in the centre of the area and the northern area groundnuts could be carried to this central railway terminus by road. The southern area produce could be taken to loading stations along the rail link. Thus, assuming the ginning factories are in the centre of the area, the cost of constructing the 110 km. track would be LS.1.3 million. This cost is based on the construction cost of 70 km. of new track at Khashm el Girba. There would be no engineering difficulties in building this railway but at least one major bridge would be required where it crossed the main canal. If it was aligned through the southern area, then at least four other bridges would be required at crossings of branch canals. The total cost of the rail link including sidings at the ginning factory, a groundnut loading bay and one bridge across the main canal would be LS.1.5 million.

It is proposed that a rail link should not be constructed. The produce can be transported out of the Project Area by road and the saving of LS.1.5 million pounds in not building the rail link would pay for a bridge across the Blue Nile near

Wad Medani. Even if a rail link was constructed it would be highly desirable to build an all-weather metalled highway. Thus in comparing the relative communication links the cost of the road to Wad Medani should not be taken into account in the comparison. But if all the produce is to be taken by road to Wad Medani it will be necessary to bridge both the Rahad river and the Blue Nile.

An analysis of the comparative freight charges is given in Appendix II.1 and is summarised in the following table:-

Table 10.1 Comparative Freight Charges - Alternative Routes

Sudan Railways Route	Distance km.	Average Rate per ton kilo. All Produce
Medani - Khartoum - Port Sudan	960	3.6 mm
Medani - Sennar - Hawata - Port Sudan	1,130	3.4 mm
Hawata - Port Sudan	885	3.6 mm
Centre of Project - Hawata - Port Sudan	995	3.6 mm

The link line to Hawata would not be a profitable route as far as the Sudan Railways are concerned and the average rate per ton kilometre would need to be increased to 8.7 mm for this section of the route to ensure that the operating and annual charges were covered. The longer route from Wad Medani to Port Sudan via Sennar and Hawata is considered the more economical despite the fact that road transport costs to Wad Medani and the costs of a bridge over the Blue Nile must be included when this route is used.

The Sudan Railways have confirmed that the existing track system from Wad Medani - Sennar - Gedaref - Port Sudan, could carry the expected annual agricultural produce of the Rahad Project. The seasonal produce of 203,800 metric tons of cotton and groundnuts would be 300 trainloads. Assuming two trains per day the crops could be moved in five months. A new station would be required to be built at Wad Medani and would cost about LS.62,000.

Table 10.2 Agricultural Produce Transportation in an Year

Item	Weight to be Transported (Metric Tons)	
	Field to Factory & Stacking Area	Project to Port Sudan
Seed cotton	95,530	-
Lint Cotton	-	37,600
Cotton Seed	-	54,800
Groundnuts in husk	168,750	-
Decorticated groundnuts	-	111,400

N.B. The figures in Table 10.2 are based on an average yield per feddan of 5 kantars (0.7 ton) of cotton and 1.25 tons groundnuts.

The cotton crop is picked from January to March and should all be transported to Port Sudan before the rains in June. The groundnut crop is picked in November and should also be exported before June.

10.12 Light Railway

Using the existing Gezira Light Railway as a prototype, the details and costs of constructing a light railway within the Project Area have been investigated. The minimum capital cost of 220 km. of track is estimated as LS.1,533,500 and the annual operating costs would be about LS.260,000. Appendix II.2 gives the cost analysis of the light railway system.

In order to compare the alternative of transport by lorries, the possible organisation of road transport has been worked out. It has been found that the capital cost of providing a fleet of vehicles to transport produce within the Project Area would be LS.425,000. This investment would have to be repeated every five years and in annual equivalent cost based on 10% capital interest is equivalent to a 40-year investment of LS.1,1000,000. The annual operating cost of the lorry fleet is estimated as LS.170,000. Appendix II.3 shows the detailed analysis of the proposed road transport.

Thus, road transport would save LS.90,000 per year on the cost of hauling the agricultural produce, cotton and groundnuts, to the Project Administration Headquarters. In comparing the light railway and road transport costs, the transport from the Central Project Headquarters to Port Sudan

has not been considered as the light railway would only have brought the produce from the field to the central processing plants. Also it should be noted that the total annual capital depreciation and interest has been costed against four months work for the lorries. If additional work could be found for those vehicles during the remaining eight months of the year then the operation of these lorries would become more attractive. On the other hand, the length of light railway track has been taken as a minimum based on the track density currently in use on the Gezira and Managil schemes. But the proposed cropping intensification in the Rahad Area is greater than in the Gezira or Managil, as two cash crops are to be grown. The harvesting season for these two crops overlap, so the minimum length of light railway track considered might not be able to cope with all this produce. Table 1 in Appendix II gives a summary of the proposed road transport costs.

10.13 Roads

Due to a shortage of natural road building materials and the large area of the Rahad Irrigation Project, it would not be economic to construct surfaced roads within the area. But it is proposed that the Project Administration Headquarters should be linked to Wad Medani by a metalled highway. Plate No.17 shows three possible routes for this road depending upon the location of bridges across the Blue Nile and Rahad rivers. It is estimated that the cost of this 25 km. of highway would be LS.250,000. This figure is based on the cost of the road at present under construction between Khartoum and Wad Medani. The length of the road depends upon the bridge sites and although LS.250,000 is the cost of the most direct route the cost may be LS.300,000. Typical cross sections of the road are shown in Plate No.25 and specifications for the road material are given in Table 2 Appendix II. Before the road can be designed in detail it will be necessary to carry out a detailed topographical alignment survey and materials investigation. It is though that suitable building material will be found along the banks of the River Rahad. The surface dressing stone may have to be hauled from Jebel Fau.

The advantages of a direct surfaced all-weather road to Wad Madani cannot be overstressed. By June 1966 Khartoum will be linked to Wad Medani by an all-weather highway and thus by building 25 km. of road the Project Headquarters would have direct road contact with the capital. It will also be of great social and material aid to both the farmers and staff if they have a direct road to a centre such as Wad Medani.

If this road link is built it is proposed that the processed agricultural produce be transported by road to Wad Medani where it could be loaded onto railwagons for transportation by Sudan Railways to Port Sudan. Appendix II.4 shows the breakdown of the vehicles required for this transportation. In season a total of fourteen vehicles would

be required at an annual operating cost of LS.70,000.

10.14 Bridge Across the Blue Nile

It is proposed that a bridge should be built across the Blue Nile near Wad Medani. This will give the Rahad Project a direct road link with the existing centre of Wad Medani and the agricultural produce will be brought across the bridge by road transport en route to the railhead. Appendix II.6 gives an appraisal on the siting and costs of the proposed bridge. Plate No. 17 shows possible locations which will require detailed site investigations. The total cost of the bridge is estimated as LS.1.5 million.

10.15 Airfield

An all-weather bitumen surfaced airfield would cost about LS.300,000. At Wad Medani there is an existing strip and plans for the reconstruction and improvement of this airfield have been prepared, but at present the Government does not propose to carry out this work. When the new Khartoum to Medani highway is complete the air traffic between Khartoum and Medani will decrease. Since Wad Medani is fairly close to the proposed northern Administrative H.Q. of the Rahad Project Area, use could be made of this existing airfield. The expenditure of LS.300,000 for an airfield for a project area of 500,000 feddans does not seem necessary when there is an existing airfield nearby. A dry-weather unsurfaced strip could be constructed near Jebel Fau and would provide air communication by Dove or D.C.3. aircraft to the Group H.Qs from Khartoum or Wad Medani. This simple airstrip should not cost more than LS.10,000.

If the land between the Rivers Rahad and Dinder to the south-west of Hawata is developed at a later stage, El Hawata will probably become the centre for communication and Administration Headquarters. There will then be need for an all-weather airfield to serve this much larger area and an all-weather airfield at El Hawata could also serve the southern part of the Rahad Area.

10.2 AGRICULTURAL PROCESSING AND WORKSHOPS

10.21 Ginning Factories

Part IV of this Report, Agriculture, recommended that medium staple cotton be grown in the proposed rotation for the Rahad Project. This cotton will be saw ginned which is the practice for medium staple cotton in the Sudan. It is possible that if roller gins were used a slightly higher selling price would be obtained but the much greater output of saw gins compared with roller gins offsets the price differential. Consideration of management and the supply of services make it advisable to use a single ginnery at one central site. If the units were split up and smaller

ginneries located in each group area, the problems of management and control of the cotton would be more difficult and certainly more expensive. On the other hand, the disadvantage of the central ginnery is the long haul from the extremities of the Project.

For the Rahad Project it is proposed to site one central ginning factory at the Project Administration Headquarters in the north of the Project Area, see Plate No.16. This site is only 25 km. by road to Wad Medani which will serve as a railhead. Electricity from the Sennar - Burri transmission system will be available and will reduce the costs of the plant. The proximity of Wad Medani will be of help in attracting the seasonal labour required. It is considered that the advantages of management control, mains electricity, and direct communication by all-weather road to Wad Medani outnumber the disadvantage of the long haul (86 km.) from the southern part of the Project.

When the area is fully developed, the mean annual seed cotton output is expected to be 675,000 kantars (one kantar of seed cotton is 312 lbs). It is recommended that four saw ginning factories be installed. Each factory will consist of four saw gins feeding one press and will be fully automatic. A typical unit is shown in Plate No. 27. The cost of one of these units complete is estimated at LS.170,000 and the total cost of the four factories, offices, stacking yard, fence and lights is estimated as LS.720,000. These costs are based on a ginnery recently planned for the Khashm el Girba Project. A typical layout of the ginning factory area is shown on Plate No. 26. Each saw gin can gin 17 kantars seed cotton per hour and will be worked for 20 hours per day during the ginning season of 135 days. Thus four units of four gins and a press will be able to gin 736,000 kantars seed cotton in one season. The ginning season is limited because the whole cotton crop should be ginned and transported to Port Sudan before the onset of the rains in late June. The proposed ginning factory will be able to cope with the average crop of five kantars of seed cotton per feddan and will have some standby capacity. Provision may have to be made to handle a bumper crop of, say, 6½ kantars of seed cotton per feddan which would give a total of 880,000 kantars to be ginned. In order to cope with this crop the ginning season could be extended by a further 26 days.

10.22 Groundnut Decortication

It is proposed that 135,000 feddans of the Rahad Area be planted with groundnuts. An average yield of 1¼ tons of nuts in husks per feddan is expected and this would produce about 0.875 tons of decorticated nuts per feddan.

After picking, the groundnuts have to be decorticated in order to separate the nuts from the husks. The farmer will transport his picked groundnuts to a central stacking station in

the nearby block village (max. distance of 10 km. from the furthest field). The groundnuts could either be decorticated at the block service village or transported in husks to a central decortication plant at the Administrative Headquarters. A central decortication plant was first considered as the crop would be more easily controlled, and the operation of one central plant would be more economical, this more so if a mains supply of electric power is available. However, the transport costs for groundnuts in husks compared with decorticated nuts is more than double since about one third of the weight is husk and due to their bulk one vehicle can carry 13½ tons nuts in husk against 30 tons of decorticated nuts. The greatly increased transportation cost therefore makes a central decortication plant uneconomic and it is proposed that the decortication be done at block village level.

For the whole Project, 15 No. groundnut decortication plants are proposed. Each plant will be able to handle the groundnut crop from about 9,000 feddans and the proposed layout of a plant consisting of two units each of two decorticating machines is shown in Plate No. 28. Each decorticating machine can handle two tons of nuts in husk per hour. The plant will be operated 20 hours a day and will decorticate an average crop in 70 days. The total cost of one complete unit of two machines is estimated as LS.9,000 and the total cost of the complete plant at each block village as LS.20,000.

10.23 Workshops and Stores

There will be three main types of mobile plant that will require workshop facilities - the agricultural machines which are mainly tractors, the heavy earthmoving machinery for maintaining the canals, and the heavy lorries, landrovers, and cars of the road transport. It is proposed that major repairs be done at a central mechanical workshop which will be established at the Project Administration Headquarters. This central workshop will do all major repairs on tractors and vehicles and will have the central mechanical spares store. There will be separate welding, machine, engine, fitting and carpentry shops and five large 40m x 15m sheds, two each for tractors and vehicles and one for excavators. This workshop will be run by the Agricultural Management as its principal purpose is for repairs to tractors and road transport. The excavator shed is for the Irrigation Division workshop staff to do minor repairs. Major overhauls to irrigation earthmoving plant will be carried out at the Ministry's workshops at Wad Medani.

Within the Project Area, there will be 15 small workshops, one located at each Block and Group Headquarters village. These small workshops will consist of one shed 25m x 10m, a fuel store, and a small spares store. These field workshops will be only for minor running repairs to tractors and motor vehicles.

The Agricultural Administration will have one store shed at each block village. This 25m x 10m shed will be for storing sacks, seeds, and some fertilizer. There will be a storekeeper at each block village to control these stores. There will be four 25m x 10m store sheds at the Project Headquarters but the policy will be to distribute the stores to the field stores as soon as possible and not to stockpile at the Headquarters. As a safeguard against the rains commencing before all the lint cotton has been transported to Port Sudan, it is proposed that some provision be made for storga.e Two larger sheds 100 metres by 45 metres could be constructed either at the Project Headquarters adjacent to the ginning factory area or possibly at Wad Medani adjacent to the railway sidings. The advantage of locating these storage sheds at the railway sidings is that the cotton can then be loaded direct from the shed to a covered railwagon and would not need to be transported by road to Wad Medani in open lorries during the rainy season. These sheds could each hold 25,000 bales of lint (5,300 metric tons) and would cost LS.40,000 each. The groundnut management will also be provided with two of these large stores so that they can store approximately 5,000 metric tons of decorticated nuts.

10.3 TELEPHONES

It is necessary on an irrigation scheme for the principal offices and water control points to be linked by a network of telephones and for effective management and water control, a phone-link will be required to the house of each Agricultural Field Inspector as well as to the Block and Group Offices. All exchanges will be automatic with the exception of the Central Project Headquarters. The estimated cost of the telephone system within the Project Area is LS.168,000.

The water which irrigates the Project Area travels 300 km. along a headreach canal, a link canal, the River Rahad, and the Project main canal before it reaches the area. A communications link will be required along the whole length of the supply route so that the water requirement and any breaches or damage to the canal could be immediately communicated back to the principal water control points. The estimated cost of a telephone line from the Project Area back to Roseires Dam is LS.99,000.

These costs have been worked out by the Sudan Posts and Telegraph Department and are the most economic communications system that the P & T engineers consider could satisfy the requirements. The possibility of replacing some of the 300 km. trunk line by VHF radio telephones has been considered but rejected. Fixed wavelength radio telephone units which can be operated by simply lifting the receiver could be installed at certain points along the link canal for about LS.1,000 per unit. The P & T do not consider such a simple system would suffice. The maintenance costs would be high and the electricity required to operate these sets would have to be supplied either by battery or generator, both of which could be unreliable. Although a

mobile patrol could have a radio fitted in a landrover, this would be immobilised during the rains when damage would be more likely to occur and inspection is most needed. The Sudan P & T Department would not install or operate a simple VHF radio telephone system as any communications system installed by the P & T must be a service to the population as well as serving another Government Department. A complex VHF radio network was considered as an alternative to the 300 km. of land line but the radio system necessary to serve the area as well as the Irrigation Control would not have been cheaper than the proposed land line. The conventional land line is considered more reliable in use and it is the current Sudan practice to use land lines on all irrigation schemes.

10.4 ELECTRICITY SUPPLY

10.41 Project Administration Headquarters

It is proposed to have mains electricity power at the Project Administration Headquarters. This power will reduce the capital costs of the ginning factory and the water plant. It will also provide power for the mechanical engineering workshops and to pump canal water for irrigating gardens, as the Headquarters site is out of gravity command.

The 110 KV overhead power line from the hydro-electric station at Sennar Dam runs through Wad Medani on its route from Sennar to Khartoum. When the Roseires Dam hydro-electric station is constructed it is proposed to take a 220 KV over head power line to Khartoum down the left bank of the Blue Nile via Wad Medani. Thus there is ample hydro-electric power available near Wad Medani.

The power demand at the Project Headquarters is estimated as:-

Ginning factory	900 KVA
Water supply pumps	100 KVA
Workshops	50 KVA
Housing, hospital etc.	150 KVA
Total :	1,200 KVA

The straight line distance from Wad Medani is 25 km. and the line will have to cross the Blue Nile at a point where it is about 500 metres wide. A bridge is proposed across the Blue Nile so the power line could cross the river in a duct in the bridge deck. An 11 KV overhead line would be suitable for transmitting the power. The total cost of the transmission lines, transformers, and distribution lines within the Headquarters is estimated as LS.55,000. Appendix II.10 gives details of the proposed electricity supply and the costs breakdown are shown in Appendix III.4.

10.42 Field Administration

It is not proposed to supply all villages with an electricity supply but villages with tubewells will have a diesel generator to supply power for the electric submersible pump. All Block H.Q. villages and also the Group H.Q. villages will be provided with a 12 KW generator which will be run from 6 p.m. to 10 p.m. to provide electric lighting for the Administration and Irrigation Staff housing and offices. The dispensary will also be supplied with electric lighting. It is not proposed to supply electricity to any other village housing and the power supplied to the staff will be for lighting only. In the other villages the generator will only be used to supply the power for pumping water from the tubewell. This 12 KW generator will cost about LS.800 and complete with distribution the total cost for each of the 12 Block H.Q. villages and three Group H.Q. villages is LS.4,200. At the other villages the cost will be included in the water supply cost.

Each of the groundnut decortication plants will have its own small lighting plant to provide electric yard lights for all night work during the groundnut harvest. This lighting plant will be in addition to the 12 KW staff housing unit.

10.5 WATER SUPPLY

10.51 Introduction

It is essential that provision be made for supplying every farmer in the Scheme with an adequate supply of pure drinking water. The Sudan Geological Survey Department are of the opinion that in the Project Area north of Jebel Fau, which is the Nubian sandstone formation, there should be no difficulty in obtaining suitable supplies of ground water by drilling tubewells. There are three tubewells in this area at present and the water from these wells has been tested for salinity and found to be respectively 10, 400, and 1000 ppm of chloride. The maximum W.H.O. permissible salt content is 600 ppm so that the water from one of these wells is not recommended for human consumption. It is considered that if this well was re-drilled some distance away, a better supply would be obtained. One of these existing tubewells is very close to the site of the proposed Project Headquarters.

In the Project Area to the south of Jebel Fau (Group III management area) it is doubtful whether a ground water supply can be obtained though test drilling should be done. Provision must be made for purifying the canal water for the villages in this area.

The maximum size of village proposed will house about 400 farmers with an average family of five persons, giving a total village population of, say, 2000 persons. The W.H.O. in

their Report on the Development of the Gezira Managil Area (1) recommended 20 gallons per person per day when water is supplied to each house and ten gallons when supplied by public tap. It will be some years before the villages reach the stage of piped water in every home, so an average consumption of 15 gallons per person per day is proposed. Thus, each village will require 33,000 gallons per day.

No provision will be made to supply water to the animals as it is assumed that they will continue to drink the canal water. The supply of adequate pure water for the population's general use will not be cheap. Unless sufficient quantity of pure water is supplied the population will resort to the irrigation canals to supplement their needs and thus the effective control of gastro-intestinal and enteric diseases and bilharzia will be impossible. If all the people on the Project are to be given an adequate pure water supply, then a capital investment of LS.1,000,000 will be required. This cost is about LS.6 per head of the population, and is therefore justified.

NOTE: (1) Report of the Mission for the Development of a Regional Plan for the Gezira Managil Area in the Sudan - United Nations 1963.

10.52 Village Supply from Tubewells

Each village will require 33,000 per day and the water will be consumed over ten hours so the bore will be required to yield 3,000 gallons per hour. This water will receive no treatment and will be pumped from the well direct to a 10,000 gallon overhead tank about six metres high. This tank will supply a 3-inch diameter ring main in the village. The main will be located so that no person has to walk more than 150 metres to a tap and there is one tap to every 100 persons.

The cost of the tubewell depends upon the depth drilled and this cannot be decided until the drilling is actually done. Assuming an average depth of 100 metres the cost of the well, pump, pump house, overhead tank, 3-inch ring main, and distribution taps and concrete aprons, is estimated as LS.9,000 per village. One attendant will be required to operate this plant and he will have to be provided with a house which will cost a further LS.1,000.

An electric submersible pump will be the most efficient pumping unit. This will require a diesel generator. It is proposed to supply the larger villages with a 12 KW generator for lighting management staff houses. A 7½ HP two-inch delivery submersible pump could supply 50 gallons per minute at a delivery head of 70 m and thus the 12 KW generator could operate this pump. Although the total depth of well drilled may be 90 m, the static water level is expected to be not more than 60 m and may be considerably less. The water pumping

could be done during the day and when the lighting load is required, from 6 p.m. onwards, it would then not be necessary to pump. A saving could be made in construction costs by installing the 10,000 gallon overhead tank on the roof of the pump house. The pump house could be made 6 m high and this would aid in lowering and lifting the pump and rising main from the well.

It should be noted that drilling is a highly technical operation and should be closely supervised by qualified staff. If a bore is done haphazardly, the result may be either impure water or the wastage of many metres of casing. Once a bore has gone wrong, there is very little that can be done to remedy the situation, and usually a completely new well has to be installed.

10.53 Village Supply from Irrigation Canals

The raw canal water requires to be filtered and chlorinated before it can be supplied as drinking water. This purification can either be done in each village or in a central water works in a service village (Block Headquarters village) and piped to the adjoining villages. The central plant has much to recommend it in respect of efficient operation and producing water of the highest degree of purity. This plant would require a capacity of 200,000 gallons per day and to guard against breakdowns, it would be necessary to have reservoir storage of at least 200,000 gallons. The canal water would be settled, clarified, filtered, and chlorinated, and then be pumped through 4-inch rigid PVC mains to the five surrounding villages. Each village would have an overhead tank and a 3-inch ring main. A non-return valve would be fitted on the supply main so that pumping would only be necessary a few hours each day. Technically, the central plant provides the most efficient water supply but the cost would be high. It is estimated that the central treatment plant would cost not less than LS.90,000. The cost of distribution to the five surrounding villages (assuming a maximum straight line service, village to satellite village distance of 5 km.) would be about LS.65,000. Thus the total capital cost of one central water treatment plant and piped distribution to five surrounding villages would be not less than LS.155,000.

On the existing Managil and Khashm el Girba Schemes the villages are supplied with canal water which is filtered by passing through a settling tank and sand filter. No chlorination is done and the plant has no biological action on the raw water. It acts only as a strainer. This system is not recommended since the water delivered from the plant has the same biological impurities as the raw canal water. This existing standard village filter costs LS.5,000 and with the distribution around the village, the total cost per village is LS.12,500. It has been estimated that these existing filter plants could be improved by adding a pressure

filter and chlorination unit. This modification would cost about LS.2,500.

Thus a group of six villages could be supplied with a modified and improved filter system for a total of LS.90,000 which is considerably cheaper than the central plant and distribution at LS.155,000. Plate No. 29 shows an outline proposal for a village supply from canal water.

The canals of the Rahad area are to be designed for night storage of irrigation water and a certain amount of sedimentation will occur in the canals. The irrigation water will only be carrying excessive silt during the flood months of July to October. It will be necessary to remove this silt before passing the water through the proposed Stellar filter. The scheme outlined in Plate No. 29 shows the canal water pumped into an elevated circular sedimentation tank. It may be necessary to speed the sedimentation by adding alum. The tank is elevated so that it can be cleaned by washing the silt out through a gravity drain.

An alternative to this sedimentation tank would be to excavate a large open earth tank (locally called a hafir) of capacity about 3,000 cubic metres. This hafir would be about 30m x 30m in area and would have to be securely fenced to keep out both animals and humans. Its disadvantages is the danger of the water becoming polluted while in the hafir but it would only be required for the period when the canal water was carrying excessive quantities of silt. For the remainder of the year the water could be pumped direct from the canal, through the Stellar filter, and up to the overhead storage tank, where it could be chlorinated. This plant would cost LS.11,000 including the overhead tank and distribution pipework. A breakdown of costs is shown in Appendix III, 4.

10.54 Project Administration Headquarters Supply

The Project Headquarters will require a central water plant to supply the houses and also the ginning factory. The Management and Irrigation Staff houses are estimated at 1,000 and allowing 20 gallons per person per day, this housing will require 100,000 gallons per day. There will also be accommodation for seasonal workers and the ginning factory to be supplied. In later stages of development, schools and a hospital will be constructed and the township may develop into a main centre. It is proposed that a water supply of capacity 250,000 gallons per day be installed initially and this plant could later be increased to 500,000 gallons per day by increased pumping from the existing tubewells, or by drilling new wells.

The water could be supplied from three tubewells each yielding 40 cubic metres per hour (8,000 gallons per hour).

(The Sudan Water Authorities, C.E.W.A., specify new bores to yield 80 cubic metres per hour minimum). Provided potable groundwater is available, the only treatment required will be chlorination which can be done in the tubewell and the water then pumped by electric submersible pumps direct to a high level storage tank. Mains electric power will be available to operate these pumps. The high level storage tank should be 25 metres high and have a capacity of 50,000 gallons. This storage tank will cost about LS.15,000. Each tubewell complete with pump, chlorinator, and building will cost LS.5,000. The complete water supply including tubewells, storage tank, mains and house connections, is estimated at LS.56,000. If it is decided to charge the householders for this water supply, meters would have to be fitted at a further capital cost of LS.10,000. A breakdown of these costs is shown in Appendix III.4.

Plate No. 30 shows a typical layout of the water plant.

CHAPTER 11

BUILDINGS

11.1 ADMINISTRATION

11.11 Agricultural Management

It is the practice on existing Irrigation Projects in the Sudan to provide housing for all management staff. Every person employed from the manager down to the office messenger and the labourer, receives a house for himself and his family. Certain seasonal workers such as the labourers in the ginning factories are housed in bunk houses.

The capital cost of providing all this housing is very high and will be an appreciable proportion of the cost of the scheme. Since all the staff on the existing schemes are provided with housing it would be impractical not to provide housing in the Rahad Project. The land to be developed is at present uninhabited and there are very few existing villages. Thus, if staff are to be recruited or transferred to develop this area, they must be provided with somewhere to live. If experienced staff are to be used it is probable that they will be transferred from the Gezira and Managil Schemes where they already occupy management staff houses. Unless similar housing is provided on the Rahad Project, it will be difficult to attract keen and competent staff. Moreover, if housing is supplied, it is possible to transfer staff when the occasion demands.

The greater part of the large cost of buildings for the Agricultural Administration is for houses for the staff. Offices will be required at each Block Headquarters village and at the Main Project Headquarters. The requirements of buildings for the Agricultural Management are shown in Appendix III.4.

11.12 Irrigation

The Irrigation Engineering Staff are also all provided with housing. The same arguments as before apply regarding the continuation of this provision in spite of the high capital cost. When it is required to have a gateman "on call" at a group of regulators in the canalisation system, it is essential to provide him with a house on site. If no house is provided he will probably live in the nearest village. The control structures are arranged in groups such that the minimum number of operators will be required. Apart from Sub-Divisional offices and stores all the buildings are houses for the staff. The requirements of irrigation buildings are shown in detail in Appendix III.4.

11,13 Central Government

If a large number of people are settled in an undeveloped area, provision must be made for a medical service and education for the children. Each village in the new Project will have an elementary school while the larger service villages will have a dispensary and an intermediate school. There will be a veterinary field station in each service village and one veterinary clinic staffed by a veterinary officer at each Group Headquarters village. The other public buildings such as a mosque and a village assembly hall will have to be built by the villagers themselves or by the local government from taxes raised from the farmers. In the early days of the scheme, the construction of these buildings will probably have to wait until the tenants have built their own houses. The detailed requirements of buildings for Social Services are shown in Appendix III.4.

11.14 Type of Building

The Ministry of Irrigation and H.E.P. have developed over the years standard type buildings for different needs. These buildings have been designed and improved to meet the local requirements of climate, availability of building materials, and the family customs of the Sudanese people. Due to the prevailing climate, the average family spends a large proportion of the day out of doors and often sleeps in the open, and so it is important for them to have an open area which is screened from public view. Consequently most people wish their house to be surrounded by a wall. The prevailing winds are N-S and in the cooler months, the cold winds blow from the north. It is usual to face the houses N-S with the rear of the house to the north and a verandah on the south side. Doors should not be on the north side as they would then allow cold winds to blow through the house each time a person entered a room. A verandah on the south will also allow the south wind, during the hot months when the wind turns, to blow into the house and will protect the south wall from the midday sun. Plates No. 22,23 and 24 show typical standard designs which are in current use in the Gezira, Managil and Khashm el Girba Schemes.

11.15 Methods of Building

The heavy cracking cotton soil makes house building difficult due to the swelling of the clay when it gets wet. Unless adequate foundations are provided the walls will crack when the rains commence. The local houses are built of mud either in the form of "jaloose" building, where the mud is just puddled into a wall, or preferably in the form of sun dried mud bricks. By itself, mud has no resistance to rain so the outside of any mud walls must be plastered with a mixture of cow dung and straw, called "zibla", to resist the

action of rain water. A refinement of mud construction is to build the inner wall with mud bricks and the outer skin of red bricks. This method of construction is called "Gishra". Due to the high maintenance costs of mud-built houses all Government buildings are either of red brick or random masonry set in mud or cement mortar.

The quality of red bricks is very poor and in certain areas although clay is available the fuel for burning the bricks is not available and consequently bricks are very expensive due to the high costs of transport. In these areas random rubble masonry has been used with success.

Due to the heat of the sun it is very desirable that roofs should be insulated. The Government designed houses usually achieve this insulation by adding a 10 cm. thickness of lime mortar on top of the roofing structure. In the cheaper houses, the roofing material is corrugated iron while the more costly houses have either brick arch roofs spanning between steel R.S.J's or reinforced concrete slabs.

All the houses have reinforced concrete tee beams for wall foundations. Floors are either concrete on top of sand fill or tiles. Latrines are provided with septic tanks for all houses.

11.16 Recommended Types and Designs

It is recommended that further experiments should be made in the use of soil cement blocks for house construction. The bed of the River Rahad has areas of sand and clay which might be suitable for block making. In 1951 experiments were made in Khartoum and some low cost houses were made using soil cement blocks which had a high sand content. These houses have weathered well. At present imported timber is used for all windows and door frames and also for roof purlins. Provided efficient saw milling can produce regular shaped units, then efforts should be made to use the local hard woods especially for roofing material. It is more difficult to work this hard wood but in other parts of the world such woods are successfully used for house construction and resists damage by termites. Efforts should also be made to reduce the cost of the lowest grade house below LS.1,000. For example, if the hosh wall is eliminated the occupier could if he wished provide his own screens from locally made matting, a common practice in the area near Hawata.

It is possible that some economy and improvement of foundations could be achieved by laying an apron of polythene sheeting extending from the walls outwards for about 1 metre. This would deflect rain water away from the wall foundations.

It is not proposed to recommend any major changes in type or design as it is thought that the present designs, which have been evolved through 30 years experience of the Gezira Project, are very suitable and take full account of the needs of the local inhabitants.

11.17 Recommended Scale of Housing

The cost of providing housing for all management and irrigation staff to the same scale at present in use on the Gezira Scheme would be very high. A study of the types provided (as shown in Plates No.22, 23 and 24) shows relatively little difference between the Type 7B and 3A, although the latter is LS.2,000 cheaper. It is proposed to make some saving and to provide some grades of staff on the new scheme with a lower scale of housing than is at present provided on the Gezira Scheme. Some of the Gezira and Managil housing is considered too lavish and costly for the purpose it serves.

The basic change recommended in the housing scales is to standardise on the Type 3A as the basic middle grade management house and all field inspectors and equivalent ranks will be housed in these. The more junior staff such as supervisors and mechanics will be given Type 2A houses while the drivers, junior clerks, messengers, labourers, etc. will continue to have Type 1 and 1A. The more senior officials will occupy Type 7B, and Type 7A (which only differs from Type 7B by a larger dining room) will only be provided for the Senior Manager level. By retaining some Type 7B and 7A houses, the top management officials, who will probably be transferred from an existing project, will continue to enjoy the same standard of housing. The Field Inspector grades will probably be new appointments or promotions from existing schemes so they will also have the same type of houses as at present. The total cost of the Proposed housing is LS.3.7 million. The following table shows the scale proposed for the Management and Irrigation staff:-

Table 11.1: Proposed Housing Scale

Position	Annual Salary Range (including allowances) (L.S.)	House Proposed	Approx. Cost of House (L.S.)	Annual Maintenance and Depreciation (L.S.)
Divisional Engineer Asst. Divisional Engineer Project Manager	2,340 - 1,060	7A	6,300	220
Asst. Divisional Engineer Block Inspectors Transport Officers Chief Classifier Civil and Mechanical Engineer	1,190 - 1,010	7B	5,500	193
Asst. Engineer Engineering Asst. Field Inspectors Senior Clerks Foremen Chief Storekeeper Block Accountants	1,040 - 592	3A	3,500	123
Fitters Electricians Checkers Supervisors	536 - 330	2A	2,500	88
Mason, Carpenter Fitter, Drivers Head Chainman Telephone Operators Clerk/Typists Mechanic Storekeeper Messenger	300 - 156	1A	1,500	53
Messengers Chainman Labourers Storeman Water Plant Attendants Watchmen Gardener	136 - 122	1	1,000	35

Type 7A House - Sitting room with dining room extension, two bedrooms, kitchen, pantry, store, bath, with large verandah on two sides. House built with garden surrounding, servant's room and garage.

Type 7B House - Identical to Type 7A but without dining room extension to sitting room.

Type 3A House - Sitting room, bedroom, sala, kitchen, store, bath, verandah. House built with hosh wall surrounding and servant's room in the compound.

Type 2A House - Similar to Type 3A but verandah and servant's room omitted. Compound is smaller and kitchen and store are in the compound detached from the house.

Type 1A House - Two rooms and verandah. Kitchen and bath all surrounded by hosh wall.

Type 1 House - One room and kitchen surrounded by hosh wall.

The housing requirements of the various departments are shown in the Tables 11.2, 11.3 and 11.4.

Table 11.2: Agricultural Management Housing

Department	House Type						Total
	7A	7B	3A	2A	1A	1	
H.Q. Administration	2		2		2	2	8
H.Q. Accounts	1		9		11	2	23
H.Q. Stores	1		4		7	11	23
H.Q. Electricity Supply			1	3	1		5
H.Q. Water Supply			1	1	1	8	11
H.Q. Miscellaneous			1		4	22	27
Field Administration	3	15	105	25	81	190	419
Agricultural Machinery			16	1	435	2	454
Block Workshop				33	15	48	96
Ginning Factory	1	1	11	42	8	19	82
Seed Heater				2		2	4
Fire Prevention			2	1	16	20	39
Groundnut Decortication	1		2	16	2	9	30
Mechanical Engineering		1	5	60	15	7	88
Civil Engineering		1	6	15	6	15	43
Transport Services		1	1	43	44		89
Forestry			2	6		16	24
Total	9	19	168	248	648	373	1,465

Total Cost for Agricultural Management Housing is
LS. 2,714,200

Table 11.3: Irrigation Housing

Department	House Type					Total
	7A	7B	3A	1A	1	
Divisional H.Q.	1	2	4	17	11	35
Divisional Workshop	-	-	-	8	9	17
Sub-Division (N)	1	1	5	19	19	45
Sub-Division (C)	1	1	5	19	19	45
Sub-Division (S)	1	1	5	19	19	45
Major canals Water control	-	-	-	13	161	174
Minor canals Water control	-	-	-	-	376	376
Total	4	5	19	95	614	737

Total Cost for Irrigation Housing is LS. 875,700

Table 11.4: Social Services Housing

Department	House Type						Total
	7A	7B	3A	2A	1A	1	
Local Government	-	1	2	2	-	-	5
Veterinary Service	-	3	-	15	3	3	24
Medical Services	-	-	3	16	4	20	43
Total	-	4	5	33	7	23	72

Total Cost for Social Services Housing is LS. 155,500

N.B. Housing for school teachers included in cost of school buildings.

The overall standard of housing is high and all grades of staff receive a well-built house. The high stardard of their housing must be taken as part of their remuneration and certainly has prestige value. The cost of building to this scale is very high as the cheapest Government-built one-roomed house (with a "hosh-wall") is LS.1,000. When it is considered that the occupant of this house may only earn LS.120 per annum, the annual cost of his house to the Government, including capital depreciation, interest charges, and maintenance is probably LS.100 or 80% of his annual salary.

It is proposed that further economies might be achieved by replacing the Type 1 house by a thatched grass tukl. The type 2A houses would be discontinued and replaced by Type 1A, and the Type 1A occupants would be downgraded to Type 1. Thus below the Type 3A, all staff would take one step down and the Type 1 occupants (Unskilled labourers, messengers etc.) would receive a grass tukl instead of a house. This drastic reduction in housing standard would reduce the Capital Cost of the Project housing from LS.3,777,400 to LS.2,089,850. A saving of LS. 1,687,550. Table 11.5 gives this cost in detail. It is recommended that staff housing standards should be considered relative to the management proposals and thus the housing scale recommended is in accordance with these proposals. The drastic cuts outlined above show what could be effected if the housing standards are reduced to an absolute minimum, a financial saving of LS.1.7 million out of a total Project cost of about LS.36 million.

Table 11.5: Housing Cost if All Junior Staff are Downgraded in Housing Standard

House Type	Agric. Manag.	Irrigation	P & T	Social Service	Total Number	Unit Cost LS.	Total Cost LS.
7A	9	1	-	-	10	6,300	63,000
7B	19	4	-	4	27	5,500	148,500
3A	168	8	3	5	184	3,500	644,000
1A	248	23	4	33	308	1,500	462,000
1	648	87	5	7	747	1,000	747,000
Locally Built Tukl	373	614	4	23	1,014	25	25,350
Total	1465	737	16	72	2,290		2,089,850

11.2 VILLAGES

11.21 Location and Size of Village

The net cultivable area is 430,000 feddans. Assuming a 12.75 feddan tenancy the total number of tenants will be 34,000. If the average size of family is five persons including the farmer then the total farming population within the Project Area will be 170,000 persons. The population survey done in the area and within five kilometres of the area estimates the existing population as 45,000 so at least 125,000 people will be required to move to the area from other regions.

Apart from the extreme north of the area there are very few existing villages within the proposed irrigation scheme. Plate No.16 shows twenty villages exist either within or adjacent to the scheme boundary. In the central and southern parts of the area there are virtually no existing settlements and new villages will have to be built. The proposed location of the new villages is shown on Plate No.16. In designing this layout the principle of a larger central service village serving smaller surrounding satellite villages has been adopted. As far as possible the villages have been located so that the maximum distance of the furthest field from the farmer's house is 3.5 kilometres and the maximum distance from the satellite village to a service village is five kilometres. Any time a farmer spends walking to his tenancy is non-productive and should therefore be kept to a minimum. On the other hand supplying village services such as pure water are expensive and thus a village should have a substantial population so as to spread the cost of these services. The intermediate school and dispensary for the surrounding villages will be in the Service Village and it is impractical to expect sick people and children of eleven years to walk or ride more than five kilometres. The villages have been sited with these distances of 3.5 and 5 kilometres in mind but due to the shape of particular areas and the canalisation layout it is not always possible to satisfy these conditions.

It has been the custom in the past to segregate the housing of the farmers and the management but this makes the provision of water supply more expensive. It is now proposed that the management staff housing be located in the same villages as the farmers. Consequently the same water supply will serve both farmers and staff and this grouping of communities will also help to foster a community spirit and encourage the social development of the villages. The Agricultural Management proposals are shown diagrammatically on Plate No.16. The area will be divided into three "Groups" and each Group into five Blocks. Each Block has been located so that it coincides with an irrigation unit and that the whole Block is irrigated from one branch canal. Table 11.6 shows the approximate areas of the various agricultural units

and also the proposed numbers of villages. In studying Table 11.6 the following points should be noted:-

i) *Class 6 land has been excluded from measured areas.

ii) Total cultivable area of 438,400 feddans exceeds estimate of 430,000 by 2%.

iii) Tubewells will be drilled at four of the existing Group I villages.

iv) Typical village layout will be designed for a maximum population of 400 tenant farmers.

v) Layout of management units and location of villages shown on Plate No.16.

Table 11.6: Management Units and Village Sizes

Group	Block	*Approx. Area (feddans) Gross	Net cultivable	No. of villages Existing	New	Total	Cultivable Area per Village	Tenants per Village	Remarks
I	1	31,000	26,400	5	4	9	2,930	230	
	2	20,400	17,300	5	3	8	2,160	170	
	3	47,400	40,200	6	4	10	4,020	315	
	4	44,400	37,700	3	6	9	4,190	328	
	5	29,800	25,300	-	6	6	4,220	331	
	Total	173,000	146,900	19	23	42			Some existing villages.
	Mean						3,500	274	
II	1	49,000	41,600	-	9	9	4,620	362	
	2	42,500	36,200	1	8	9	4,020	315	
	3	28,000	23,800	-	6	6	3,960	310	
	4	22,600	19,200	-	5	5	3,840	301	
	5	42,800	36,400	-	8	8	4,550	357	
	Total	184,900	157,200	1	36	37			
	Mean						4,250	333	
III	1	37,800	32,100	-	7	7	4,590	360	
	2	34,000	28,800	-	7	7	4,110	322	
	3	31,000	26,400	-	6	6	4,400	345	
	4	34,100	29,000	-	6	6	4,840	387	Max. size village
	5	21,200	18,000	-	5	5	3,600	282	
	Total	158,100	134,300	-	31	31			
	Mean						4,330	340	
Grand	Total	516,000	438,400	20	90	110			
O/A	Mean						3,980	312	

The average block area is 29,000 feddans gross and it is proposed that there should be at least six villages in this area. One of these will be the Block Headquarters village and will thus have additional management staff living in it. The only staff living in the other villages will be the field inspector and tractor drivers. The average size of each village is 340 farmers, each with a family of five, making a total village population of 1,700 persons.

In each group, one of the Block Headquarters villages will also house the Group Headquarters but this will only differ from a standard Block Village by having additional staff houses.

The total net cultivable area of 430,000 feddans will require 110 villages. In the north 20 existing villages will be considered as remaining and being used by tenants, i.e. the villagers participating in the scheme and remaining in their present houses. Thus a total of 90 new villages will be laid out for a total farming population of 139,000 persons.

11.22 Housing for Farmers

The possibility of providing houses for the new tenants has to be considered. In the past, in the Gezira and Managil Schemes, no housing has been provided for the tenant farmers but in fact in these areas, there were already established villages and the people living in the villages took up holdings in the Projects. Many people were therefore able to participate in the scheme without having to move their homes. In the recent Khashm el Girba Project, all the housing has been provided by the Government. This Project is unique in that the people were being forcibly removed from their original homes near Wadi Halfa, which will be submerged by Lake Nasser. The compensation which was paid by the Egyptian Government, was used to finance the building of new homes for these people. In the northern part of the Rahad Project Area, there are a few existing villages and it can be assumed that these people will take part in the Project. If they do become tenant farmers, then they will, where possible, continue to live in the existing villages, and the full complement of new villages will not be required. On the other hand, for two-thirds of the Project Area, there is little existing habitation and the new farmers will need housing. The cheapest form of permanent housing built for Government employees cost LS.1,000 for each house and those built for the Khashm el Girba farmers cost between LS.1,700 and LS.2,000 each. The cost of providing similar houses for all the new tenants in the Rahad Project would be LS.30 million, a cost which could not be supported by the Project.

11.23 Layout of Villages

The layout of the villages will be standardised and

each village will have a drinking water supply. There will be a dispensary provided by the medical authorities at every Block Headquarters village and the central village facilities such as mosques, village hall, etc. will have to be provided by the village council. Although the capital cost of the water supply will be borne by the Project, the operating cost will have to be paid for by the farmers themselves. This is the practice in the Gezira Scheme where once the water supply unit has been constructed, it is handed over to the local authorities who then have to recoup from the villages the cost of the attendants' wages and also the annual maintenance cost for work done by the central team of water supply maintenance men. It is not proposed to provide an electricity supply within the villages but the Block Village will have a supply which will only be connected to the quarters of the management officials and to the dispensary. Plates No.18, 19 and 20 show proposed layouts for three types of villages. The standard house plot for one family is 400 sq. metres.

11.24 Provision for Schools

At the present time, the population of the Rahad Project Area is about 45,000 people. This population is mainly in the north of the Project Area and there are at present only three elementary schools in the area. Since it is proposed to bring a large number of people to farm and settle in this Area, provision will have to be made for schooling for their children. Assuming that there will be one family to every 12.75 feddans of irrigable land and an average family will consist of five persons, the total population of the Rahad Project Area will be about 170,000 persons. This population will be spread over approximately 110 villages. The average new village unit of 340 farmers will have a total population of 1,700 persons. In order to obtain the percentage of school-going children out of the total population, the same figures have been used as in the United Nations' Regional Development Plan for Gezira-Managil area. These figures are based upon age distribution worked out by the Bureau of Educational Statistics of the Sudan's Ministry of Education.

The ratio of school-going children population to the total population is boys 13-15% and girls 10-12%. Of the total student population the distribution in age groups is age 5-6 pre-elementary - 23%, 7-10 elementary - 41%, age 11-14 intermediate - 36%.

The education system in the Sudan provides schools at four levels, viz:-

1) Pre-elementary
2) Elementary
3) Intermediate
4) Secondary Level

The pre-elementary level is for the age group 5-6 and are private schools only. If these pre-elementary schools are required in the Project Area, it is assumed that they will be privately run by village leaders, and no provisions will be made for school buildings. The Government will be providing elementary and intermediate schools for the families of the tenant farmers. At this stage, it is proposed to only consider elementary and intermediate schools in the Project Area. It is assumed that for education above intermediate level, i.e. secondary level and higher level, the students will have to travel outside the area to places such as Wad Medani. Since 1955, the Republic of the Sudan has made a great effort to develop the elementary and intermediate education. It is assumed that this extension of educational facilities will be continued in the new Project Area. The recommended standards of the Ministry of Education are that each elementary school shall consist of 200 pupils and each intermediate school shall consist of 160 pupils. The U.N. Mission for the development of the Regional Plan for Gezira-Managil Area state that owing to paucity of funds and want of trained teachers, the Republic of the Sudan may not be in a position to provide for universal and compulsory education at intermediate stage by the year 1975. Accordingly, they have estimated that only 25% of the children of the age group 11-14 will be able to receive the facilities of intermediate education by 1975. This figure of 25% will also be assumed for the basis of planning schools in the Rahad Project Area.

If one average village of 340 farmers and total population 1,700 persons is considered, bearing in mind the student population factors previously stated, it will be seen that in each village there are 238 boys and 187 girls of school-going age. In the elementary school age group of 7-10 years, there will be 98 boys and 77 girls. Although it is the policy of the Ministry of Education to have separate schools for boys and for girls, it will be assumed that in the Rahad Project, the one elementary school in each village will serve the total of 175 boys and girls. The layout of the villages has been designed such that about five villages are clustered round one central service village. This central service village is also the Block Headquarters as far as the scheme management is concerned. Except for a few isolated cases, all the surrounding five villages are within five kilometres of the central service village. Thus it would be convenient to site the intermediate school in the service village. The one management block will consist of about six villages and the total average population of the area will be 11,300 persons. In the intermediate school age group of 11-14 years, there will be 570 boys and 450 girls. Assuming that only 25% of these students will be able to continue their education at intermediate level, then intermediate school places will have to be provided for 143 boys and 113 girls. This would mean one intermediate boys' school and one intermediate girls' school in each block village.

Thus, the ideal for the Rahad Area would be one elementary school in every village and in each block village, as well as an elementary school, there will be one intermediate boys' school and one intermediate girls' school. The cost of building all these schools will be nearly two million pounds. Although this is the ideal to be aimed at, it is proposed that, in the first instance, the scale to be provided shall be one elementary school to every village and one intermediate school in each service village. A total of 92 elementary schools and 16 intermediate schools are recommended for the initial stage of the Rahad Area development.

CHAPTER 12

PROJECT WORKS, COSTS AND PROGRAMME

12.1 MAIN WORKS INCLUDED IN THE PROJECT

The main works recommended to be carried out for the Rahad East Bank Project are described below and the costs summarized in Table 12.1 showing total amount, foreign exchange and customs duty.

12.11 Canal Headworks on East Bank at Roseires Dam

The Ministry of Irrigation and H.E.P. have asked for the canal headworks to be provided on the east bank with discharging capacity of 360 cumecs. This is a similar capacity to that proposed for the future headworks on the west bank. The east bank headworks comprises three outlets in the east transitional buttresses connected by penstocks to the canal headworks which is sited on higher ground to the east of the concrete dam.

12.12 Headreach Canal - K.0. to K.27

The headreach canal is to be excavated with a design capacity 132 cumecs and 65 cumecs of this is required for the irrigation supply to the Rahad East Bank Project. The remaining 67 cumecs capacity in the headreach is available for further development of the Rahad Project or for the first stage development of the Roseires Project.

It is planned that excavation of the headreach canal will be by tractor-drawn scraper trains and that the earthworks for both the headreach and the Rahad Link Canal be included in one major contract.

12.13 Rahad Link Canal - K.27 to K.191

The Link Canal discharging into the River Rahad is to be excavated with design capacity of 65 cumecs. The canal structures are designed for 83 cumecs so that the canal can in the future be enlarged to take this flow. Regulators are provided at the head and tail of this canal and siphons will convey the canal discharge under the River Dinder and the Khor el Atshan. There are also numerous cross drainage works for the smaller drainage lines.

It is planned that excavation be carried out by tractor-drawn scraper trains.

12.14 River Rahad Barrage at Malek

The barrage is required to divert the River Rahad flow including the supply by canal via the Link Canal, into the Project Main Canal. The barrage is designed to pass a flood of

Table 12.1: Summary of Costs of Project Works

Item	Description		Amount 1000LS	Foreign Exchange 1000LS	Customs Duty 1000LS
I.	IRRIGATION WORKS, BUILDINGS AND SERVICES				
A.	Preparatory Work		156	53	15
B	Purchase of Land and Compensation		25	-	-
C	Canal Headworks including alteration to Roseires Dam		2,400	(1,500)	(300)
D	Roseires to Rahad Canal:	Earthworks	6,656	4,659	559
		Structures	2,144	862	281
E	Rahad Barrage at Malek		372	173	52
F	Project Main Canal:	Earthworks	3,201	2,241	269
		Structures	743	327	105
G	Distributaries:	Earthworks	1,557	654	148
		Structures	2,183	1,026	308
H	Drains and Escapes:	Earthworks	137	58	13
		Structures	118	45	16
J	Workshops		128	77	31
K	Buildings for Agriculture and Irrigation		4,075	1,603	495
L	Other Buildings		1,558	592	178
M	Water Supply		1,008	510	153
N	Electricity Supply		118	58	21
O	Communications: Roads, Bridges etc.		2,025	1,120	323
		Telephones	267	143	57
	ITEM I SUB TOTAL		28,871	15,701	3,324
II	AGRICULTURAL PROCESSING PLANTS				
A	Ginning Factory		720	425	114
B	Groundnut Decortication Plants		300	216	54
	ITEM II SUB TOTAL		1,020	641	168

Table 12.1 (Contd.)

Item	Description	Amount 1000LS	Foreign Exchange 1000LS	Customs Duty 1000LS
III.	EXCAVATING PLANT	328	255	62
IV.	LAND PREPARATION (1)			
	Bush Clearance	336	204	34
	Land Smoothing	420	261	48
	ITEM IV SUB TOTAL	756	465	82
V.	AGRICULTURAL MANAGEMENT (1)			
	Vehicles	727	458	201
	Tractors	747	583	88
	Agricultural Implements	666	373	93
	Miscellaneous Plant	192	143	34
	ITEM V SUB TOTAL	2,332	1,557	416
	ITEMS I, II, III, IV & V - TOTAL	33,307	18,619	4,052
VI.	CONTINGENCIES (2)	3,331	1,862	405
VII.	ENGINEERING AND SUPERVISION (3)	3,000	1,500	-
	PROJECT TOTAL	39,638	21,981	4,457

Footnotes (1) For details see Part II (Economics).

(2) Taken as 10% on Items I, II, III, IV & V.

(3) Taken as 10% on Items I, II and III.

200 cumecs and the canal headworks has a capacity of 138 cumecs.

12.15 Main Canal

The Project Main Canal has a design capacity of 110 cumecs and a total canal length of 162 kilometres. Nine cross regulators are provided at intervals along the canal where the distributaries offtake in groups. The first offtakes are at K.30 on the canal.

The main canal alignment is adjacent to the Qal'at Arang hills between K.65 and K.80. This reach of the canal includes a short length with high command, up to 3.0 metres, at K.67. There is also a two-kilometre length in deep cutting between K.73 and K.75 where the maximum depth of cut to bed-level is about 20 metres. A considerable part of this excavation is expected to be in hard rock. The channel width is narrowed to eight metres for this deep cutting and the rock excavation is provisionally estimated at 165,000 cubic metres.

It is planned that excavation be carried out by scraper trains and that the earthworks for the main canal be included in one major contract.

12.16 Distributaries

The canalized area of 475,000 feddans is served by nine major canals with a total length of about 190 kilometres. The capacity of the major canals is in the range from 4 to 18 cumecs.

In addition there are about 1,600 kilometres of minor canals, 650 kilometres of double watercourses, 7200 kilometres of watercourses and 16,800 kilometres of field laterals.

It is planned that excavation of the major canals will be by dragline and excavation of the minors by elevating graders. The double watercourses are normally excavated by hand as a suitable type of machine has not yet been obtained for excavating these channels.

The watercourses and field laterals are normally excavated by ditching ploughs. Recent practice on irrigation projects in the Sudan has been for the Ministry of Irrigation to mark out the field laterals on the ground and for the Agricultural Management to carry out the ditching operation against repayment.

The necessary control structures include regulated falls, vertical lifting rollers sluice gates and movable weirs on the major canals. Control of distribution to the minor canals is by movable weirs. Circular night storage weirs with pipe regulators are provided at intermediate points on the minors.

The outlet from the minors comprise 0.50 metre diameter pipe regulators for supply to the double watercourses and 0.35 metre field outlet pipes and valves for supply to the standard watercourses.

12.17 Drains and Escapes

This work involves the construction of approximately 65 kilometres of major drains and 320 kilometres of minor drains. These figures represent 33 per cent and 20 per cent of the respective total length of major and minor canals in the Project.

The provision of escape regulators, with the necessary channels, on the main canal at K.20, K.75 amd K.150 is also included.

12.18 Buildings and Workshops

The construction of buildings for the staffs of the Ministry of Irrigation, the Agricultural Management and other Government departments is required comprising about 2,600 buildings including 2,290 houses.

In addition workshops are provided for the Agricultural Management and for the Ministry of Irrigation.

12.19 Electricity and Water Supplies

Tubewells are to be used for the water supply to 64 villages; also filter plants to supply 31 villages in the southern part of the area from the irrigation canals as water supplies cannot be obtained from groundwater.

In addition it is necessary to provide a water supply either by tubewells or by filter plant to the Project Headquarters and the three Irrigation Sub-Division Headquarters.

Provision is made for mains electricity supply to the Project Headquarters by transmission line from Wad Medani, a distance of 30 kilometres. Separate installations consisting of small diesel driven generators are planned for the 15 Agricultural Block Headquarters.

12.20 Communications

Allowance is made in the estimates for the construction of bridges over the Blue Nile and Rahad rivers and an all-weather road from Wad Medani to the Project Headquarters.

A pontoon ferry across the Blue Nile is provided for use during the development period.

A dry weather landing strip is planned for the Southern Group Headquarters and a loading station on the Sudan Railways line near Wad Medani.

The estimate also includes for a system of telephones throughout the Project area including a link along the supply canal from the Rahad to Roseires Dam.

12.21 Agricultural Processing Plants

A central ginning factory consisting of four units is included and it is planned to have this factory sited at the Project Headquarters. Fifteen groundnut decortication plants, each comprising of four decortication machines, are provided.

12.22 Preparatory Work

The preparatory work includes land settlement and compensation, the survey of canal and drain lines throughout the Project area and the provision of a "Misga" to make a temporary water supply available for the construction works. It is planned that a supply be pumped from the Blue Nile at a point approximately due west of Sherif Yacoub, and conveyed by a small channel for eight kilometres across the Blue Nile - Dinder Gezira. The supply can then be pumped a second time through a siphon under the River Rahad and thence by rising main to the high ground north of Sherif Yacoub at about R.L. 415.0 metres. From this point "Misgas" can be excavated to the north and south for a total length of about 50 kilometres. This will ensure a water supply from Ein el Luweiqa in the south to Abdullah in the north and will facilitate construction works throughout most of the area in Groups 1 and 2.

12.3 PROVISION OF EATHMOVING PLANT

12.31 Major Earthworks Contracts

It is planned that the excavation of the main supply canal from Roseires Dam to the River Rahad and the Project Main Canal be let as separate earthworks contracts. The total volume of earthworks in these two contracts is given below:-

	Earthworks Million Cubic Metres
(1). Supply Canal from Roseires Dam to River Rahad	29.4
(2) Project Main Canal	14.2

A total contract period of 27 months is proposed for the supply canal from Roseires Dam to the River Rahad. Allowing six months for mobilisation of plant and equipment the available working time is 21 months. The contract is comparable in size to that which was carried out for the excavation of the Gezira New Main Canal and Managil Canal, 1957 - 1959. It is estimated that 29 scraper trains, comprising 20 scrapers and 39 - 360 H.P. tractors, will be needed for carrying out this work. In addition, a number of lighter tractors with dozer attachments for trimming the excavation, motor graders, fuel and water tankers, low loader trailers, motor transport and workshop equipment will be required. The estimated cost of plant required is shown in Table 12.1.

A contract period of 24 months is proposed for the Project Main Canal excavation of which four months is set aside for mobilisation and 20 months allowed for working time.

It is estimated that 14 scraper trains, comprising 14 scrapers and 19 - 360 H.P. tractors, will be needed for this contract together with a similar proportion of ancillary plant as for the larger contract.

12.32 Project Canalisation Earthworks

A summary of the total earthworks quantities in the distributary canals, escapes and drains is given in Table 12.2

Table 12.2: Summary of Earthworks and Excavating Plant

Earthworks	Excavating Plant	Total Length (km)	Earthworks (Million Cubic Metres)
Major Canals	Dragline	190	3.76
Major Drains	"	65	0.40
Minor Drains	"		
Escapes	"	-	0.37
Minor Canals	Elevating Grader	1,680	10.37
Double Watercourses	Hand	650	2.26
Watercourses	Ditching Plough	7,200	5.45
Field Laterals	" "	16,800	4.26
	Total for Project Canalization		27.35

It is assumed that all the Project canalization earthworks will be excavated either directly by the Ministry of Irrigation or by local contractors. In the event of all the excavation being carried out directly, a certain amount of new equipment will need to be purchased to supplement the Ministry of Irrigation's plant fleet. An estimate of the plant required is given in the detailed estimate, Appendix III.4. It is presumed that no draglines are available but that five out of an estimated total of ten elevating graders are available for work on the Rahad Project and that the necessary blade graders for preparing and maintaining access roads throughout the Project area are available.

12.4 WORKS PROGRAMME

The implementation of the Rahad East Bank Project is planned to be completed in a period of four years. The year, for planning purposes, is taken from 1st July to 30th June.

The works programme is scheduled to complete canalisation of 310,000 feddans comprising Groups 1 and 2 by the end of the third year. The remainder of the Project area of 165,000 feddans in Group 3, will be canalized and brought under cultivation by the end of the fourth year. It is considered preferable to delay canalization of Group 3 until the fourth year, because of the remoteness of this part of the Project area from the Blue Nile the nearest available reliable water supply. Canalization can be more easily effected in Group 3 when a water supply is available in the Project Main Canal.

If a decision is taken during 1965 summer to implement the Project as soon as possible then the programme dates are as follows:-

Year One	ends	June 1966
Year Two	"	" 1967
Year Three	"	" 1968
Year Four	"	" 1969
Year Five	"	" 1970

The proposed works programme is shown in Table 12.3.

Table 12.3: Works Programme for Rahad Project

Project Works	Item (ref.Appendix III)	Construction Period (Years)
Works to be started during Year One:		
Preparatory Work	IA	1
Land Resettlement & Compensation	IB	1
Supply canal Roseires to Rahad - Earthworks	ID	1,2,3,
Workshops	IJ	1,2,3,
Water supply	IM	1,2,3,4
Communications	IO	1,2,3,4,5
Works to be started during Year Two:		
Canal Headworks and alteration to Roseires Dam	IC	2,3
Supply canal Roseires to Rahad - Structures	ID	2,3

Project Works	Item (ref. Appendix III)	Construction Period (Years)
Works to be started during Year Two(contd.)		
Rahad Barrage at Malek	IE	2,3
Project Main Canal - Earthworks	IF	2,3
" " " Structures	IF	2,3
Distributaries - Earthworks	IG	2,3,4
" Structures	IG	2,3,4
Drains and Escapes	IH	2,3
Buildings for Agricultural, Irrigation Management	IK	2,3,4,5
Blue Nile Bridge	IO	2,3,4
Rahad Bridge & Road to Project H.Q.	IO	2
Landing Strip	IO	2
Railway Loading Station	IO	2
Telephones	IO	2,3
Ginning Factory	IIA	2,3,4,5
Works to be started during Year Three		
Other Buildings (excl. schools)	IL	3,4
Works to be started during Year Four		
Groundnut Processing Plants	IIB	4,5
Works to be started during Year Five		
Schools	IL	5,6,7,8,9,10.

APPENDIX I

CANALISATION LAYOUT DESIGN AND DIMENSIONS

I.1. STANDARD LAYOUT WITH 80 FEDDAN "NUMBERS"

(a) Canals and field channels may not cross a natural drainage line.

(b) Minor canals are so far as possible spaced at 1498 metre to accommodate five 80 feddan fields. The alignment of the Minors should follow an overall ground slope of 20 cm. per km.

(c) The lines of watercourses, i.e., parallels between the minor canals, should so far as possible have slopes of at least 5 cm. per km. and not exceeding 20 cm. per km. The upper limit for slope must be strictly adhered to as this is considered the maximum permissible for the field furrows which are normally parallel to the watercourses. (See Paragraph 2 (b) below).

(d) The major canals are normally spaced at intervals of 10 to 15 kilometres. They are sited on high ground and aligned across the contours so that they follow generally the steepest natural ground slope from the main canal towards the river. The tail reaches of major canals may be on flatter slopes when aligned parallel to the river.

Regulated falls, varying from 0.5 to 1.0 metre drop may be sited at minor canal offtakes where the major is following the steeper slopes from the main canal towards the river. Another solution is to provide larger falls, up to 2.0 metre drop, which are sited at alternate minor canal offtakes so reducing the number of control structures required to the standard Gezira practice. Where the Majors are aligned on flatter slopes, cross regulators are provided at alternate minor canal offtakes, i.e. normally at intervals of 2996 metres. The water level upstream of these regulators should not be more than 1.00 m. above the ground level, and at the same time this level should be high enough to satisfy the two conditions of design water levels described below. It should be 0.50 to 0.60m above the upstream pool level of the next cross regulator, to provide adequate water slope on 3.0 km. of canal (say 10 cm. per km) and sufficient head on the regulator, 20 to 30 cm.

At the same time, the minor canal will require a pool level at least 85 cm. above the ground level, which is

made up as follows:-

Minimum water level in minor canal above cultivation.	0.20
Night storage depth in first reach of minor canal and water slope assumed to be 1.0 cm. per km. for 3 km.	0.33
Head through movable weir from major pool to the minor canal.	0.30
Total	0.83 m.

II.2. MODIFIED LAYOUT FOR AREAS WITH LESS UNIFORM TOPOGRAPHY

In order to achieve as regular a layout as possible, the above criteria may be relaxed when necessary as follows:-

(a) A watercourse line may rise up to 10 cm. and a lateral may rise up to 5 cm.

(b) When it is not possible to align the watercourses with slopes within the limits described in paragraph 1. (c) above, then the field layout may be modified as follows:-

(i) Where the watercouse is aligned on ground with slope between 20 cm. and 40 cm./Km. the spacing of the laterals should be reduced to 78 metres. This will provide plots of 75 metres instead of the standard 150 metre width. The furrow length in this case will be 75 metres and the fall over this length will not exceed 3 cm.

(ii) On steeper ground where the water course is aligned with slope between 40 cm. and 1.0m/Km. the spacing of the laterals should be maintained at the standard distance of 153 metres.

The plots will be divided into border (Angayas) by small banks (Tagnets) and additional field channels provided to convey the irrigation water from the laterals to the borders. For ground slope of 1.0m/km, the furrow length in the borders will be reduced to 30 metres so that the fall over this length will not exceed 3 cm.

(c) The slope of minor canal lines may be reduced below 10 cm. per km.

(d) The command upstream of Major regulators may be increased to 1.20 metre for short reaches of canal.

I.3 STANDARD DISTANCES FOR NIGHT STORAGE CANALS (ALL DISTANCES IN METRES)

(a) Distance between field laterals:

10 feddan Plot = 150 m. x 280 m.
Width of lateral = 3 m.
153 m.

(b) Distance between Watercourses

10 feddan Plot = 280 m. x 150 m.
Width of water course = 6 m.
Width of road = 6 m.
292 m.

(c) Distance between Minor Canals

(1) 5 No. parallel 80 feddan fields between adjacent Minors.

Centre line of Minor to Outer Toe	9.5	
Width of Road	6.0	
½ width of watercourse	3.0	
Centre line of minor to centre line of watercourse		18.5
4 No. Numbers @ 292		1168.0
5th Number to edge of cultivation		283.0
Width of bank	3.0	
Minor drain	9.0	
Width of road	6.0	
Outer toe to centre line of Minor	10.5	28.5
Distance between centre line of Minors		1498.0

(2) Spacing for 80 feddan field length between adjacent Minors

Centre line of Minor to Outer Toe	10.50	
Width of Road	6.0	
½ Width of field lateral	1.5	
Centre line of Minor to centre line of lateral		18.0
8 plots @ 153 m.		1224.0
½ width of field lateral or bank	1.5	
Width of road	6.0	
Minor drain	9.0	
Outer toe to centre line of Minor	10.5	
Centre line of Minor to centre line of lateral		27.0
Distance between centre lines of Minors		1269.0

(d) Distance between Double Watercourses

½ width of Double Watercourse	4.0
Width of road	6.0
½ width of lateral	1.5
8 No. Plots @ 153m.	1224.0
½ width of bank	1.5
Drain	9.0
Width or road	6.0
½ Width of Double watercourse	4.0
	1256.0

(e) Centre Line 1st Double Watercouse to parallel Major

Centre line of Major to Outer Toe, say	17.8
Outer toe to centre line of carrier canal	2.9
Centre line of carrier canal to Outer toe	8.3
Width of road	7.0
½ Width of double watercourse	4.0
	40.0

(f) Night Storage Weirs-
Intermediate Pipe Regulators

Centre line of roadway is 25.0m downstream the centre line of the Double Watercourse.

(g) Minor Head - Moveable Weir or Pipe Regulator

Centre line of roadway is 31.5m from the centre line of the Major.

(h) Major Regulator

Centre line of roadway is 35.0m. downstream the Minor offtake.

APPENDIX II

II.1. TRANSPORTATION OF AGRICULTURAL PRODUCE FROM THE PROJECT TO PORT SUDAN

There are three alternative routes by which the Rahad Project agricultural produce could be transported to Port Sudan.

Alternative A: New railway line to be built from Hawata to centre of the Project Area. All produce carried by railway via this line to Hawata and then via Gedaref to Port Sudan.

Alternative B: Bridge built across the Blue Nile near Wad Medani. Produce carried by road transport to Medani and then on existing railway line northwards via Khartoum and Atbara to Port Sudan.

Alternative C: Road transport to Wad Medani and then by railway on existing track south to Sennar and then to Port Sudan via Hawata and Gedaref.

The following table shows the freight cost of an average year's crop:-

Freight Rates per Ton Kilometre by Alternative Routes to Port Sudan

Sudan Railways Route	Distance Km.	Lint		Seed		Groundnuts		All Produce Total freight cost	Av. Rate per Ton Km.
		LS. per ton	Total freight charge	LS. per ton	Total freight charge	LS. per ton	Total freight charge		
Medani-Khartoum - Port Sudan	960	6.6	248,160	3.1	169,880	2.5	278,500	696,540	3.6mm
Medani-Sennar-Hawata-Port Sudan	1130	7.4	278,240	3.4	186,320	2.3	311,920	776,480	3.4mm
Hawata-Port Sudan	885	6.1	229,360	2.9	158,920	2.3	256,220	644,500	3.6mm
Centre of Project-Hawata-Port Sudan	995	6.9	259,440	3.2	175,360	2.6	289,640	724,440	3.6mm

If 110 km of new track are constructed for a total capital cost LS. 1.5 million then the annual depreciation and interest charge will be about LS. 150,000. At the overall average freight rate of 3.6 mm per ton kilometre, the revenue to Sudan Railways from carrying the average annual agricultural produce of 203,800 metric tons will be LS. 80,600. Very little other traffic is envisaged apart from the Rahad Project agricultural produce. This LS. 80,600 will not cover the capital charges let alone pay for the fuel, wages and maintenance, so the freight charge of 3.6 mm. is not realistic for this section of track. The actual operating costs are estimated as 2.0 mm per ton kilometre. Thus, the cost of transporting the produce from the centre of the Project to Hawata is:-

Capital Depreciation and Interest	=	150,000
Operating Cost $\frac{203,800 \times 110 \times 2.0}{1000}$	=	45,000
	LS.	195,000

This total cost LS. 195,000 is 8.7 mm per ton/kilometre. Thus the total annual cost from the Project Area to Port Sudan will be LS. 195,000 + LS. 644,500 = LS. 839,500.

If the alternative of road transport to Wad Medani and then rail to Port Sudan is considered the cost of the Blue Nile Bridge must be taken into account. The cost of transporting the produce from the Project Area to Wad Medani will be:-

Capital Interest and Depreciation	=	153,000
Road Transport $\frac{203,800 \times 25 \times 13}{1000}$	=	66,000
	LS.	219,000

(Assuming contract haulage rate of 13 mm per ton/kilometre)

The total annual cost from the Project Area to Port Sudan via Khartoum will be LS. 219,000 + LS. 696,540 = LS. 915,540.

A comparison of the annual freight charges on three routes is:-

Alternative A	LS. 839,500	(Assuming a freight rate of 8.7 mm per ton/kilo for the haul from Project to Hawata)
" B	LS. 915,540	
" C	LS. 995,480	

If the new railway line is built and operated at existing Sudan Railways freight rates the transportation costs from the

Project to Port Sudan, (Alternative A) would be LS. 724,440.

The capital costs of the Blue Nile Bridge and 110 km of new railway track are estimated to be about the same. On existing freight rates, the carrying of the produce to Port Sudan via a new spur line to Hawata, will save about LS. 191,000 per annum compared with road transport to Wad Medani over a new bridge and then by rail to Port Sudan via Khartoum and Atbara. If the existing railway track is unable to carry this extra freight, then it could be sent by the alternative route to Port Sudan via Sennar and Hawata. The total freight cost of this alternative route would be LS. 271,000 more than via the new spur, and LS. 80,000 more than via the most direct route from Wad Medani.

Estimates show that the new spur line would not be a profitable venture as far as the Sudan Railways are concerned and on the existing freight rates they would make a loss of at least LS. 100,000 per annum operating this line. The average produce freight charge of 3.6 mm. would have to be increased to 8.7 mm to make this section of track cover the operating and capital charges.

The total capital depreciation and interest of the proposed Blue Nile Bridge has been charged against the road transport from the Project Area to the railhead at Wad Medani. Although this bridge is essential for the road transport, there will be many other users who will also benefit from a bridge. For instance there is the great social benefit to the people living and working on the Project who will be given access to the social amenities of Wad Medani. It is not possible to cost these benefits but when comparing the relative Project transportation routes for the produce it is perhaps unfair to put the full cost of the bridge against the road transportation of the Project Agricultural produce. A more realistic comparison would be to charge half the bridge capital depreciation and interest charges to the produce transportation and half to the other users' benefits, including the main route from Wad Medani to Gedaref.

The annual freight costs of road transport to Wad Medani and the existing railway to Port Sudan via Khartoum appear to be LS. 191,000 greater than the alternative construction of a new spur line. If the estimated operating loss on the new line of LS. 100,000 and half the annual capital costs of the bridge, i.e. LS. 75,000, is taken into account then the additional cost of transportation via Medani compared with direct to Hawata is only about LS. 16,000.

Thus it is proposed that a road bridge should be built across the Blue Nile and that an extension of the

Sudan Railways 3'6" gauge track will not be required. Although the capital required for the bridge and railway extension is the same the actual produce transportation costs to Port Sudan will be greater if a new railway line is omitted. But if the amenity aspect of the bridge is considered and allowance made for increased operating, depreciation and interest charges on the new line then the annual costs are similar. The social and amenity benefit of a bridge linking the Project Area with Wad Medani outweighs the possible apparent increase in freight costs.

II. 2. LIGHT RAILWAY APPRAISAL

An alternative to road transport within the Project Area is a Light Railway as in the Gezira and Managil Schemes. The Gezira Light Railway (G.L.R.) will be used as a comparison for cost and layout.

The original G.L.R. was built in 1925 and prior to the Managil Extension in 1956, there was 292 km. track serving a cultivable area of 1,000,000 feddans. When the Managil Extension of a further 870,000 feddans was developed between 1956 and 1963, the length of light railway track was increased by 533 km. to give a total of 825 km. This increased track density was partly due to the irregular shape of the Managil Extension and to the fact that unlike the original Gezira Area, the Managil Extension had no Sudan Railways 3'6" gauge track running through its length.

The areas under cotton cultivation in the Gezira and in the Managil are 248,000 feddans and 264,000 feddans respectively. Since the light railway was built purely to transport the cotton crop the track length to cultivated area relationship must be considered relative to the cotton area. Thus the track length to cotton area for the Gezira and Managil Schemes are respectively 850 and 500 feddans to one kilometre of track.

The cotton area in the Rahad Project is 135,000 feddans. Relating this area to the track densities of the Gezira and Managil Schemes, the length of track required would be 159 km. and 270 km. respectively, but since two main crops are proposed for the Rahad Area, some additional track will be required. Even if the main track was capable of carrying the groundnut crop as well as the cotton crop additional sidings would have to be provided for the loading of the groundnuts. Since in the Rahad Area it is not proposed to have a Sudan Railway 3'6" gauge railway, the light railway would have to carry all the agricultural produce. Thus the minimum length of light railway track is considered to be 220 km.

The estimated cost of constructing 220 km. light railway is:-

Rails, accessories, and sleepers @ LS. 3,336/km.	733,900
Construction cost @ LS. 822/km.	180,600
Bridges across canals	
3 Major crossings @ LS. 4,000	12,000
10 Minor " @ LS. 1,500	15,000
One Motor Grader	12,000
Locomotives	200,000
Rolling Stock	175,000
Buildings	40,000
Signals etc. @ LS. 750/km.	166,000
LS.	1,533,500

To estimate the annual operating cost, the existing costs of the G.L.R. will be used. For 825 km. track the annual wages cost is LS. 224,800. Thus we will assume that for 220 km. track the wages will be LS. 60,000.

One year's operating costs are estimated as:-

Wages	60,000
Capital Depreciation (40 years life) & Interest	168,900
Stores	10,000
Maintenance of track LS. 80/km.	17,600
" " rolling stock	1,000
" " building	2,500
LS.	260,000

If this light railway carries all the cotton and decorticated groundnuts to the main HQ, the total haul in one year will be:-

Seed Cotton	4,035,000 ton/km.
Decorticated nuts	5,100,000 ton/km.
	9,135,000 ton/km.

Thus assuming the cotton and groundnuts are the only items carried, the cost per ton kilometre is:-

$$\frac{260,000 \times 1,000}{9,135,000} = 28.5 \text{ mm.}$$

In practice some fertilizer and seed would be carried but this would be a small percentage of the total. The Gezira Light Railway only carries 4% of non-cotton associated items per annum. The cotton seed and fertilizer are only 5% of the annual freight.

The tonnage carried during the months of August, September, October and November is negligible. The only wet month during which any quantity of freight is carried is July during which about 5% of the yearly total is hauled. The light railway is also sometimes put out of action by washing out of the tracks. The farmers and their families receive no benefit from any wet season mobility as the light railway is used solely for the transportation of cotton and associated agricultural products. Even if a light railway were constructed there still remains the problem of transporting the produce from the fields to the loading stations. The present practice is to use animal transport, but if a system of road transport is introduced, then it may be possible to take some produce direct from the fields to the processing plants.

II. 3. ROAD TRANSPORTATION COSTS

For the purpose of calculating the agricultural produce to be transported and the distances it has to be moved, the Rahad Area has been divided into 3 Groups which approximate to the proposed 3 Management Groups. Within these groups, unit areas have been measured and the average haul to the Project HQ Area (the high ground north of Sherif Yacoub) has been determined. The summation of the areas and hauls in the respective Groups become:-

Group	Est.Net Cultivated Area (Feddans)	Mean Annual Agric.Produce (metric tons)		Haul in ton km.		Mean Haul
		Seed Cotton	Groundnuts *	Seed Cotton	Groundnuts	km.
I (North)	128,000	28,400	50,100	426,000	750,000	15
II (Centre)	161,700	35,900	63,400	934,000	1,772,000	28
III(South)	140,300	31,200	55,250	2,685,000	4,750,000	86
TOTAL:	430,000	95,500	168,750	4,045,000	7,272,000	Mean=42

* This is the weight of groundnuts in husks. To obtain the weight of nuts decorticated multiply by 0.7

It will be assumed that a separate transport fleet will be required for both main crops. Although the groundnut picking season commences about one month before the cotton picking season and also finishes sooner, it is not considered practical to attempt to overlap the transportation vehicles. The picking season for the cotton crop is about six months and for the groundnuts 2 months, but for the transportation it will be assumed that the whole crop must be moved from the fields to the processing plants in four months.

On the assumption that all the agricultural produce will be moved from the villages in 30 ton diesel trucks with trailers, the capital cost of one vehicle and trailer will be taken as LS. 12,500 and the life of one vehicle will be assumed as 5 years.

The cost of running one lorry and trailer per year is:-

Capital Depreciation - 1/5 of LS. 12,500 Interest on Capital at 10%	=	3,300
Crew Wages - 17 weeks @ LS. 2.500/day	=	300
Office Overheads	=	150
Repairs	=	500
Fuel - (20,000 km.)	=	200
Contingencies	=	550
Total per year	LS.	5,000

The vehicle requirements will be considered for each Group and for each crop to be carried.

Crop	Group	Mean Haul (km)	Produce to be moved (Metric tons)	Produce carried by one vehicle in 4 months (Metric ton)	Number of vehicles required
Seed Cotton	I (North)	15	28,400	6,950	4
	II (Centre)	28	35,900	5,200	7
	III(South)	86	31,200	31,200	9
Ground nuts in husk	I (North)	15	50,100	5,500	9
	II (Centre)	28	63,400	4,100	15
	III(South)	86	55,250	2,750	20
Decor-ticated ground-nuts	I (North)	15	35,100	12,200	3
	II (Centre)	28	44,400	9,200	5
	III(South)	86	38,700	6,100	6

The above table is based on each vehicle working 6 days per week for 4 months i.e. 102 working days.

The loads carried by one lorry and trailer are:-

Seed Cotton	17.0 metric tons
Groundnut in husks	13.5 metric tons
Decorticated groundnuts	30.0 metric tons

Seed Cotton

A total of 20 vehicles with trailers will be required to transport the seed cotton to the Ginning Factory. The cost of operating these vehicles will be 20 x 5,000 = LS. 100,000 per annum.

The average cost of transportation will be :

$$\frac{100,000 \times 1,000}{4,045,000} \text{ mm per ton kilometre} = \underline{24.8}$$

This is a maximum cost as the whole depreciation and capital interest charges for a year have been charged against four months operation. If further work (e.g. carrying fertilizer and seed) is done during the remaining eight months of the year, then the cost per ton kilometre would be reduced.

The seed cotton haulage cost per ton kilometre for each group becomes:

Group I $\frac{4 \times 5{,}000 \times 1{,}000}{426{,}000}$ = 46.9 mm

Group I $\frac{7 \times 5{,}000 \times 1{,}000}{934{,}000}$ = 37.1 mm

Group III $\frac{9 \times 5{,}000 \times 1{,}000}{2{,}685{,}000}$ = 16.7 mm

A comparison with haulage rates quoted by local contractors gives close agreement, viz:

Mean Haul Distance	Rate per ton kilometre	
	Quoted by Contractor	Calculated
Up to 15 km	50 mm	47 mm
from 15 to 40 km	40 mm	37 mm
Over 40 km	18 mm	17 mm

Groundnuts

To remove the groundnut crop in husks to a central decortication plant will require a total of 44 vehicles. The total annual operating cost would be 44 x 5,000 = LS. 220,000 and the cost per ton kilometre transported would be:-

$$\frac{220{,}000 \times 1{,}000}{7{,}272{,}000} = 30.3 \text{ mm}$$

If the groundnuts are decorticated at village level and then transported, costs will be greatly reduced and a total of 14 vehicles with trailers would be required. The annual operating cost will be 14 x 5,000 = LS. 70,000 and the cost per ton kilometre will be :-

$$\frac{70{,}000 \times 1{,}000}{5{,}090{,}000} = 13.8 \text{ mm}$$

This results in saving in transport of LS. 150,000 per annum. Although decortication at village level makes management more difficult and will increase the annual management costs by about LS. 20,000, the extra cost of transporting the husks makes central decortication out of the question.

TABLE II. 1 SUMMARY OF ROAD TRANSPORTATION COSTS

Group	Mean Haul (km)	Agricultural produce to be moved (ton kilo)			Number of Vehicles with Trailers Required			Annual Operating Cost per ton kilo (mm.)		
		(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
		Seed Cotton	G/Nuts in Husks	G/Nuts Decorti-cated						
I	15	426,000	750,000	525,000	4	9	3	46.9	60.0	28.5
II	28	934,000	1,772,000	1,240,000	7	15	5	37.1	42.3	20.2
III	86	2,685,000	4,750,000	3,325,000	9	20	6	16.7	21.0	9.0
TOTAL		4,045,000	7,272,000	5,090,000	20	44	14	24.8	30.2	13.8

II. 4. ROAD TRANSPORT FROM PROJECT HQ TO RAILHEAD AT WAD MEDANI

The proposed Project HQ is about 25 km. due east of Wad Medani. The agricultural produce of the area will be processed and collected at the main HQ and will then have to be transported by rail to Port Sudan. A metalled road can be constructed for about LS. 10,000 per kilometre compared with L.S. 13,000 per kilometre for railway track. It would therefore be cheaper to build a road which will have the added benefit of giving the people a direct link with the township of Wad Medani and its social amenities. Even if a rail link was constructed a road would also be required. The construction of an all-weather metalled road is recommended and the produce can be carried to Wad Medani by road transport. The Rahad river and the Blue Nile will be bridged.

The produce to be moved each season is:-

Lint Cotton	37,600 metric tons
Cotton Seed	54,800 metric tons
Decorticated G/Nuts	111,400 metric tons
Total	203,800 metric tons

The distance to be hauled is 25 km. along a metalled highway and allowing 1 hour at each end for loading and unloading, one vehicle should be able to do a return trip in 4 hours. These vehicles can work 20 hours per day and could make 5 trips per day. This produce will be moved over 4 months (102 working days). One lorry and trailer can carry 30 tons of each of these products. Total tonnage to be moved in an average season is 203,800 tons.

In 4 months one vehicle will carry 102 x 5 x 30 = 15,300 tons

$$\text{Number of vehicles required} = \frac{203,800}{15,300} = 14$$

The cost of transporting this 203,800 tons of produce to Wad Medani is thus 14 x 5,000 = LS. 70,000 or 13mm per ton kilometre.

The capital cost of the transport fleet is 14 x 12,500 = LS. 175,000

II.5 COMPARISON OF ROAD AND LIGHT RAILWAY TRANSPORT

The transport will be considered purely for removing the cotton and groundnut crops from the field collecting

areas to the Project HQ. For the purpose of comparison with the light railway, the cotton and groundnut crops will each be considered to have a separate fleet of lorries. In practice, especially if the road transport was let out to contract, it might be possible to overlap these transport fleets and achieve some economy in vehicles. The costs however are calculated assuming separate fleets and these can be considered maximum costs though in practice they may well be less.

Agricultural Produce to be moved in thousand ton/kilo			Light Railway			Road		
Seed Cotton	Decorti-cated Ground-nuts	Total	Capital cost 1000 LS.	Annual Op. Cost 1000 LS.	Cost per Ton km. mm.	Capital Cost 1000 LS.	Annual Op. cost 1000 LS.	Cost per Ton km. mm.
4,045	5,090	9,135	1,533.5	260	28.5	425*	170	18.6

*Repeated every 5 years.

The above costs show that the light railway would require a much larger capital investment and would be more costly to operate. The road transport has the added attraction of spreading the capital investment over 5 year periods and should also encourage private investment if the haulage can be let out to contract. Thus it is recommended that road transport be used within the Project Area and a light railway will not be required. Since the haul roads will be required to be kept graded, provision should be made for 2 motor graders to work continuously grading the main haul roads. The annual cost of operating 2 graders including interest on capital and depreciation is about LS. 16,000. If this road maintenance is added to the road haulage cost, it is still considerably cheaper than a light railway.

II.6 ROAD TRANSPORT COSTS FROM FIELDS TO RAILHEAD

In calculating the vehicle requirements for moving each crop it has been assumed that crops move firstly from the fields to Project H.Q. and then from Project H.Q. to the railhead at Wad Medani. This has been done to facilitate comparison with a light railway system within the project. In fact the groundnut crop will be transported direct from the decortication plant at block level to the railhead at Wad Medani. The vehicle requirements have been revised to take this into account and are:-

(i)	Seed cotton from fields to Project H.Q.	20 No.
(ii)	Lint and cotton seed from Project H.Q. to Wad Medani	6 No.
(iii)	Groundnuts from decortication plants to Wad Medani	17 No.
	Total	43 No.

The total transport cost per year is therefore LS. 215,000, the capital cost every five years is LS. 537,500 and the cost per ton kilometre overall is 15mm.

II.7. BRIDGE ACROSS THE BLUE NILE

The proposed site for the Project Administration Headquarters is only 25 km. due east of Wad Medani. It is proposed that the agricultural produce from the Rahad Area should be carried to Wad Medani and then transported by Sudan Railways to Port Sudan. If the new Project could have a direct link with Wad Medani it would be of immense social benefit to the new settlers and would be a great help in the development of the area.

At present, there are ferries across the Blue Nile at two points near Wad Medani. These ferries only carry one lorry at a time and can barely cope with the present traffic

flow. They would not be able to take the new Project traffic. Although a new ferry could be installed to serve the Rahad Project, it would only be able to deal with the normal day to day traffic and would not be able to carry the agricultural produce of the area. If a direct rail link to Hawata is not built then the agricultural produce will have to be brought out via Wad Medani and will have to cross the Blue Nile. A bridge will be essential and the cost of the bridge will be compensated by the saving in not constructing a 110 km. rail link.

Several possible sites for a bridge have been considered. Topographically the river downstream of the mouth of the River Rahad where the Abu Haraz ferry now operates is a very promising bridge site. If a bridge was built here it would not be necessary to bridge the Rahad as well, but the disadvantage is that the route into the Rahad Area would lead into the extreme north of the Project Area and the distance from Wad Medani to the proposed H.Q. would be increased by about 10 km. A bridge near Abu Haraz would possibly serve Guneid Sugar Factory but Guneid has its own ferry and once the Khartoum to Medani highway is complete, probably the Sugar Factory traffic will cross the Nile by ferry and then link direct with the metalled highway. Light traffic from Guneid to Wad Medani would use a bridge at Abu Haraz but this traffic could easily travel a few more kilometres on dirt roads and then cross by a bridge nearer Wad Medani. Thus it is proposed that a bridge site be located closer to Wad Medani than Abu Haraz.

If the bridge is sited nearer Wad Medani on a more direct route to the proposed H.Q. it would then be necessary to build a bridge across the River Rahad. The Rahad is not a wide river and is contained within the banks. It is dry during the months December to June, so construction would not be difficult. It is estimated that a bridge with a span of 70 metres could be constructed for LS. 150,000.

Three possible bridge sites on the Blue Nile are indicated on Plate No. 17 with the routes shown to the Project Headquarters. At these sites the river appears to be reasonably stable and the river spans are between 400 and 500 metres. There does not appear to be extensive flooding over the river bank so expensive approach spans would not be necessary. Before any decision can be taken, detailed site investigation should be done and drilling will be required to determine the presence of rock on which to found the bridge piers. The suitability of the bridge sites as regards the direct route to the Project Area is in the order of the routes (i.e. 1, 2, 3). But from purely the topographic considerations of the three bridge sites, it is thought that site No. 2 at Hantoub is possibly the best. Tubewells for water supply have been drilled at Hantoub and these borings indicate that the sandstone formation commences about 20 metres below the

ground level so that the rock may lie about 5 to 10 metres below river bed level. The depth and location of suitable foundations for the bridge piers will probably decide the final bridge site. It is recommended that a detailed site investigation be carried out for the Blue Nile Bridge and at the same time borings be made for the Rahad Bridge. The estimated cost of this site investigation is LS. 20,000.

The 700 metre river span of the new bridge at present under construction at Shambat (across the Nile) is costing about LS. 1.7 million. It is estimated that a 500 metre river span Wad Medani could be constructed for LS. 1.2 million and the total cost of the complete bridge would be not more than LS. 1.5 million.

II.8. GINNING CAPACITY

The Rahad Area will have 135,000 feddans medium staple cotton which will give a mean annual yield of 675,000 kantars seed cotton and a maximum annual yield of 880,000 kantars. Medium staple cotton is picked somewhat earlier than long staple cotton and whereas it is now current practice to start ginning towards the end of January, it is considered that in the Rahad Project ginning could commence at the beginning of January. If the present 135 day ginning season is allowed from the beginning of January there is ample time for the whole crop to be moved from the area before the onset of the rains. If there is a bumper crop the ginning season could be extended until the middle of June and this would extend the season by a further 26 days.

There appears to be a large discrepancy between the output per saw gin as quoted by the manufacturers and that obtained in practice at the Wad El Huri ginning factory. Some manufacturers quote as high as 29 kantars per gin per hour, while the design for the proposed new Khashm El Girba factory was based on a conservative figure of 17 kantars per gin per hour. For the 1964 season, the average output obtained at Wad El Huri was only 10 kantars per gin per hour. Proposals for a new project must assume a reasonable level of efficiency in operation of the machinery and so an output of 17 kantars seed cotton per gin per hour will be used in estimating the ginning capacity. This figure of 17 does have some allowance for maintenance and minor breakdowns.

The capacity of one saw gin per season of 135 days is 17 x 20 x 135 = 46,000 kantars seed cotton. Either three or four saw gins can feed one press, four units of four gins and one press is proposed which will handle 736,000 kantars.

For a bumper crop, the season could be extended a further 26 days. Thus four units could gin a further 4 x 4 x 17 x 20 x 26 = 141,000 kantars. The total ginning capacity would then be 877,000 kantars which is only 3,000 kantars less than the maximum expected yield.

II.9. GROUNDNUT DECORTICATION PLANT

A Management Block will control an average of 29,000 feddans cultivable land. This area will grow 9,000 feddans groundnuts which in an average year will yield about 11,000 tons of groundnuts in husk. One groundnut decorticating machine can handle about 2 tons per hour and during the picking season, these machines could be worked 20 hours per day. Thus, the daily input capacity of one decorticating machine is say 40 tons. The groundnut picking season is about 50 days and to obtain maximum decortication efficiency, the nuts should be decorticated soon after picking. If four machines are placed at each block village and worked 20 hours per day, the average yield of the block, i.e. 11,000 tons, will be decorticated in $\frac{11,000}{4 \times 40} = 69$ days.

An allowance of 70 days decortication is therefore reasonable and at each block village, two units each with 2 decortication machines driven by one diesel engine would suffice. Some form of protection from the sun would be needed and the compound should be large enough to store about ¼ the total season's produce of the area it serves. Since the plant is required to work at night, electric lighting is required and this will be supplied by a small lighting generator. Each decorticating machine requires 12 HP, so one 30 HP engine could drive two machines. Plate No. 28 shows a typical layout of a decortication compound.

II.10. MAINS ELECTRICITY SUPPLY.

The 11 KV overhead line will take its supply from an existing sub-station at Wad Medani and the 25 km. of line costs LS. 1,100 per kilometre. An open type sub-station will be required at the Project headquarters which would be equipped with one 500 KVA transformer, one ring main unit, a low tension feeder and a security fence. The estimated cost of the sub-station is LS. 2,000.

The maximum economical distance for low tension power supply is 600 metres so it will be necessary to have 4 No. 100 KVA pole transformers in the township area to step down the domestic power. These pole transformers will cost LS. 300 each and the water plant will also require one. The Ginning Factory will require 2 No. 500 KVA transformers which will cost LS. 1,550 including concrete base and security fence. The total cost of the electricity supply to the Project Headquarters is estimated as LS. 55,000 and the cost breakdown is shown in Appendix III.4.

TABLE II 2.1 GRADING REQUIREMENTS FOR AGGREGATE ROAD BASE

Sieve Designation	Alternative Gradings Percentage by weight passing square mesh sieve								
	A	B	B-1	C	C-1	D	D-1	E	E-1
3 inch	100								
2 inch		100	100						
1½ inch		70-100	70-100	100	100				
1 inch		55-85	55-85	70-100	70-100	100	100		
¾ inch			50-80		60-90		70-100	100	100
⅜ inch			40-70		45-75		50-80		
3/16 inch	15-45	20-50	30-60	25-55	30-60	30-60	35-65	35-65	45-80
B.S.No.7			20-50		20-50		25-50		30-60
No.36			10-30		10-30		15-30		20-35
No.200	0-10	0-10	*5-15	0-10	*5-15	0-10	*5-15	0-10	*5-15

* N.B. For gradings B-1, C-1, D-1, and E-1, the fractions passing the No.200 sieve shall not be greater than two thirds of the fractions passing the No. 36 sieve.

TABLE II.22 Requirements of Selected Borrow for Cement and Bitumen Stabilisation

B.S. Sieve	Percentage by weight passing
3 inch	100
No. 200	25

The portion of the material passing a No. 36 shall have a plasticity index of not more than 6.

APPENDIX III

ESTIMATES

1. Construction Rates
2. Engineering and Supervision Costs
3. Assumed Life of Project Works
4. Detailed Estimate
5. Timing of Investment and Manpower Requirement

APPENDIX III

ESTIMATES

III.1 Construction Rates

III.11 The rates used in estimating costs for the main construction items for structures are given overleaf in Table III.1. The rates have been calculated for the centre of the Rahad East Bank Project area and assume materials obtained as follows:-

1) Cement ex Khartoum by lorry on Blue Nile east bank.
11) Sand ex Blue Nile by lorry.
111) Gravel ex Blue Nile at El Masid by lorry.
1V) Bricks ex Wad Medani by ferry across Blue Nile then by lorry.
V) Granite rubble and aggregate ex Jebel Fau by lorry.

Gravel may also be obtained at Jebel Lebaitor, due east of Rufa'a. Use of material from this source will effect a considerable saving in cost compared with gravel from El Masid.

Additions to the rates listed in Table III.1 have been made in all estimates as follows:-

1) For all canalization structures on the Project main canal and distributaries, ten per cent for contingencies.

2) For all structures on the supply canal from Roseires Dam to the River Rahad and for the Malek Barrage and headworks provision has been made to cover mobilisation, access to site and water supply, also an addition of 20 per cent for contingencies.

III.12 A summary of the rates used in the estimates for cost of buildings is given in Table III.2. These rates are also based on the cost of materials for the centre of the Project Area. An addition of approximately five per cent for contingencies has been included in the estimates for all buildings.

Table III.1 : Construction Rates for Structures.

Item	Unit	Rate LS/mms
Earthwork:		
Excavation for foundation	M3	0.250
Earthwork filling for road, ramps etc.	M3	0.400
Excavation in canal block	M3	0.200
Concrete:		
6:3:1 mass in foundations	M3	10.000
4:2:1 mass in foundation rafts & cut-offs	M3	12.000
4:2:1 mass in piers, walls. etc.	M3	15.000
4.:2:1 reinforced in road slabs & kerbs including shuttering	M3	17.000
3:1½:1 reinforced in slabs including shuttering	M3	18.000
Masonry:		
Rubble masonry in 4:1 P.C.M. in walls, abutments, piers	M3	9.000
Ditto in 3:1 P.C.M.	M3	10.000
Cutwater block masonry in 3:1 P.C.M.	M3	17.000
0.40m rubble masonry pitching in 4:1 P.C.M. on 0.10m gravel backing	M2	4.000
0.40m dry rubble pitching on 0.10m gravel backing	M2	2.750
Brickworks		
Brickwork in 4:1 P.C.M.	M3	9.000
Half brick shuttering in 4:1 P.C.M.	M2	0.900
Pointing and Rendering:		
Pointing in 2:1 P.C.M. in exposed surfaces masonry	M2	0.400
Rendering stoplog grooves in 2:1 P.C.M.	M2	0.500

Table III.1 : Construction Rates for Structures (Contd.)

Item	Unit	Rate LS/mms
Jointing:		
2 cm. bitumen joint between adjacent surfaces	M2	1.000
1 cm. ditto	M2	0.500
Steelwork:		
Supply, cut, bend and fix M.S. bars	Ton	100.000
Supply and erect handrails including two coats paint	ML	1.000

Table III.2 Construction Rates for Buildings

Item	Unit	Rate LS/mms.
Earthwork:		
Excavation in foundations	M3	0.250
Earthwork under floor and around walls including ramming etc.	M3	0.250
Concrete:		
6:3:1 mass in foundation	M3	10.000
4:2:1 reinforced in lintels roof slab and floor	M3	17.000
8:3:1 lime concrete under floor well rammed	M3	7.500
5:3:1:½ Lime Homra concrete on roof well rammed	M3	9.000
Masonry:		
Rubble masonry in mud including pointing in 3:1 P.C.M.	M3	5.500
Brickwork:		
Red brick in 8:1 P.C.M. including flush lime pointing	M3	7.000
Roofing (Timber):		
Supply working and fixing timber of required size in rafters	Ft 3	1.750
Providing and fixing C.G.I. sheets 7'0" including fixing complete	No.	2.250

Table III.2 Construction Rates for Buildings (Contd.)

Item	Unit	Rate LS/mms.
Joinery:		
Providing & fixing door Type D1.	No.	8.000
Providing & fixing door Type D3	No.	10.000
Providing & fixing window W8	No.	5.000
Providing & Fixing window W10	No.	3.000
Decoration:		
Inside plaster 10:1 P.C.M. 0.25m thick	M2	0.250
Lime or colour wash, 2 coats	M2	0.200
Bitumastic paint on C.G.I. sheets, 2 coats	M2	0.200
Approved paint on ceiling and timber, 3 coats	M2	0.400
Reinforcement:		
Supply, cut, bend and fix M.S. bars	Ton	85.000

III.13 The rates used for earthworks in canal construction are given in Table III.3. The rates are based on the assumption that the main supply canal and major distributary canals will be excavated using scraper trains drawn by crawler type tractors. The minor distributary canal rates assume excavation using Domor elevating graders. The smaller field channels including watercourses and laterals will be excavated by tractor drawn ploughs. The rate for the double watercourse channel assumes hand work as the size of this channel is too large for excavation by plough and too small for excavation by dragline or scraper units.

Table III.3 Excavation Rates for Canals

Item	Unit	Rate LS/mms
Main and Supply Canals:		
Rock excavation	M3	1.000
Earth excavation in cut	M3	0.200
Ditto in borrow pits for forming banks	M3	0.250
Major Distributary:		
Earth excavation in cut	M3	0.120
Ditto in borrow pits for banks	M3	0.250
Minor Distributary:		
Earth excavation forming banks by Domor	M3	0.040
Carrier Channels by dragline	M3	0.120
Double Watercourse:		
Earth excavation and forming banks	M3	0.135
Watercourse:		
Earth excavation	M3	0.025
Field Lateral:		
Earth excavation	M3	0.016
Drains:		
Earth excavation in drain	M3	0.100

An addition of ten per cent for contingencies has been included in the estimates on all earthworks costs for canal construction.

III.14 An addition of ten per cent has been included to the direct costs as a contingency item.

III.2 Engineering and Supervision Costs

An addition of ten per cent has been included to the total estimated cost for preparation of designs, contract documents and supervision of the works.

III.3 Assumed Life of Project Works

For computing the annual charges to be made against **revenue account as provision** for depreciation, the assumed life of the project works is given in Table III.4 below -

Table III.4 Assumed Life of Project Works

Description	Life Years
Earthworks in canals, roads and airfields Major irrigation structures including barrage, canal regulators, siphons etc.	80
Bridges, steelwork or reinforced concrete; Irrigation structures on minor canals	50
Buildings and workshops Steelwork in canal regulators Electricity and telephone transmission lines Water supply installations	40
Ginning Factory	30
Mechanical plant for water supply	25
Telephone exchange equipment	20
Groundnut decortication plant	10

APPENDIX III

III.4 DETAILED ESTIMATE

I. IRRIGATION WORKS, BUILDINGS AND SERVICES

- A Preparatory Work
- B Purchase of Land
- C Canal Headworks including alteration to Roseires Dam
- D Supply canal Roseires Dam to River Rahad
- E River Rahad Barrage at Malek
- F Project Main Canal
- G Distributaries
- H Drains and Escapes
- J Workshops
- K Buildings for Agricultural and Irrigation Management
- L Other Buildings
- M Water Supply
- N Electricity Supply
- O Communications

II. AGRICULTURAL PROCESSING PLANTS:

- A Ginning Factories
- B Groundnut Decortication Plants

III. EARTHWORK PLANT

IV. CONTINGENCIES

V. SUPERVISION

III.4 DETAILED ESTIMATE

I. IRRIGATION WORKS, BUILDINGS AND SERVICES

I.A. Preparatory Work

		Qty	Unit	Rate LS	Amount 1000 LS	Foreign Exchange 1000 LS	Customs Duty 1000 LS
1	Survey all canal and drain lines for Project Canalization	475,000	Fed.	0.075	35.6		
2	Provision of temporary water supply pumped from Blue Nile including two pump stations, 5 km. rising main and 60 Km. Misgas			Sum	110		
3	Operating and maintenance costs for temporary water supply	2	year	5.000	10		
	Total				155.6	53	15.4
I.B	Purchase of Land and Compensation						
1	Compensation for Land expropriated for canals, drains villages, etc.	11,000	Fed.	1.400	15.4	-	-
2	Compensation for buildings removed	-	-	Sum	9.6	-	-
	Total				25		
I.C	Canal Headworks including alteration to Roseires Dam						
1	Provision of outlets in dam and canal headworks, discharging capacity 360 cumecs - Total			Sum	(2,400)*	(500)*	(300)*

*These figures assumed in same ratio as for other major canal structures.

III.4 DETAILED ESTIMATE

I. IRRIGATION WORKS, BUILDINGS AND SERVICES

I.D. Supply Canal Roseires Dam to River Rahad

	Qty.	Unit	Rate LS	Amount 1000 LS	Foreign Exchange 1000 LS	Customs Duty 1000 LS
(a) Earthworks						
K0 - K27 (Q=132 cumecs)						
Cut	14,624,000	M3	0.200	2,925		
Borrow	241,000	M3	0.250	60		
Rock Excavation	110,000	M3	1.000	110		
K27 - K191 (Q=65 cumecs)						
Cut	13,545,000	M3	0.200	2,709		
Borrow	840,000	M3	0.250	210		
Flood Protection Works			Sum	37		
10% Contingencies				605		
Sub-total				6,656	4,659	559
(b) Structures						
K27 Regulator Group (including escape)			Sum	193		
Dinder Siphon (including 4.0m road bridge and escape)			Sum	287		
Khor el Atshan Siphon (including 4.0m road bridge and escape)			Sum	115		
Rahad Outfall at Wad Miskin (including river protection works)			Sum	199		
Cross Drainage Works:						
Khor El Aqaliyin Underpass						
Khor Abu Muhar Underpass						
Khor Kenana Underpass						
K140.5 Underpass						
Culverts and Siphons	58					
Surface Water Inlets	5		Sum	585		

III.4 DETAILED ESTIMATE

I. IRRIGATION WORKS, BUILDINGS AND SERVICES

I.D. Supply Canal Roseires Dam to River Rahad (Contd.)

	Qty.	Unit	Rate LS	Amount 1000 LS	Foreign Exchange 1000 LS	Customs Duty 1000 LS
(b) Structures (Contd)						
Bridges						
4.0m Road Bridges						
K7.8						
K51.1						
K71.8						
K106.4						
K118.8						
K128.3						
K144.0						
K163.5						
K191(Rahad)			Sum	184		
Footbridges						
K16.0						
K21.0						
K31.5						
K83.3						
K184.3			Sum	25		
Animal Ramps	19		Sum	25		
Flood Protection Works			Sum	174		
20% Contingencies				357		
Sub-total				2,144	862	281
Total				8,800	5,521	840
I.E. River Rahad Barrage at Malek						
Barrage Structure			Sum	181.7		
Head Regulator			Sum	93.6		
20% Contingencies				55.1		
Sub-total				330.4		
Earthworks			Sum	37.6		
10% Contingencies				3.8		
Sub-total				41.4		
Total				371.8	173	52

III.4 DETAILED ESTIMATE

I. IRRIGATION WORKS, BUILDINGS AND SERVICES

I.F Project Main Canal

	Qty	Unit	Rate LS	Amount 1000 LS	Foreign Exchange 1000 LS	Customs Duty 1000 LS
(a) Earthworks						
Cut	12,159,000	M3	0.200	2,432		
Borrow	1,251,000	M3	0.250	313		
Rock Excavation	165,000	M3	1.000	165		
10% Contingencies				291		
Sub-total				3,201	2241	269
(b) Structures						
Cross regulators:						
K30			Sum	63		
K44.5			"	56		
K57			"	50		
K80			"	50		
K91.5			"	43		
K103.5			"	28		
K119.5			"	15		
K138			"	15		
K154			"	10		
K162			"	9		
Cross Drainage Works:						
K6 culvert			Sum	12		
K8 underpass			"	29		
K67.8 overflow weir			"	25		
K70.3 culvert			"	12		
K71.9 culvert			"	10		
K76.2 culvert			"	8		
K80 inlet structure			"	5		
K81 inlet structure			"	5		
Single pipe culverts	46	No.	"	230		
10% Contingencies				68		
Sub-total				743	327	105
Total				3,944	2568	374

III.4 DETAILED ESTIMATE

I. IRRIGATION WORKS, BUILDINGS AND SERVICES

I.G Distributaries serving 53,500 feddans N.C.A. commanded by K91.5 Major Canal

	Qty.	Unit	Rate LS	Amount 1000 LS	Foreign Exchange 1000 LS	Customs Duty 1000 LS
(a) Earthworks						
1. Major canals	425,000	M3	-/120	51		
2. Minor canals						
(a) Supplying outlets three double watercourses. 6.00M3/M.L. Canal	612,000	M3	-/040	24.5		
(b) Supplying outlets direct 7.00M3/M.L. canal	580,000	M3	-/040	23.2		
(c) Gannabias 3.50 M3/M.L. canal	46,000	M3	-/120	5.5		
3. Double Watercourses, Watercourses and Field Laterals						
(a) Double watercourses 3.50M3/M.L.	266,000	M3	-/135	35.9		
(b) Watercourses .75M3/M.L.	640,000	M3	-/025	16		
(c) Field Lateral 0.25M3/M.L.	500,000	M3	-/016	8		
				164.1		
10% Contingencies				16.4		
Earthworks Total				180.5	75.8	17.1
(b) Structures:						
Major Canal						
1. Reg. Fall 2.0m/16 cumecs	1	No.	23,000	23		
2. Reg. Fall 1.04m/15 cumecs	1	No.	19,000	19		
3. Reg. Fall 1.71./12 cumecs	1	No.	19,000	19		
4. Reg. Fall 1.20m/8 cumecs	1	No.	12,000	12		
5. RSG 1 x 2.50m	3	No.	7,110	21.3		

III.4 DETAILED ESTIMATE

I. IRRIGATION WORKS, BUILDINGS AND SERVICES

I.G. Distributaries serving 53,500 feddans N.C.A. commanded by K91.5 Major Canal. (Contd.)

	Qty.	Unit	Rate	Amount 1000 LS	Foreign Exchange 1000 LS	Customs Duty 1000 LS
(b) Structures (Contd.)						
Minor Canals (see Table 1)		LS	107,000	107		
(c) F.O.Ps, F.O.Vs etc.		LS	48,300	48.3		
(d) Bush clearance etc.		LS	-	- (1)		
Structures Total (2)				249.6	117.3	35.2
Distributaries Total				430.1	193.1	52.3

Notes: (1) Provision has been made in estimate for Agricultural Operations (Part IV of Report)

(2) 10% Contingency included in individual rates for structures so is not added to total amount.

III.4 DETAILED ESTIMATE

I.G. Table 1 : Minor Canal Structures

Item	Description	Qty.	Unit	Rate LS	Amount LS
1	M.W.II 0.80m	10	No.	2410	24,100
2	M.W.II 1.00m	3	No.	2490	7,470
3	M.W. I 0.60m	2	No.	920	1,840
4	M.W. I 0.80m	2	No.	960	1,920
5	M.W. I 1.00m	2	No.	1050	2,100
6	M.W. I 1.30m	6	No.	1120	6,720
7	CNSW/1.00/0.50m	2	No.	300	600
8	" /1.00/0.76m	3	No.	410	1,230
9	" /1.50/0.50m	3	No.	330	990
10	" /1.50/0.76m	1	No.	440	440
11	" /1.50/0.91m	1	No.	540	540
12	" /2.00/0.50m	2	No.	360	720
13	" /2.00/0.76m	5	No.	470	2,350
14	" /2.00/0.91m	8	No.	570	4,560
15	" /2.50/0.50m	1	No.	390	390
16	" /2.50/0.76m	4	No.	500	2,000
17	" /2.50/0.91m	5	No.	590	2,950
18	" /3.00/0.50m	1	No.	420	420
19	" /3.00/0.76m	4	No.	520	2,080
20	" /3.00/1.01m	4	No.	620	2,480
21	" /3.00/1.01m	5	No.	730	3,650
22	" /3.00/1.24m	1	No.	820	820
23	P.B. 1.24m	8	No.	820	6,560
24	P.B. 1.01m	1	No.	740	740
25	P.B. 0.91m	1	No.	650	650
26	P.R. 0.50m	99	No.	280	27,720
27	P.R. 0.76m	1	No.	390	390
	Total				106,630
	Say LS				107,000

Notes:- 1) M.W. = Movable Weir
2) C.N.S.W. = Circular Night Storage Weir
3) P.B. = Pipe Bridge
4) P.R. = Pipe Regulator

III.4 DETAILED ESTIMATE

I. IRRIGATION WORKS, BUILDINGS AND SERVICES

I.H. Drains and Escapes

	Qty.	Unit	Rate LS	Amount 1000 LS	Foreign Exchange 1000LS	Customs Duty 1000 LS
1. Escapes on Main Canal at K.20, K75 and K150						
(a) Earthworks	373,000	M3	0.100	37.3		
(b) Structures						
1) 10 cumec regulator at K20			Sum	19		
2) Ditto at K75			"	28.5		
3) 5 cumec regulator at K.150			"	16		
2. Drains						
(a) 1) Earthwork in Major Drains	480,000	M3	0.100	48		
2) Ditto in Minor Drains	394,000	M3	0.100	39.4		
(b) Structures (50% earthworks cost)			Sum	43.7		
				231.9		
10% Contingencies				23.1		
Total				255	103.0	29.0

III.4 DETAILED ESTIMATE

I. IRRIGATION WORKS, BUILDINGS AND SERVICES

I.J. Workshops

Description	Number Required		Unit Cost LS.	Total Cost LS.	Foreign Exchange LS.	Customs Duty LS.
	Agri-culture	Irri-gation				
Block Work-shop 25m x 10m	15	-	4,000	60,000	36,000	14,400
Tractor Shop 15m x 40m	3	-	8,000	24,000	14,400	5,800
Vehicle Shop 15m x 40m	2	-	8,000	16,000	9,600	3,800
Machine, Engine & Fitting Shop	1	-	12,000	12,000	7,200	2,900
Central Stores	1	-	8,000	8,000	4,800	1,900
Excavator Shop 15m x 40m	-	1	8,000	8,000	4,800	1,900
Total Cost	120,00	8,000		128,000	76,800	30,700

III.4 DETAILED ESTIMATE

I. IRRIGATION WORKS, BUILDINGS AND SERVICES

I.K. Buildings for Agricultural and Irrigation Management

Table 1. Agricultural Management Buildings.

Table 2. Irrigation Buildings.

Table 3. Housing for Agricultural Management and Irrigation Staff.

Table I: AGRICULTURAL MANAGEMENT BUILDINGS

Building	Project H.Q.	Field Admin.	Block Work-shop	Ginn. Factory	Fire Prev.	G'nut Decort	Mech. Eng.	Civ. Eng.	Total	Unit Cost LS.	Total Cost LS.	Foreign Exchange LS.	Customs Duty LS.
Project H.Q. Office	1	-	-	-	-	-	-	-	1	25,000	25,000	9,500	2,800
Office 20m x 8m	-	15	-	2	-	-	-	-	17	3,500	59,000	22,600	6,800
Store Shed 100 x 45m	-	-	-	2	-	-	2	-	4	40,000	160,000	96,000	38,400
Store Shed 25m x 10m	4	15	-	1	-	-	-	1	21	3,000	63,000	37,800	15,100
Store Shed 5m x 4m	1	15	-	-	-	-	-	-	16	300	4,800	2,900	1,200
Fuel Store 12m x 6m	1	-	-	-	-	-	-	-	1	1,500	1,500	600	200
Fuel Store 3m x 2m	-	15	-	-	-	-	-	-	15	250	3,750	1,400	400
Rest House & Club	1	-	-	-	-	-	-	-	1	10,000	10,000	3,800	1,100
Bunkhouses	-	-	-	20	2	31	1	-	54	1,000	54,000	20,500	6,100
Fire Station & Office	-	-	-	-	1	-	-	-	1	5,000	5,000	1,900	600
Total											386,550	197,000	72,700

Table 2 : IRRIGATION BUILDINGS

Building	Div. H.Q.	Sub. Div. (North)	Sub.Div. (Centre)	Sub.Div. (South)	Total No.	Unit Cost LS.	Total Cost L.S.	Foreign Exchange LS.	Customs Duty LS.
Divisional Office	1	-	-	-	1	25,000	25,000	9,500	2,800
Sub-Divisional Office	-	1	1	1	3	6,500	19,500	7,400	2,200
Section Eng. Office	-	2	2	2	6	2,200	13,200	5,000	1,500
Store Shed	2	1	1	1	5	3,000	15,000	9,000	3,600
Petrol Store 12m x 6m	1	-	-	-	1	1,500	1,500	600	200
Petrol Store 3m x 2m	1	1	1	1	4	250	1,000	400	100
Official's Club	1	1	1	1	4	2,000	8,000	3,000	900
Rest House	-	1	1	1	3	2,500	7,500	2,800	900
Workers' Club	1	1	1	1	4	1,500	6,000	2,300	700
Car Park Shed & Latrines	1	1	1	1	4	400	1,600	600	200
Total							98,300	40,600	13,100

Table 3: HOUSING FOR AGRICULTURAL MANAGEMENT & IRRIGATION STAFF

House Type	Requirements		Total Number	Unit Cost LS.	Total Cost LS.	Foreign Exchange LS.	Customs Duty LS.
	Agric.	Irrig.					
7A	9	4	13	6,300	81,900		
7B	19	5	24	5,500	132,000		
3A	168	19	187	3,500	654,500		
2A	248	-	248	2,500	620,000		
1A	648	95	743	1,500	1,114,500		
I	373	614	987	1,000	987,000		
Total Number	1465	737	2,202		3,589,900 *	1,365,000	409,000

* N.B. The total cost for housing can be divided as follows:-

Agricultural Management LS. 2,714,200

Irrigation LS. 875,700

III.4 DETAILED ESTIMATE

I. IRRIGATION WORKS, BUILDINGS AND SERVICES

I.L. Other Buildings

Table 1. Other Buildings
Table 2. Other Housing.

Table 1: OTHER BUILDINGS

Building	Number Reqd.	Unit Cost LS.	Total Cost LS.	Foreign Exchange LS.	Customs Duty LS.
Dispensary	16	1,400	22,400	8,500	2,600
Veterinary Station	12	1,000	12,000	4,600	1,400
Veterinary Clinic	3	1,400	4,200	1,600	500
Elementary School	92	11,000	1,012,000	384,600	115,400
Intermediate "	16	20,000	320,000	121,600	36,500
Total	139		1,370,600	520,900	156,400

Table 2: OTHER HOUSING

House Type	Requirements		Total Number	Unit Cost LS.	Total Cost LS.	Foreign Exchange LS.	Customs Duty LS.
	P&T	Services					
7B	-	4	4	5,500	22,000	-	-
3A	3	5	8	3,500	28,000	-	-
2A	4	33	37	2,500	92,500	-	-
1A	5	7	12	1,500	18,000	-	-
1	4	23	27	1,000	27,000	-	-
Total	16	72	88		187,500	71,300	21,400

N.B. i) Services include Local Government, Medical and Veterinary but not school teachers' housing which is included in cost of school buildings.

ii) The total cost of other housing can be divided into
Post & Telegraphs LS 32,000
Services LS155,500

III.4 DETAILED ESTIMATE

I. IRRIGATION WORKS, BUILDINGS AND SERVICES

I.M Water Supply

	Qty.	Unit	Rate LS.	Amount 1000 LS.	Foreign Exchange LS.	Customs Duty 1000 LS
Tubewell supply to villages	64	No.	9000	576	275.2	75.5
Filter plant supply to villages	31	No.	11000	341	189.1	65.1
Tubewell (or filter) supply to Irrigation Sub.Div. H.Q.'s.			Sum	25	13	4
Project Admin. H.Q.			"	66	33	8.6
Total				1,008	510.3	153.2

I.N. Electricity Supply

Mains supply to Project H.Q.			Sum	55	25	10
Supply to Block H.Q. village	15	No.	4200	63	33	11.4
Total				118	58	21.4

I.O. Communications

All-weather road from Wad Medani to Project H.Q.	30	Km	10000	300	120	30
Bridge over Rahad River			Sum	150	90	27
Bridge over Blue Nile			"	1500	860	260
Pontoon ferry across Blue Nile (for use during construction)			"	2.5	1.5	.7
Dry weather landing strip			Sum	10	3	.5
Railway Loading Station			"	62	45	5
Total				2024.5	1119.5	323.2
Telephones within Project Area			Sum	168	90	36
Telephone link from Project back to Roseires Dam			Sum	99	53	21
Total				267	143	57

III.4 DETAILED ESTIMATE (Contd.)

	Qty.	Unit	Rate L.S.	Amount 1000 LS.	Foreign Exchange 1000 LS.	Customs Duty 1000 LS.
II. AGRICULTURAL PROCESSING PLANTS						
A. Ginning Factories						
One central ginning factory consisting of 4 units and central storage area			Sum	720	425	114
B. Groundnut Decortication Plants						
Groundnut decortication plant consisting of two units each having two decortication machines	15	No.	20000	300	216	54
Total				1020	641	168
III. EXCAVATING PLANT						
The items included in this estimate are required to supplement the Ministry of Irrigation's plant for excavation of the canalisation included in detailed estimates "I.G." and "I.H." (Distributaries, Drains and Escapes)						
1. Dragline, 1½ cu.yd. 45 ft. boom	8	No.	29000	232	178.4	44.5
2. Motor grader, 115 HP. (flywheel) with 24 ft. elevating jib attachment	5	No.	15200	76	60.3	15.1
3. Crawler tractor 230 H.P. including cable control unit	1	No.	17200	17.2	14.9	2.2
4. Ditching plough for use with 230 H.P. crawler tractor	1	No.	2200	2.2	1.7	0.4
Total				327.4	255.3	62.2
Say				328	255.3	66.2

III.4 DETAILED ESTIMATE (Contd.)

	Qty.	Unit	Rate LS.	Amount 1000 LS.	Foreign Exchange 1000 LS.	Customs Duty 1000 LS.
IV. CONTINGENCIES						
Ten per cent added to the total costs				3,022	1,653	3.54
V. ENGINEERING & SUPERVISION						
Ten per cent added to the total estimated costs to cover designs, contract documents and supervision of the works.				3,000	1,500	-

APPENDIX III

III.5 Timing of Investment and Manpower Requirement

The timing of investment required to implement the project works and manpower requirements of skilled and unskilled labour are detailed in Tables 5.1, 5.2 and 5.3. Skilled labour requirements have been sub-divided into foreign and Sudanese on an assessment of the present availability of skilled Sudanese labour for construction works.

Table 5.1	Rahad Project Costs by Year
Table 5.2	Manpower Requirement for Project Works - Unit Rates
Table 5.3	Manpower Requirement for Project Works - By Year

Table 5.1: Rahad Project Costs by Year

Item	Description	Project Costs by Year (1000 LS)									
		Year One		Year Two		Year Three		Year Four		Year Five	
		Local	Foreign	Local	Foreign	Local	Foreign	Local	Foreign	Local	Foreign
I.	Irrigation Works, Buildings & Services										
A	Preparatory Work	103	53	-	-	-	-	-	-	-	-
B	Land Purchase and Compensation	25	-	-	-	-	-	-	-	-	-
C	Canal Headworks and alteration to Roseires Dam	-	-	450	750	450	750	-	-	-	-
D	Supply Canal Roseires to Rahad - Earthworks	543	1520	727	1570	727	1569	-	-	-	-
	" " " Structures	-	-	641	431	641	431	-	-	-	-
E	River Rahad Barrage at Malek	-	-	100	87	99	86	-	-	-	-
F	Project Main Canal - Earthworks	-	-	600	1501	360	740	-	-	-	-
	" " " - Structures	-	-	208	164	208	163	-	-	-	-
G	Distributaries - Earthworks	-	-	301	218	301	218	301	218	-	-
	" - Structures	-	-	386	342	386	342	385	342	-	-
H	Drains and Escapes - Earthworks	-	-	40	29	39	29	-	-	-	-
	" " " - Structures	-	-	37	23	36	22	-	-	-	-
J	Workshops	17	26	17	26	17	25	-	-	-	-
K	Buildings for Agricultural and Irrigation Management	-	-	614	391	606	386	621	410	631	416
L	Other Buildings (excl. Schools)*	-	-	-	-	70	43	70	43	-	-
M	Water Supply	100	92	150	155	197	200	51	63	-	-
N	Electricity Supply	-	-	-	-	50	47	10	11	-	-
O	Communications: Roads, Bridges, Airfield, etc.	1	2	240	380	342	423	315	312	7	3
	Communications: Telephones	-	-	62	71	63	71	-	-	-	-
P	Schools	-	-	-	-	-	-	-	-	136	86

Table 5.1: Rahad Project Costs by Year (Contd.)

Item	Description	Project Costs by Year (1000 LS)									
		Year One		Year Two		Year Three		Year Four		Year Five	
		Local	Foreign	Local	Foreign	Local	Foreign	Local	Foreign	Local	Foreign
II.	Agricultural Processing Plants										
A	Ginning Factory	-	-	79	102	79	102	78	101	78	101
B	Groundnut Decortication Plants	-	-	-	-	-	-	56	144	28	72
III.	Earthmoving Plant (for M.I.H.E.P.)	-	-	73	255	-	-	-	-	-	-
IV.	Contingencies	79	169	472	651	467	565	189	164	88	68
V.	Engineering and Supervision	123	123	556	556	512	512	175	175	78	78
	Totals	991	1985	5753	7701	5650	6724	2251	1983	1046	824

Note: Schools will be constructed from Year 5 onwards and the construction period will be 6 years.

APPENDIX III

III.5 Table 5.2: Manpower Requirement for Project Works - Unit Rates

Description	Quantity and Unit	Man-Day		
		Foreign Skilled	Sudanese Skilled	Sudanese Unskilled
(1) Major Earthworks				
Earthworks in main and supply canals	1000M3	1.35	5.65	4.0
(2) Earthworks in Distributary canals, drains and escapes				
Excn. by dragline in any channel	1000M3	-	5.5	10.0
Excn. by elevating grader in minor canals	"	-	2.75	4.0
Excn. by ditching plough in watercourse	"	-	0.55	0.8
Excn. by ditching plough in field lateral	"	-	1.1	1.6
Excn. by hand in double watercourse	"	-	1.25	253.0
(3) Major Structures (Barrage, Main Canal Headworks, Regulators & Siphons)				
Mass concrete	M3	0.05	0.15	0.6
Prepare and fix steel reinforcement	Ton	2.0	6.0	6.0
Steelwork erection in regulator gates	Ton	1.0	2.0	3.0
Other items as in (4) below				
(4) Irrigation Structures and Buildings				
Excavation in foundations	M3	-	-	0.33
Backfilling " "	M3	-	-	0.33
Mass concrete	M3	-	0.2	1.67
Prepare and fix steel reinforcement	Ton	-	8.0	8.0
Steelwork erection in regulator gates	Ton	-	3.0	6.0

III.5 Table 5.2: Manpower Requirement for Project Works - Unit Rates - (Contd.)

Description	Quantity and Unit	Man - Day		
		Foreign Skilled	Sudanese Skilled	Sudanese Unskilled
(4) Irrigation Structures and Buildings (Contd.)				
Rubble Masonry	M3	-	0.5	1.5
Dry Rubble pitching	M2	-	0.25	0.5
Brickwork	M3	-	0.5	1.5
Pointing	100M2	-	4.0	4.0
Rendering	100M2	-	8.0	8.0
Plastering	100M2	-	8.0	8.0
Floors, brick on edge	100M2	-	7.0	15.0
Woodwork in roof & verandah	Ft.3	-	0.5	0.5
Joinery in doors etc.	LS1.000	-	0.4	0.4
Fixing C.G.I. roofing sheets	100M2	-	3.33	3.33
Painting, 2 coats colourwash	100M2	-	3.0	-
Painting, woodwork 3 coats	100M2	-	9.0	-

Table 5.3: Manpower Requirements for Project Works - by Year

Item	Total (1000 man days)			Year One			Year Two			Year Three			Year Four			Year Five		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
I. Irrigation Works, Buildings & Services																		
A Preparatory Work	-	9	10	-	9	10	-	-	-	-	-	-	-	-	-	-	-	-
C Headworks	13	48	173	-	-	-	6	24	86	7	24	87	-	-	-	-	-	-
D Supply Canal - Earthworks	40	166	118	4	16	12	18	75	53	18	75	53	-	-	-	-	-	-
D Supply Canal - Structures	12	43	154	-	-	-	6	21	77	6	22	77	-	-	-	-	-	-
E Malek Barrage	2	8	27	-	-	-	1	4	13	1	4	14	-	-	-	-	-	-
F M. Canal -Earthworks	19	80	57	-	-	-	9	40	28	10	40	29	-	-	-	-	-	-
F " -Structures	4	15	54	-	-	-	2	7	27	2	8	27	-	-	-	-	-	-
G Distributaries - Earthworks	-	60	660	-	-	-	-	20	220	-	20	220	-	20	220	-	-	-
G " Structures	-	69	294	-	-	-	-	23	98	-	23	98	-	23	98	-	-	-
H Drains - Earthworks	-	7	13	-	-	-	-	2	4	-	3	5	-	2	4	-	-	-
H " - Structures	-	4	16	-	-	-	-	1	5	-	2	6	-	1	5	-	-	-
J Workshops	-	5	9	-	2	3	-	2	3	-	1	3	-	-	-	-	-	-
K Agric. & Irrig. Buildings	-	476	936	-	-	-	-	119	234	-	119	234	-	119	234	-	119	234
L Other Buildings (excl. Schools)	-	187	373	-	-	-	-	-	-	-	14	27	-	13	27	-	-	-
M Water Supply	-	50	150	-	11	33	-	15	45	-	20	60	-	4	12	-	-	-
N Electricity Supply	-	10	10	-	-	-	-	-	-	-	8	8	-	2	2	-	-	-
O Roads, Bridges, etc.	30	81	216	-	-	-	10	23	62	10	29	77	10	29	77	-	-	-
O Telephones	-	40	60	-	-	-	-	20	30	-	20	30	-	-	-	-	-	-
L Schools	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	54
II. Agricultural Processing Plants																		
A Ginning Factory	-	20	40	-	-	-	-	5	10	-	5	10	-	5	10	-	5	10
B Groundnut Plants	-	9	18	-	-	-	-	-	-	-	-	-	-	6	12	-	3	6
Totals:	120	1387	3388	4	38	58	52	401	995	54	437	1065	10	224	701	-	152	304

Note

a) Manpower categories in Table above: (1) Foreign skilled (2) Sudanese skilled (3) Sudanese unskilled.

b) After Year Five construction of schools will continue.

APPENDIX IV

OPERATION AND MAINTENANCE ANNUAL CHARGES

IV.1 The proposed establishment for staff for operating and maintaining the irrigation works is given in Chapter 9. In Table IV.1 is given the estimated annual cost of providing these staff, based on the ruling scales of pay and allowances. This Table is set out in the form of a Nominal Roll of Staff for the Rahad Irrigation Division. The numbers of water control staff will be amended when the final layout of canalization is prepared.

IV.2 In addition to the permanent classified and unclassified staff, daily paid labour and contractors are employed for canal clearance, weeding, maintenance of banks etc. By reference to irrigation budgets and from a preliminary estimate of the cost of the maintenance works required, the following estimate of annual recurring charges was prepared and is detailed in Table IV.2.

IV.3 A possible programme of construction will give the first crops on 300,000 feddans during "Year 4" of the construction period. There will be a reduction in staff costs for this first year and also the full impact of maintenance of canals and houses will not occur. The details of the build-up of staff are given in Table IV.1. The corresponding estimate of maintenance and operation costs are as follows:-

Year	Area Irrigated Feddans	Operation and Maintenance LS.
4	300,000	206,500
5	475,000	277,000
6	475,000	339,000
7	475,000	365,000

Table IV.1: Operations and Maintenance - Nominal Roll and Annual Charges

	Construction Timing Area cropped - Feddans		Year 4 300,000		Year 5 475,000		Year 6 475,000		Year 7 475,000		Year 8 475,000	
	Scale	Total Annual Pay	No	LS	No	LS	No	LS	No	LS	No	LS
Admin.& Professional												
Divisional Engineer	1050-1185	1360	1	1360	1	1360						
A/Divisional "	645-1005	1060	3	3180	4	4240						
Sub-Prof.& Technical												
Sen. Asst. Engineer	660-1100	1010	3	3030	4	4040						
Asst. Engineer	480-630	730	7	5110	10	7300						
Section Foreman	260-510	532	1	532	1	532						
Technical Subordinate	180-300	290	2	580	3	870						
Clerical/Accounts												
Senior Clerk	320-475	590	1	590	1	590						
Clerk	180-300	333	5	1665	6	1998						
Junior Clerk	108-180	202	2	404	3	606	AS FOR YEAR 5					
Accountant	320-475	532	1	532	1	532						
Bookkeeper	108-180	202	1	202	1	202						
MAIN CANAL & BRANCHES	Group											
Reis Cl.I	10.500 - 17.500	285	1	285	1	285						
Reis Cl.II	8.300 - 12.900	219	12	2628	12	2628						
Water Ghaffir Cl.I	7.800 - 9.900	185	20	3700	20	3700						
" " Cl.II	6.600 - 8.800	164	21	3444	34	3444						
DISTRIBUTARIES												
Earthwork												
Labour Overseer	16.500 - 23.500	308	2	616	3	924						
Reis Labour	12.300 - 17.500	248	4	992	6	1488						
Head Chainman	12.300 - 17.500	265	8	2120	12	3180						

Table IV.1: Operations and Maintenance - Nominal Roll and Annual Charges (Continued) (2)

	Construction Timing Area cropped - Feddans		Year 4 300,000		Year 5 475,000		Year 6 475,000		Year 7 475,000		Year 8 475,000	
	Group	Total Annual Pay	No	LS	No	LS	No	LS	No	LS	No	LS
DISTRIBUTARIES (contd)												
Chainmen	6.600 - 9.900	155	16	2480	24	3720						
Mounted Messenger	6.600 - 9.900	155	8	1240	12	1860						
Structures												
Water Ghaffir Cl.I	7.800 - 9.900	185	44	10175	65	12025						
" " Cl.II	6.600 - 8.800	164	36	5904	55	9020						
Fitter Class IV	10.500 -17.500	265	2	530	3	795						
Board Ghaffirs												
Reis Cl.II	8.300 -12.900	199	10	2190	15	3285						
Water Ghaffir Cl.I	7.800 - 9.900	185	60	11100	90	16650						
" " Cl.II	6.600 - 8.800	164	180	29520	271	44444						
								AS FOR YEAR 5				
MECHANICAL												
Rahad Workshops												
Mechanic	10.500 -17.500	265	1	265	2	530						
Fitter Cl.III	8.300 -12.900	199	2	398	4	796						
Labourer	5.800 - 7.800	125	4	500	8	1000						
Car Drivers	8.300 -12.900	199	15	2985	20	3980						
BUILDINGS												
Mason	10.500 -17.500	265	3	795	4	1060						
Carpenter	10.500 -17.500	265	1	265	1	265						
Labourer	5.800 - 7.800	125	6	750	6	750						
Gardeners	5.800 - 7.800	125	12	1500	15	1875						

Table IV.1: Operations and Maintenance - Nominal Roll and Annual Charges (continued) (3)

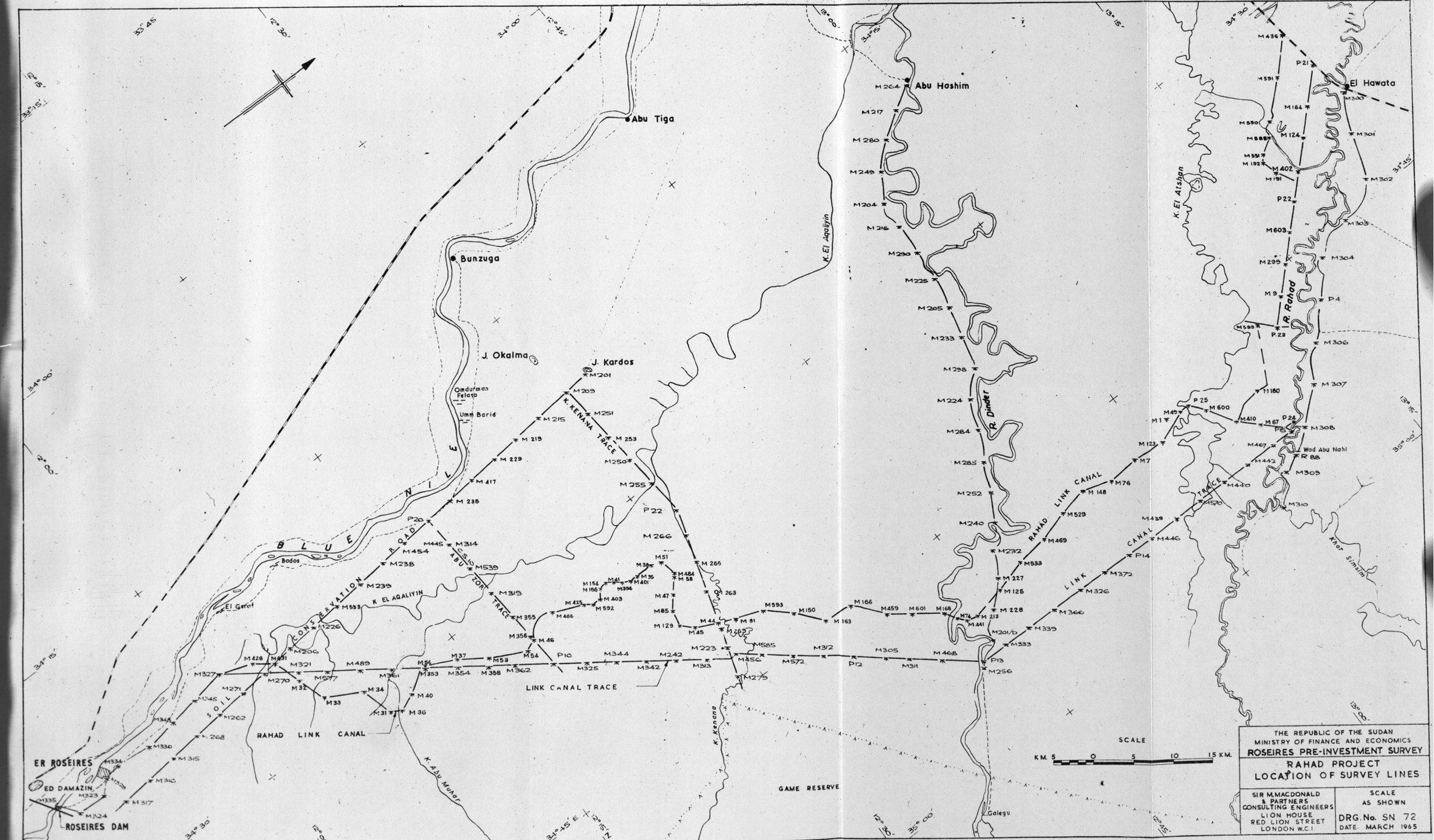
	Construction Area cropped - Feddans	Timing	Year 4 300,000		Year 5 475,000		Year 6 475,000		Year 7 475,000		Year 8 475,000	
	Group	Total Annual Pay	No	LS	No	LS	No	LS	No	LS	No	LS
SERVICES												
Arabic Tele.Operator	8.300 - 12.900	199	12	2388	16	3184						
Messengers	6.600 - 9.900	155	7	1085	9	1395						
Watchmen	6.600 - 9.900	133	2	266	2	266						
TOOLS												
Storeman	6.600 - 9.900	172	4	688	5	860						
Total Staff												
Running Costs:-												
Works				132860		145680		145680		145680		
Services				33000		84000		146000		171500		
Tools				40000		46400		46400		46400		
				600		600		600		600		
Total				206460		276680		338680		364180		
Say				206500		277000		339000		365000		
Local Currency				202500		271500		332500		358000		
Foreign Exchange				4000		5500		6500		7000		
Note: Provision of Motor Transport												
(M.T.D. Hire charges included in this estimate) Saloon (No.)				3		4		4		4		
Lorry (No.)				1		1		1		1		
Landrover (No.)				11		15		15		15		

Table IV.2 Estimate of Annual Recurring Charges 475,000 feddans

Item and Description	Sub Total LS	Total LS
Permanent Staff		
Classified	22270	
Unclassified	123410	
		145680
Works		
Main Canal	8800	
Distributary Canals	52800	
Escapes and Drains	10400	
Mechanical Workshops	88200	
Buildings	11300	
		171500
Services		
Mechanical Transport	18750	
Posts & Telegraphs	18750	
Telephone Attendants, Water Supply, Sanitation, Welfare etc.	8900	
		46400
Tools		
Tools, tents, Instruments etc.	600	600
Total		364,180
Say		LS 365,000

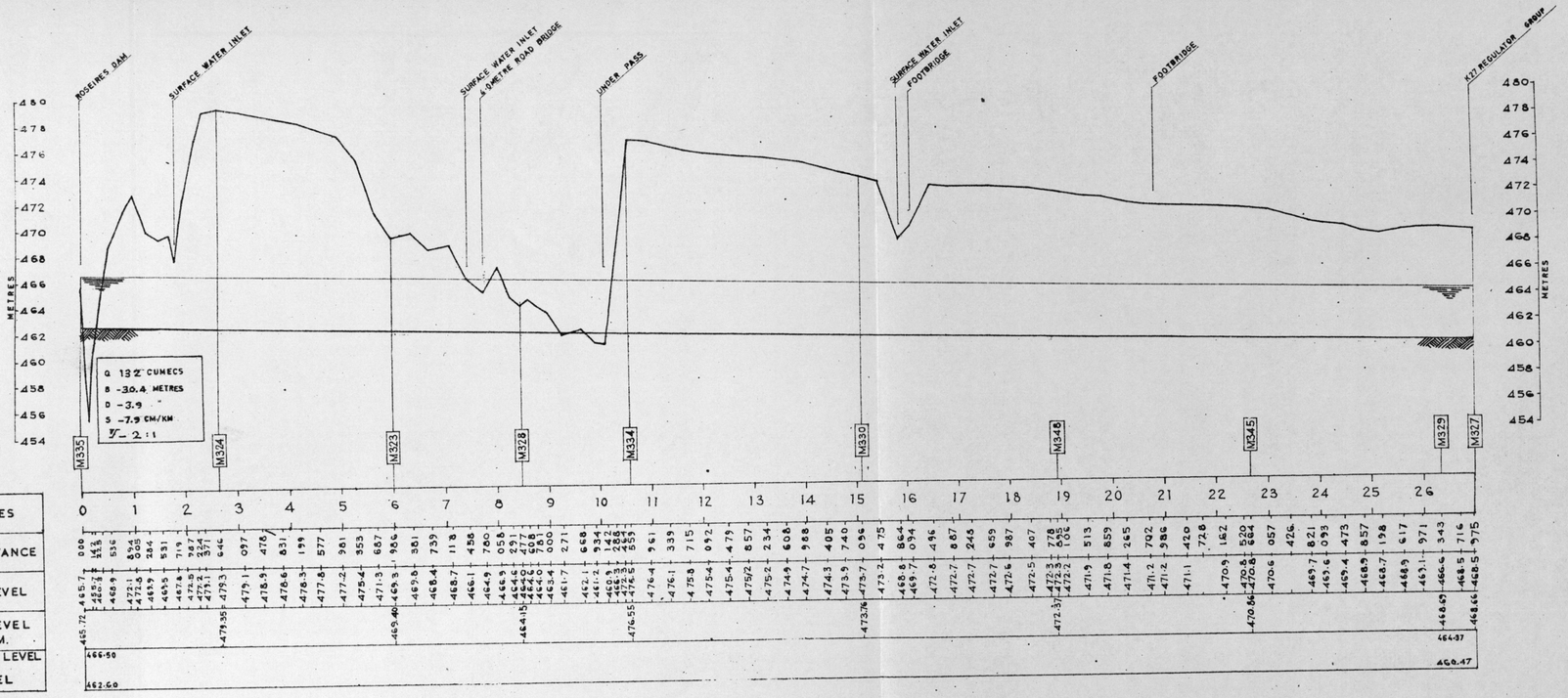
This estimated annual cost is LS.0.750 per feddan which compares with the 1963/4 Budget for the Gezira Scheme.

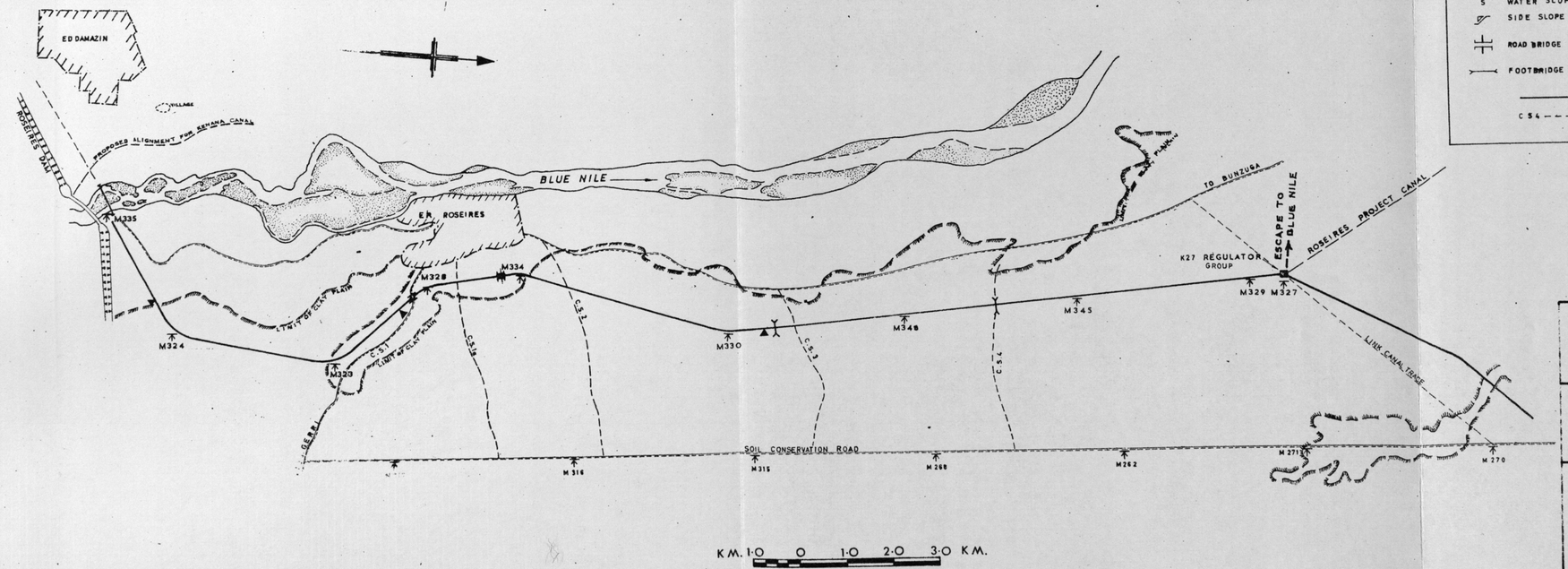

PLATE I.
KHARTOUM
KHARTOUM PROVINCE
KASSALA PROVINCE
R. Atbara
KASSALA
AULIA DAM
BLUE NILE
GEZIRA SCHEME
GUNEID PUMP SCH.
Hasaheisa
Khasm el Girba
15°00'
WAD MEDANI
MANAGIL SCHEME
R. Rahad
SHUKRIYA RUFA R.C.
EL HOSH R.C.
BLUE NILE PROVINCE
KASSALA PROVINCE
RAHAD PROJECT AREA
EL MADINA R.C.
EL HOSH R.C.
Ein El Luweiqa
J. FAU
K. Setit
MANAGIL R.C.
KOSTI R.C.
EL HOSH R.C.
SENNAR R.C.
PROJECT MAIN CANAL
Gedaref
14°00'
R. Dinder
K. Abu Fargha
Tuneidba
Abu Uruq
RAHAD BARRAGE
Mafaza
GEDAREF NORTH R.C.
GALA EN NAHAL R.C.
Dar Chemola
SENNAR DAM
Sennar
SENNAR R.C.
RUFA SHARG R.C.
GEDAREF NORTH R.C.
RUFA SHARG R.C.
NORTH FUNG R.C.
Hawata
Es Suki
Hasira
GALA EN NAHAL R.C.
GEDAREF NORTH R.C.
El Gueisi
K. El Atshan
TAIL REGULATOR
Rabak
Kosti
Singa
K. EL ATSHAN SIPHON
Wad Abu Nahl
K. Sim Sim
Abu Hashim
13°00'
Gallabat
Karkoj
RUFA SHARG R.C.
NORTH FUNG R.C.
ABU HUGAR R.C.
K. El Agaliyin
RAHAD LINK CANAL
DINDER SIPHON
Galegu
K. Raga
K. Galegu
K. Gadanu
K. Atesh
LEGEND
Project Area
Main Canal
Jebelein
J. Kardos
Bunzuga
NORTH FUNG R.C.
K. Kenana
ER ROSEIRES R.C.
ETHIOPIA
K. Abu Hara
K. Umm Delwes
GAME RESERVATION BOUNDARY
INTERNATIONAL BOUNDARY
Abu Muhar
K27 REGULATOR GROUP
J. Magano
K. Umm Gadaya
ROSEIRES HEADREACH CANAL
Geiger
K. El Ahmar
K. Abu Khadra
UPPER NILE PROVINCE
BLUE NILE PROVINCE
INGASANA R.C.
ER ROSEIRES R.C.
Er Roseires
HEAD REGULATOR
Ed Damazin
ROSEIRES DAM
Renk
K. Doleib
K. Donya
SCALE:- 1:1,000,000
KM10 0 10 20 30 40 50KM
33°00'
34°00'
35°00'
36°00'
THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY
RAHAD PROJECT
PROJECT PLAN
SIR M. MACDONALD & PARTNERS, CONSULTING ENGINEERS, LION HOUSE, RED LION STREET, LONDON, W.C.1.
SCALE AS SHOWN
DRG. No. SN 71.
DATE: APRIL, 1965.



PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

PLATE 4





NOTATION

Q	DESIGN CAPACITY	M33	BENCH MARK
B	BED WIDTH		
D	DEPTH	M34	INTERSECTION POINT
S	WATER SLOPE		
	SIDE SLOPE		ROAD BRIDGE
	UNDERPASS		FOOTBRIDGE
	SURFACE WATER INLET		CANAL ALIGNMENT
C S 4	CROSS SECTION		

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

RAHAD LINK CANAL
KO - K 26·975
LONGITUDINAL SECTION AND STRIP PLAN

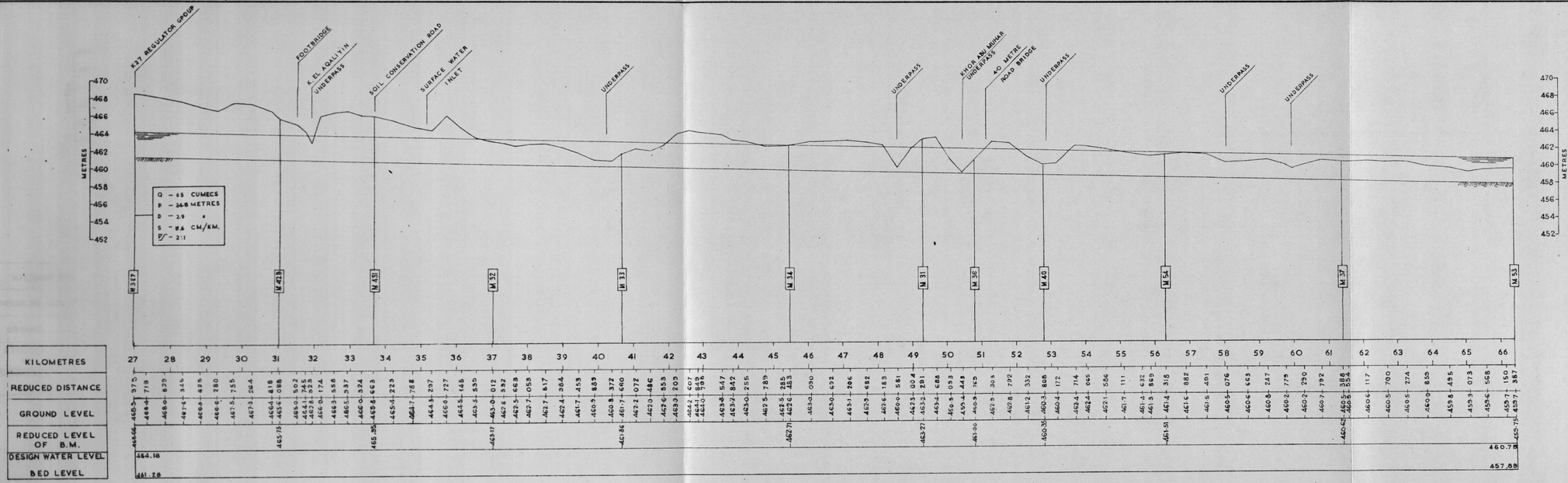
SIR M. MACDONALD & PARTNERS, CONSULTING ENGINEERS, LION HOUSE, RED LION STREET, LONDON, W.C.I.

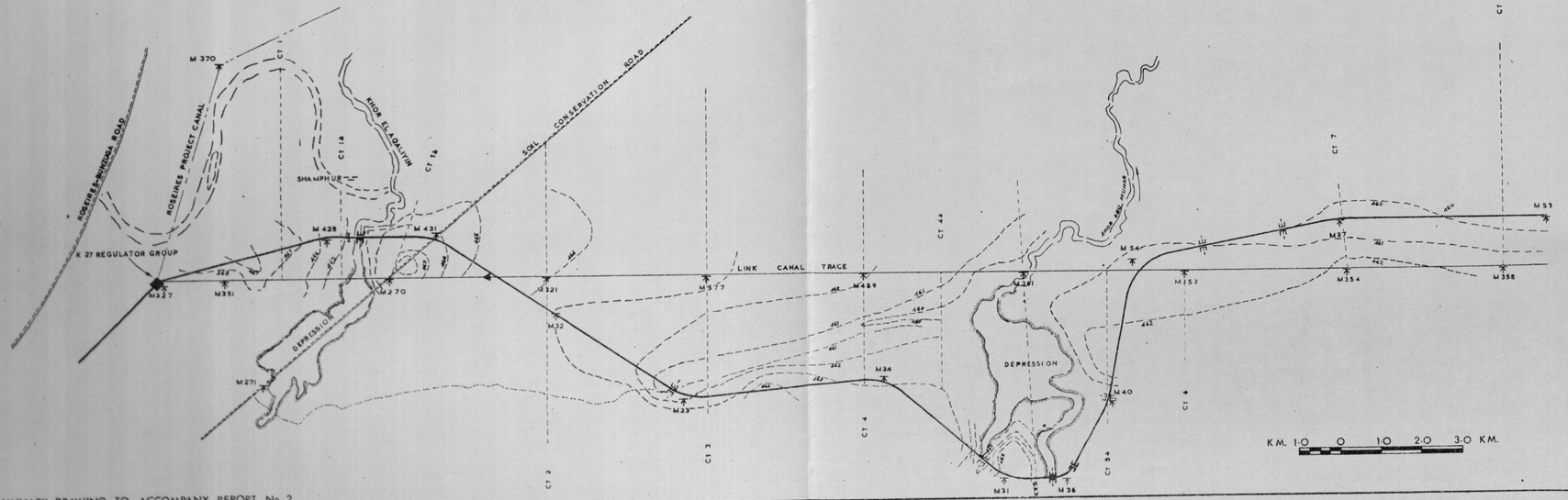
SCALES AS SHOWN

DRG. No. S11 74.
DATE: MARCH, 1965.

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

PLATE 5





NOTATION

Q	DESIGN CAPACITY	M 32	BENCH MARK
B	BED WIDTH	M 34	INTERSECTION POINT
D	DEPTH		UNDERPASS
S	WATER SLOPE		SURFACE WATER INLET
SS	SIDE SLOPE		CANAL ALIGNMENT
	ROAD BRIDGE	CT 4	CONTROL TRACE
	FOOTBRIDGE		

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

RAHAD LINK CANAL
K 26·975 – K 66·387
LONGITUDINAL SECTION AND STRIP PLAN

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

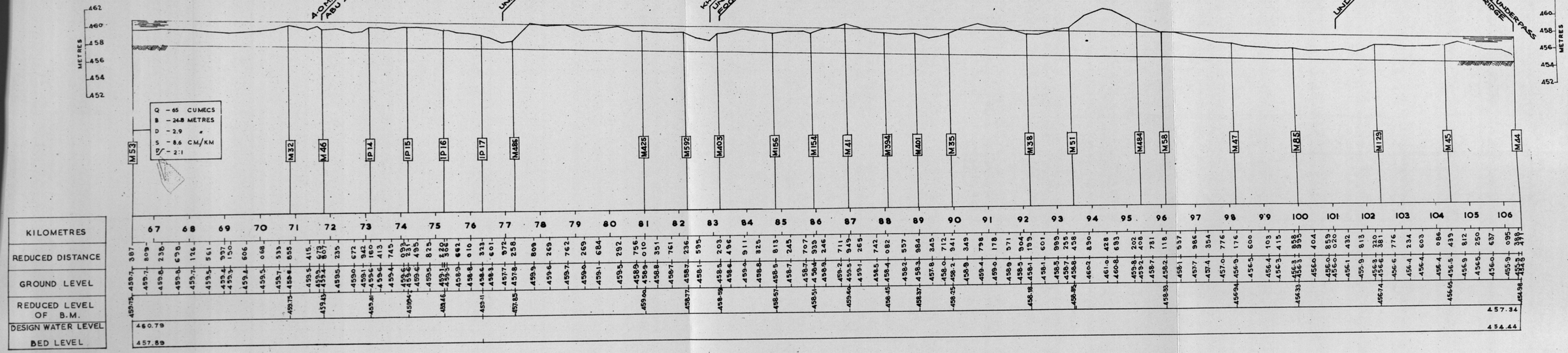
SCALES AS SHOWN

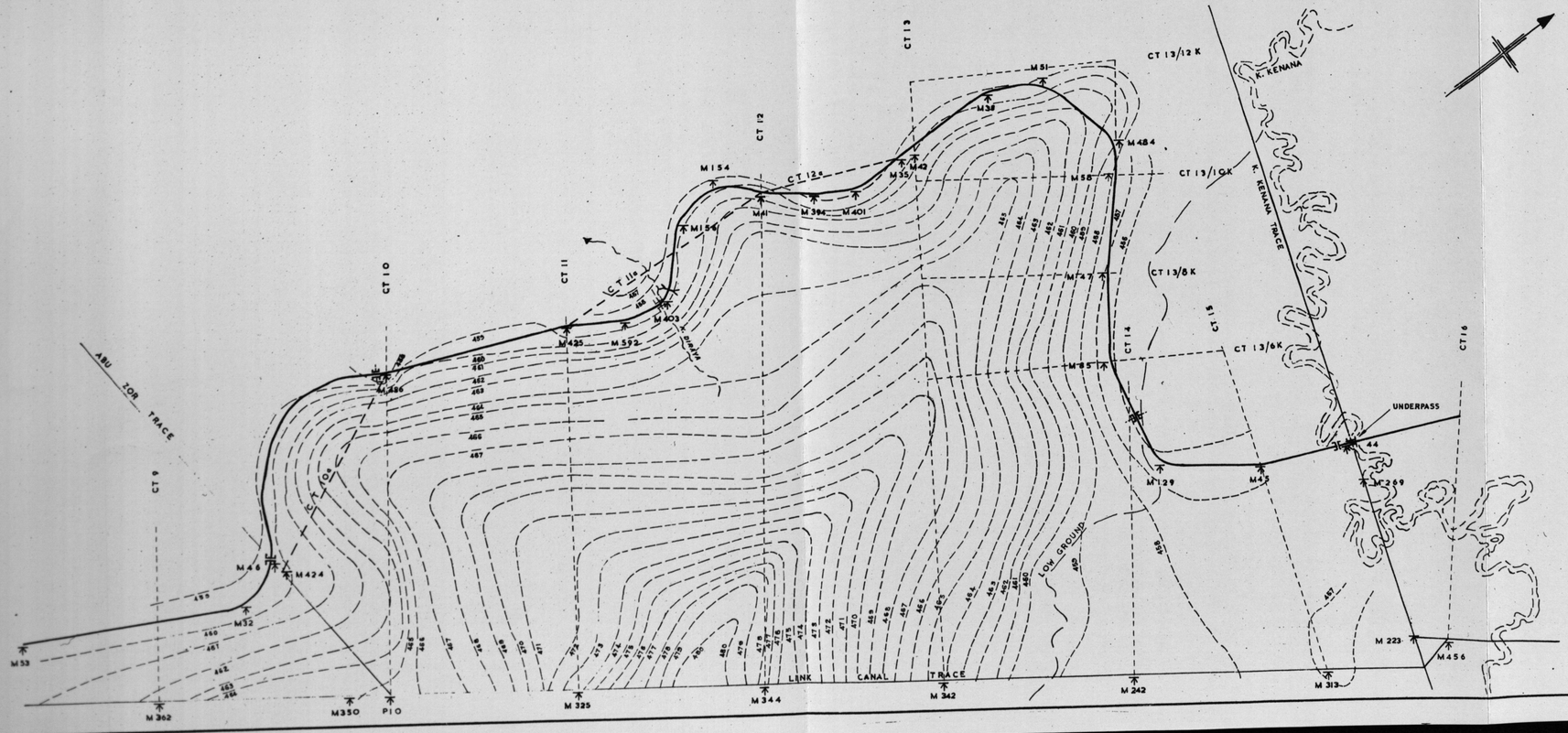
DRG. No. SN 75.

DATE: MARCH, 1965.

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

PLATE 6





SCALE

KM. 1·0 0 1·0 2·0 3·0 KM.

NOTATION

Q	DESIGN CAPACITY	CT3	BENCH MARK
B	BED WIDTH		
D	DEPTH	IP14	INTERSECTION POINT
S	WATER SLOPE		
z/	SIDE SLOPE		UNDERPASS
	ROAD BRIDGE		SURFACE WATER INLET
	FOOTBRIDGE		CANAL ALIGNMENT
		CT4	CONTROL TRACE

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

RAHAD LINK CANAL
K66·387 – K106·741
LONGITUDINAL SECTION AND STRIP PLAN

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

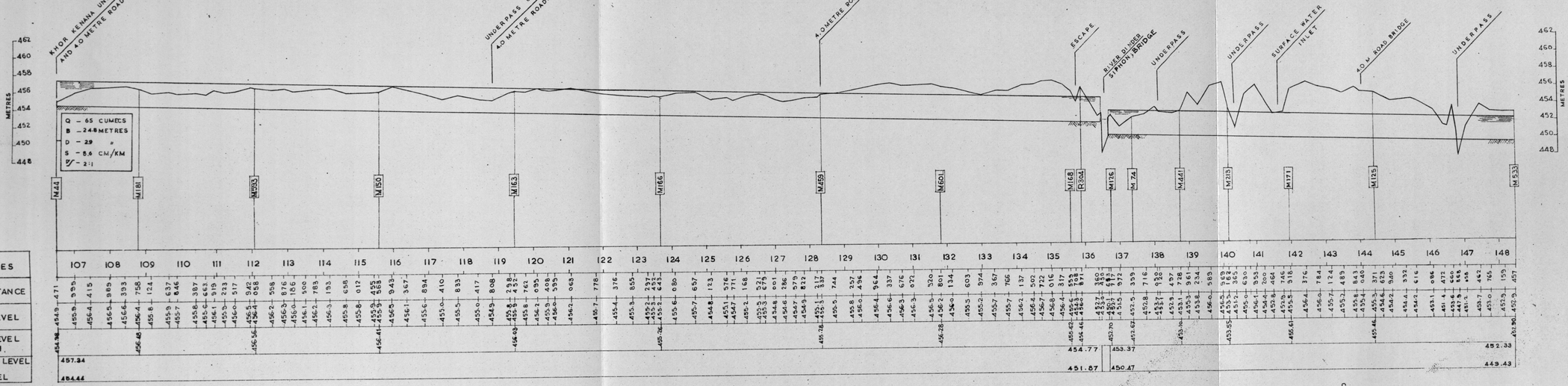
SCALES AS SHOWN

DRG. No. S N 105.

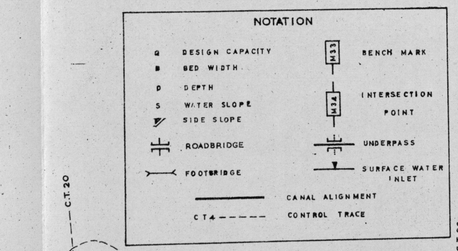
DATE: MARCH, 1965.

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

PLATE 7



KILOMETRES	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148
REDUCED DISTANCE	999	989	978	968	958	948	938	928	918	908	898	888	878	868	858	848	838	828	818	808	798	788	778	768	758	748	738	728	718	708	698	688	678	668	658	648	638	628	618	608	598	588
GROUND LEVEL	459.9	459.4	456.6	456.4	455.8	456.5	456.2	456.3	455.8	455.9	456.1	456.4	455.9	455.8	456.2	456.7	455.4	455.3	455.2	455.6	455.7	454.8	455.2	455.3	455.6	455.7	455.2	454.8	455.6	456.5	456.2	456.4	456.6	456.3	456.5	456.2	455.8	455.4	455.3	455.4	455.3	455.5
REDUCED LEVEL OF B.M.	456.48		456.48			456.58				456.41			456.40				455.78		455.78	456.28									454.77	453.37													452.33
DESIGN WATER LEVEL	457.34																																									
BED LEVEL	454.44																													451.67	450.47												449.43



SCALE
KM. 1·0 0 1·0 2·0 3·0 KM.

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

RAHAD LINK CANAL
K106·471 – K148·457
LONGITUDINAL SECTION AND STRIP PLAN

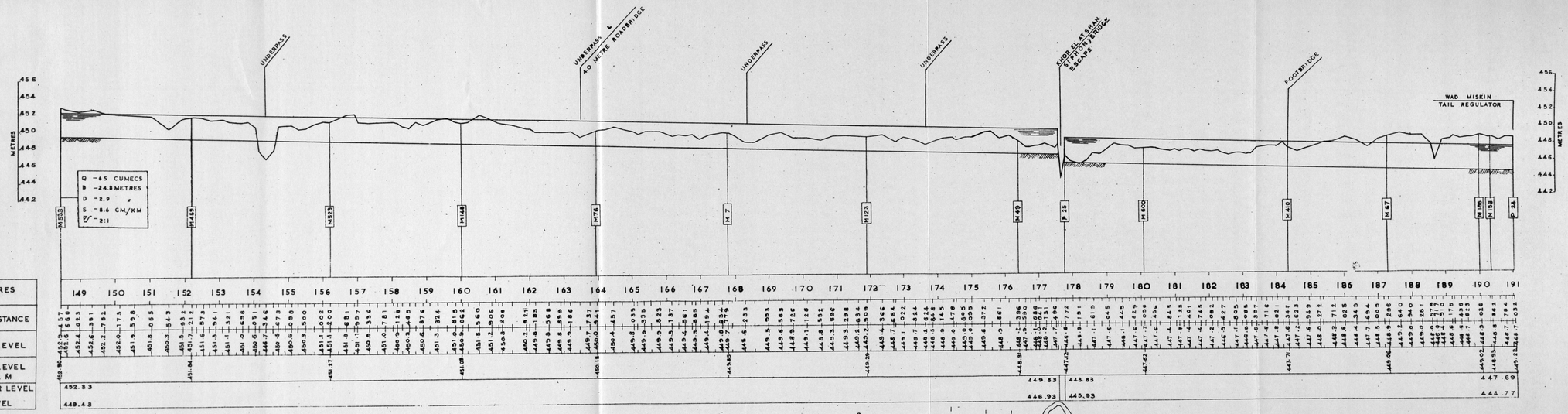
SIR M. MACDONALD & PARTNERS, CONSULTING ENGINEERS, LION HOUSE, RED LION STREET, LONDON, W.C.I.

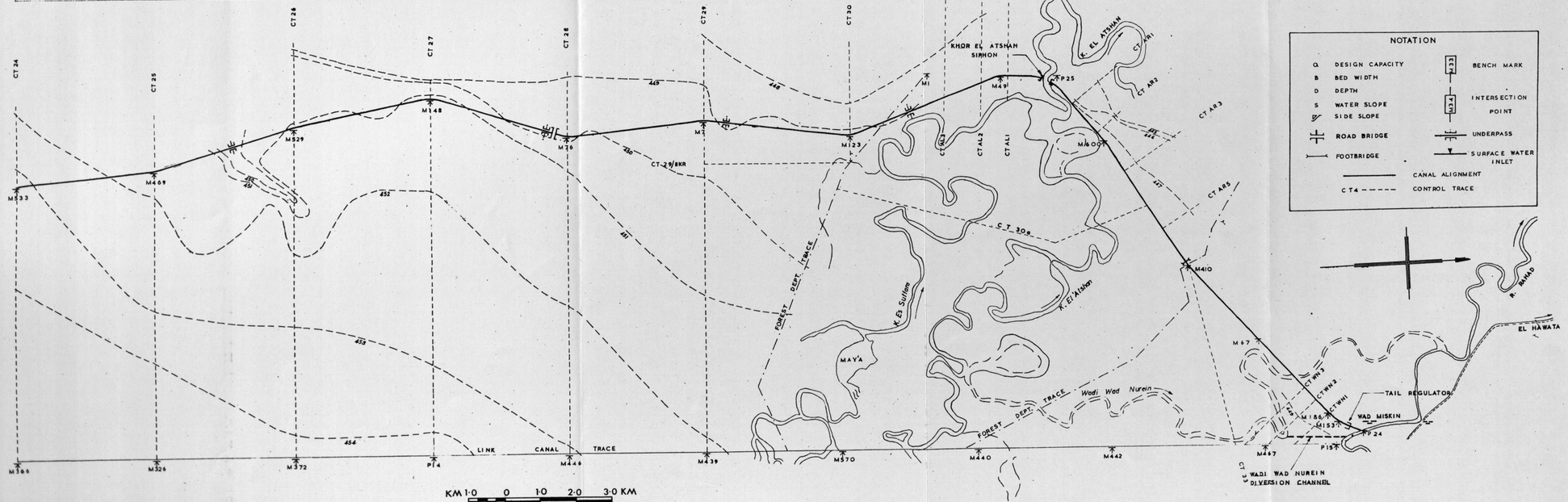
SCALES AS SHOWN

DRG. No. SN77

DATE: MARCH, 1965.

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2.





NOTATION

Q	DESIGN CAPACITY	233	BENCH MARK
B	BED WIDTH	234	INTERSECTION POINT
D	DEPTH		
S	WATER SLOPE		
Z	SIDE SLOPE		
	ROAD BRIDGE		UNDERPASS
	FOOTBRIDGE		SURFACE WATER INLET
	CANAL ALIGNMENT		
CT4	CONTROL TRACE		

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

RAHAD LINK CANAL
K148·457 – K191·032
LONGITUDINAL SECTION AND STRIP PLAN

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

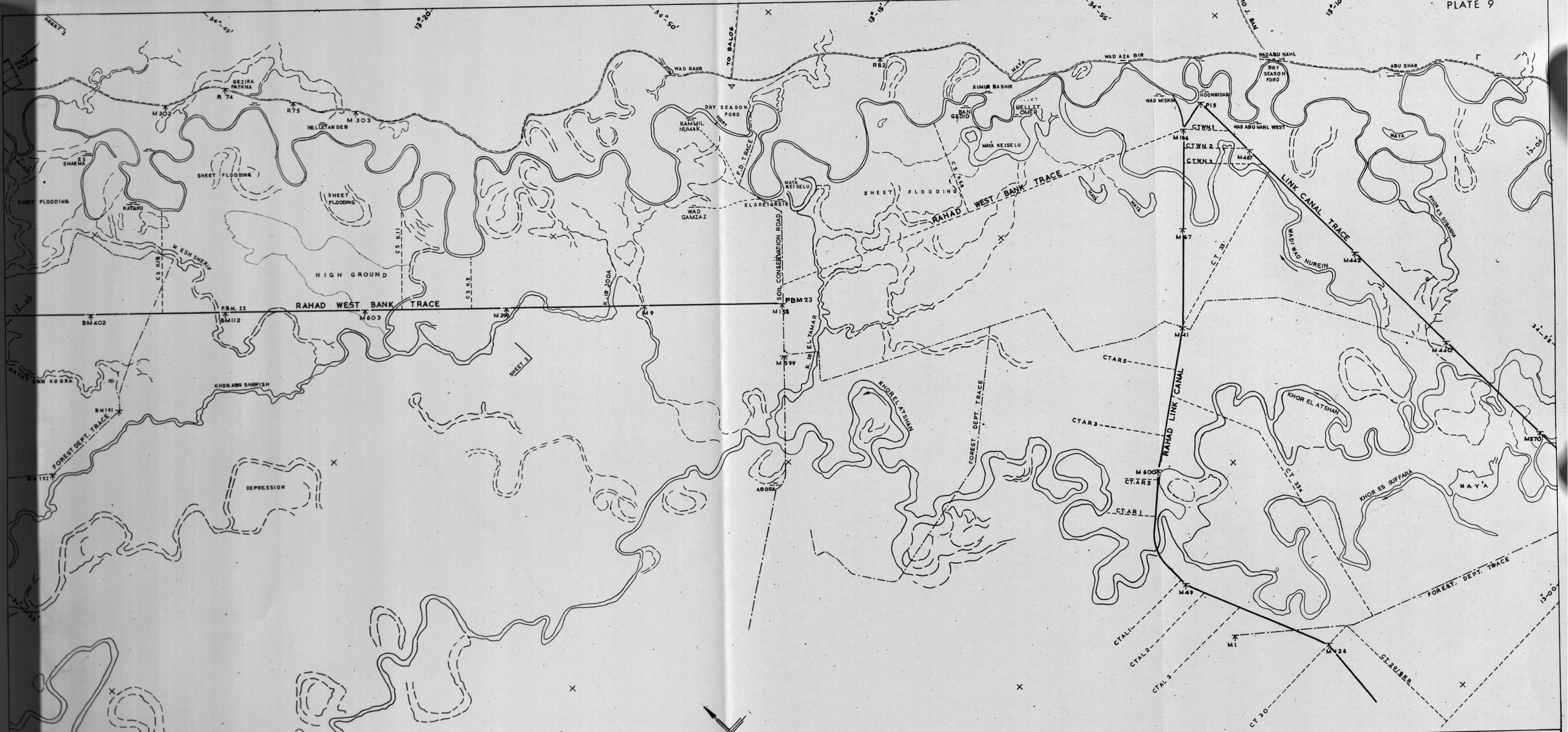
SCALES AS SHOWN

DRG. No. SN 78

DATE: MARCH, 1965.

PRELIMINARY. DRAWING TO ACCOMPANY REPORT No. 2

PLATE 9



THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS

ROSEIRES PRE-INVESTMENT SURVEY

RAHAD PROJECT
RAHAD SPILL AREAS—SHEET 1

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

SCALE
AS SHOWN

DRG. No. SN.79

DATE: MAY 1965

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

PLATE 10

13° 35′ 13° 30′ 13° 25′ 13° 20′ 13° 15′

34° 40′ 34° 35′ 34° 30′

GEDAREF

SHEET 1

R72 R. RAHAD S SHARMA KATAKU M ESH SHERIF P22 M112

PUMP SCHEME WAD DEILAG M301 SHEET FLOODING

R71 AMAR EL KHALIFA SINGINGAW KCC ST2

RLY. STA. 441 R70 UMM ZEBIL REST HOUSE

M300 EL HAWATA JARMAI WAD EL SHAIR

RAHAD WEST BANK TRACE M402 M124 MAYAT UM KOMA BM 191 BM 192 KHOR ABU SHAWISH DEPRESSION

FOREST RESERVE

BURBOR S.D.B.M 10036 R50 BELLU M 164 M 551

BM 588 BM 550 SHALLAY KHOR EL ATSHAN

R27 AZUZA M 122 QASIM R. RAHAD

P.B.M 10035 43372 P.B.M 21

SULIMAN GAROSHA GARGOSHA MULLALA KHOR WAD ELAMIN

M 476 DEPRESSION AND OLD WATER-COURSES UMM BARR

M 165 FOREST DEPT. TRACE VILLAGE UMM KAMDA HAFIR SHAMIYA

HEIMURA SARJAM BURRA EL MAFAZA R25 UMM SUTDIBA RUWINA HATI EL QUESIR ABU DIGGIN P3 MALEK YUSIF M512 BANAT

DABANGA SARKIN NOMA DABALOBA REAGH M 352 RIVER RAHAD UMM QUHARA HIGLIGA KUKU R30 SHAGGA M 294

P.B.M 10034 BM 436 HAFIR M 147 KABUSA UMM DUHAB HAFIR

M 259 M 144 HASRA STN.

KM 1·0 0 1·0 2·0 3·0 KM

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

RAHAD PROJECT

RAHAD SPILL AREAS—SHEET 2

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

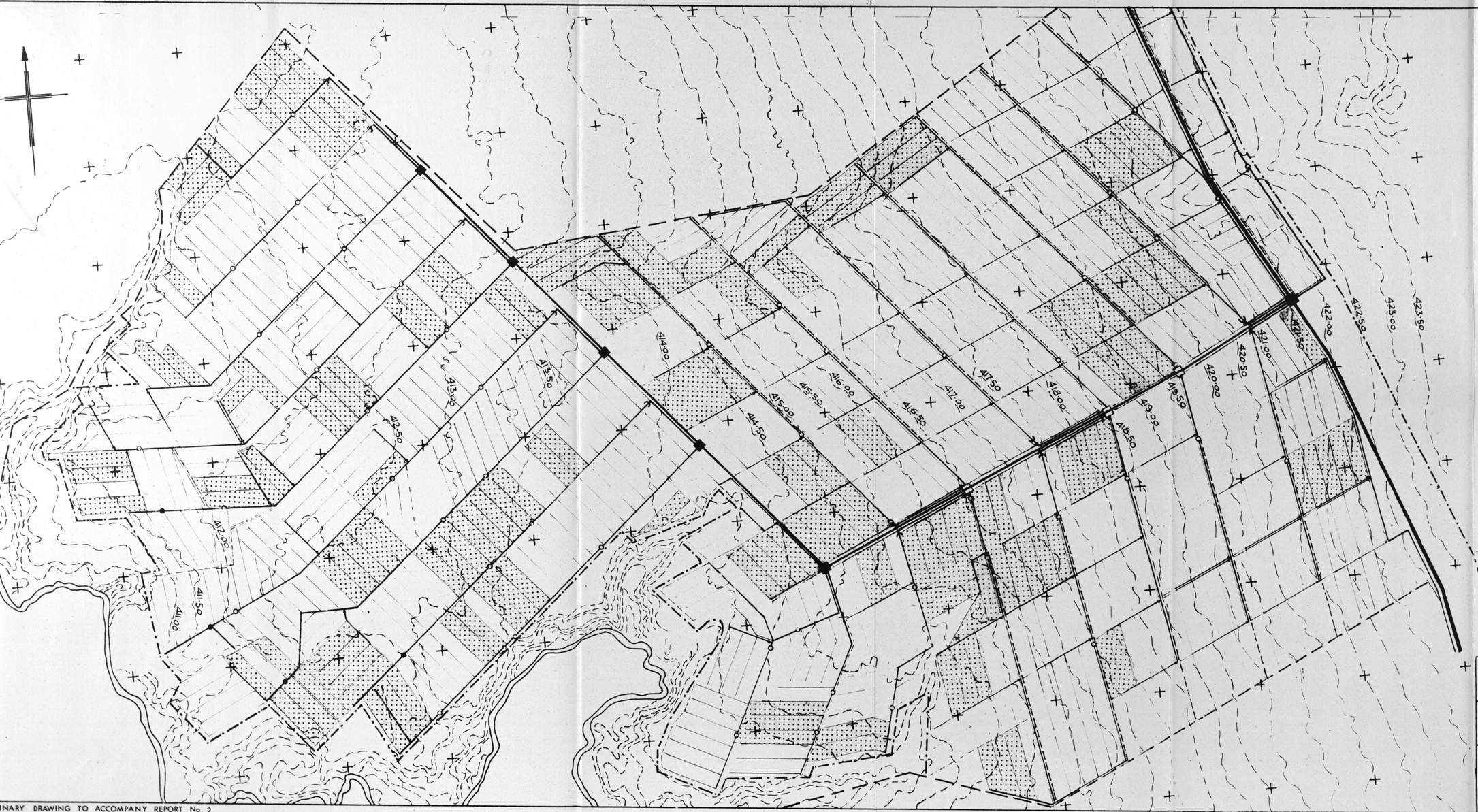
SCALE AS SHOWN

DRG. No. SN 80

DATE: MAY 1965

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

PLATE 13



- MAIN CANAL
- MAJOR CANAL
- MINOR CANAL
- DOUBLE WATERCOURSE
- WATERCOURSE
- LIMIT OF IRRIGATION
- MAJOR DRAIN
- MINOR DRAIN
- 412·00 CONTOURS
- MAIN CANAL REGULATOR GROUP
- MAJOR CANAL REGULATOR GROUP WITH FALL
- MAJOR CANAL REGULATOR GROUP
- CIRCULAR NIGHT STORAGE WEIR
- PIPE REGULATOR
- PIPE BRIDGE
- AREAS WITH SHORTER FURROWS, 30 TO 75 M. LENGTH (NOTE: STANDARD FURROW IS 150 M.)

SCALE

K.M. 1·0 0·5 0 1·0 2·0 K.M.

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

RAHAD PROJECT
K91.5 MAJOR CANALIZATION LAYOUT

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

SCALE AS SHOWN

DRG. No. SN 83

DATE: MAY 1965

INARY DRAWING TO ACCOMPANY REPORT No. 2

PLATE 14

33° 15′ 33° 30′ 33° 45′

15° 00′

14° 45′

TO KHARTOUM

Wad Rawa

Kamlin

BLUE NILE

Laota

Abu Ushar

Gannib

Hassa Heissa

Rufa'a

TO WAD MEDANI

Abu Horira

El Gurra'a

Borida

Abu Sham

El Hawalda

Tundub

Hasanab

Tambul

GUNEID PUMP SCHEME

53,000 F.

77,700 F.

93,000 F.

27,000 F.

Umm Asha

Abu Galfa

Saiyal Dakhakhin

Wad El Khabir

CANAL LINE

GUNEID LINK CANAL

400

395

405

LEGEND

------ Lines Levelled by Ministry of Irrigation & H. E. P. 1962

--------- Lines Levelled by Sir M. Mac Donald & Partners 1965

(6) Land Classification 1963/4 Soil Survey

NOTE:

THE CANAL LINES SHOWN ARE BASED ON LIMITED CONTOUR KNOWLEDGE AVAILABLE.

KM 5 0 5 10 15 KM

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS

ROSEIRES PRE-INVESTMENT SURVEY

RAHAD IRRIGATION PROJECT NORTHERN EXTENSIONS IN GUNEID AREA

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

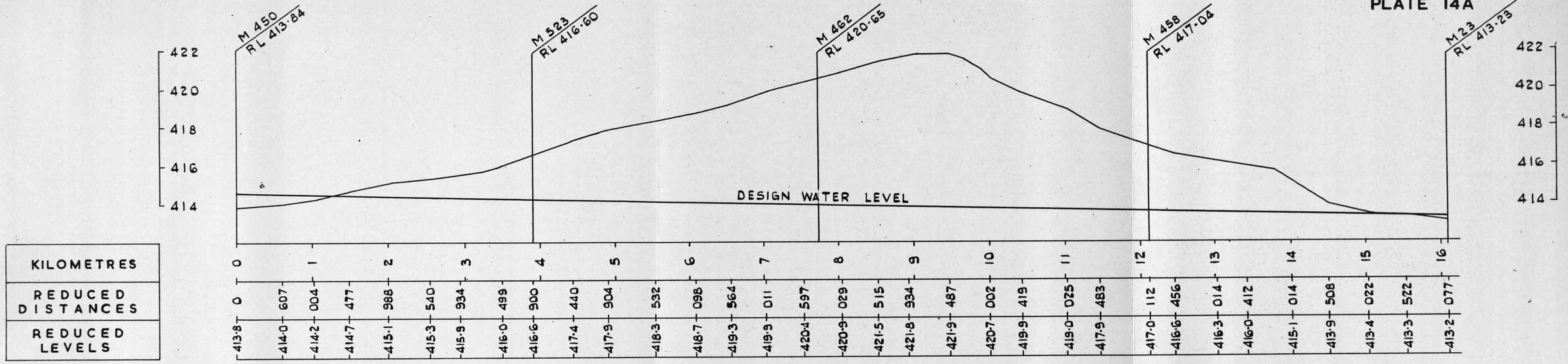
SCALE AS SHOWN

DRG. No. SN 84

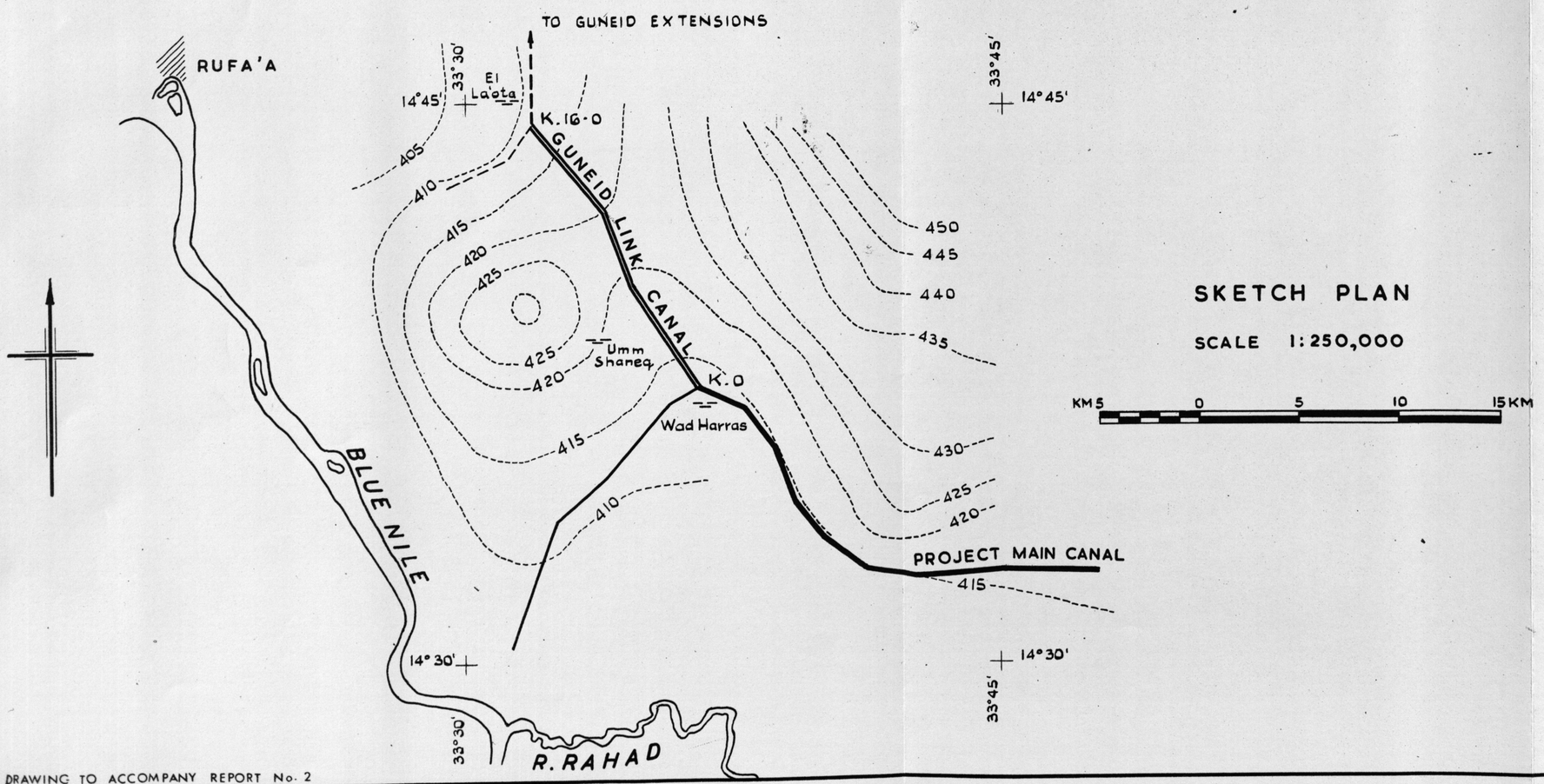
DATE:- MAY 1965.

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

PLATE 14A



GUNEID LINK CANAL — LONGITUDINAL SECTION



SKETCH PLAN

SCALE 1:250,000

KM 5 0 5 10 15 KM

NOTES.

1. GUNEID LINK CANAL OFFTAKES AT APPROX. K. 162 ON PROJECT MAIN CANAL

2. DESIGN DIMENSIONS

   DESIGN CAPACITY, Q = 31 CUMECS
   WATER SURFACE WIDTH, $W_S = 4{\cdot}0\,Q^{1/2}$ APPROX.
   BEDWIDTH, B = 10·7 M
   DESIGN WATER DEPTH, D = 2·9 M
   WATER SURFACE SLOPE, S = 7·9 CM/KM

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

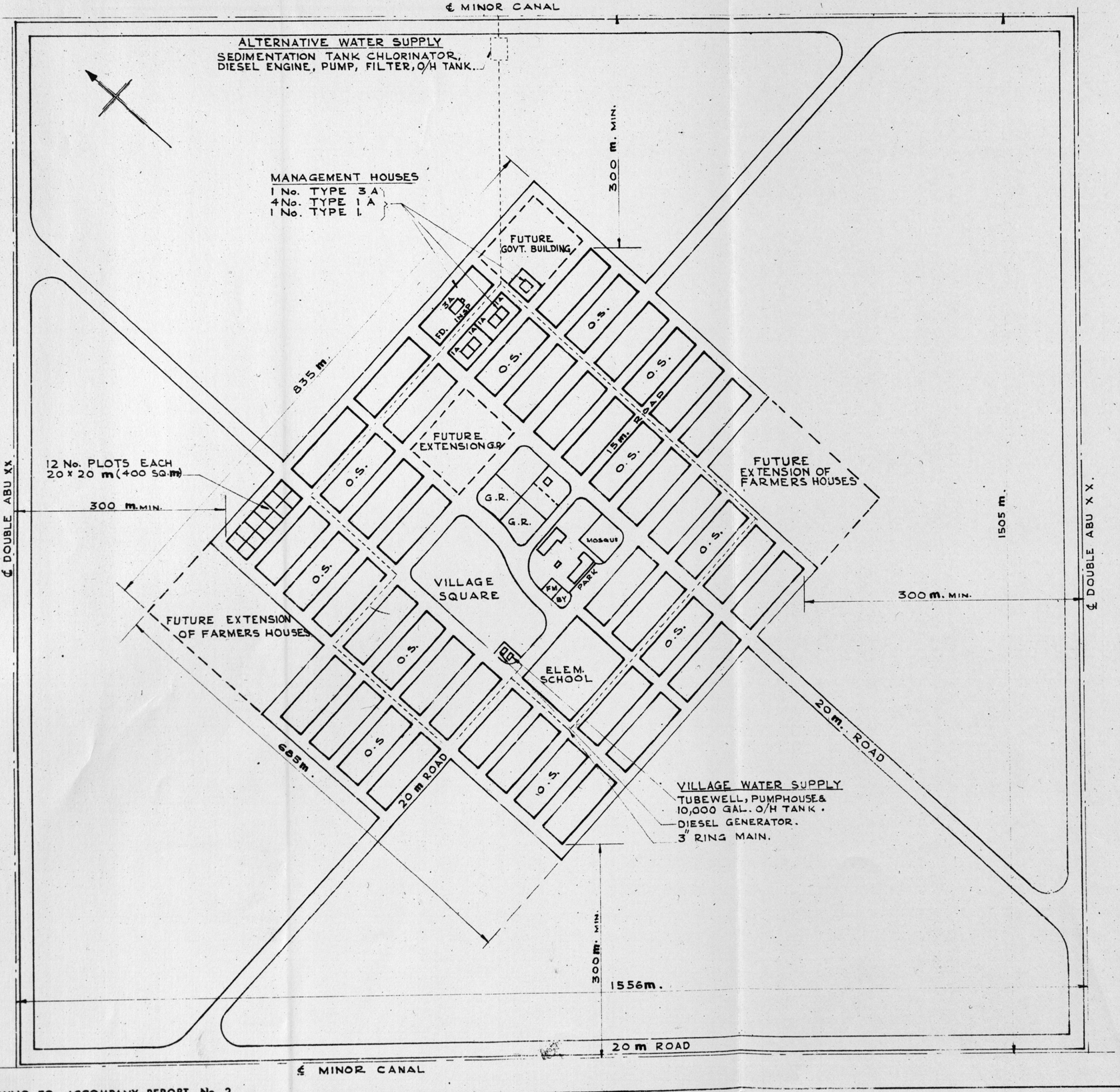
RAHAD IRRIGATION PROJECT
GUNEID LINK CANAL

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

SCALES AS SHOWN

DRG. No. SN 105
DATE: MAY, 1965.

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2



NOTES:-

1. VILLAGE TO BE ORIENTATED TO FACE PREVAILING N-S WIND.
2. PIPED WATER TO MANAGEMENT HOUSES, MOSQUE, SCHOOL, & DRESSING STATION.
3. PLANNED POPULATION IS 400 FAMILIES EACH WITH A PLOT OF 400 SQ m.
4. VILLAGE AREA INCLUDING ACCESS ROADS IS 170 FEDDANS
5. SURROUNDING AREA OF 380 FEDDANS FOR PASTURE & VEG. GARDENS.
6. MINIMUM WIDTH OF ROAD 15 m.
7. G.R. GOVT. RESERVE.
   O.S. OPEN SPACE.
   BY. BAKERY.
   F.M. FLOUR MILL.

SCALE

M. 100 0 100 200 300 M.

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

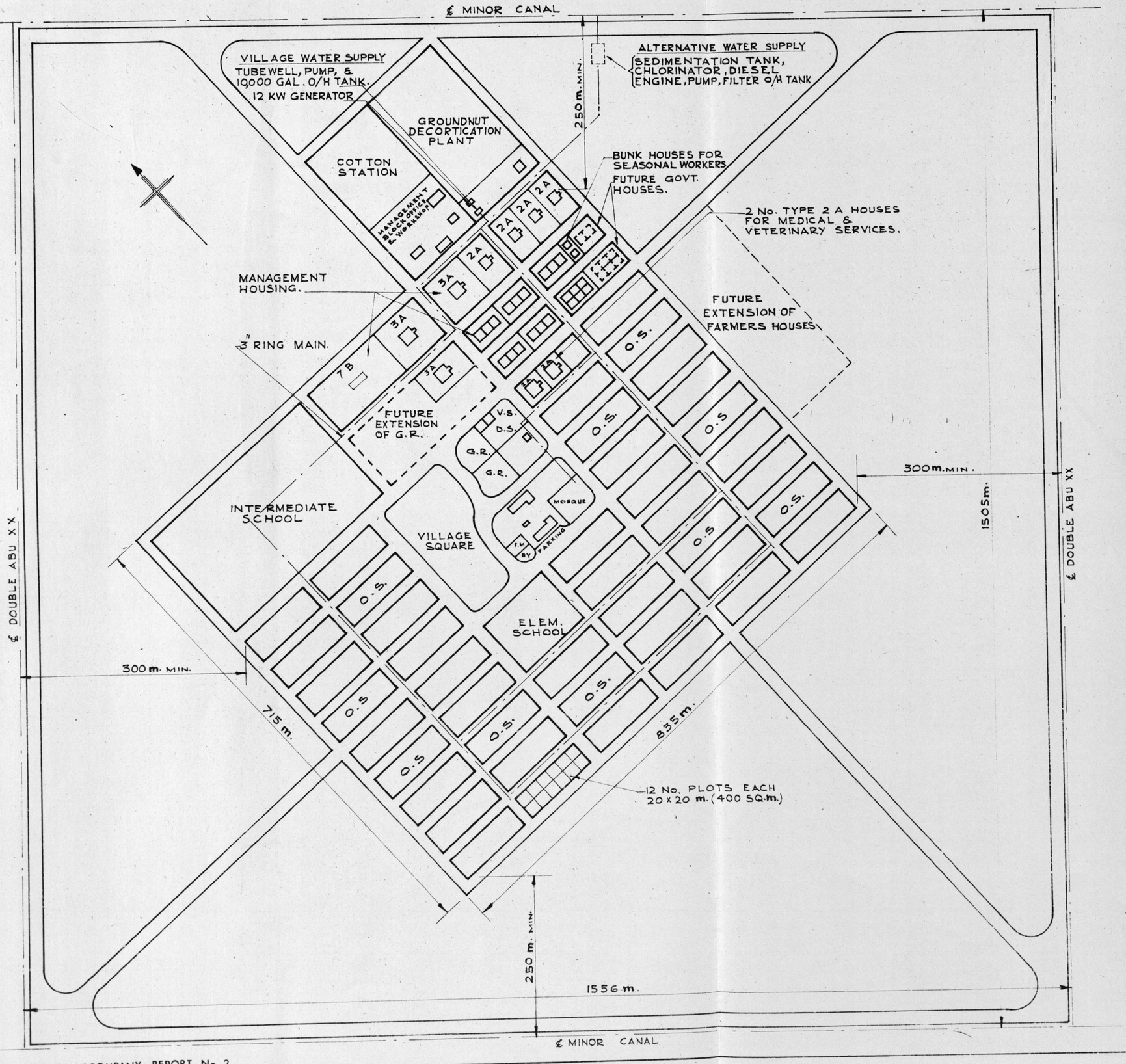
LAYOUT OF TYPICAL VILLAGE

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

SCALE AS SHOWN

DRG. No SN 87
DATE: MAY 1965

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2



NOTES:

1. VILLAGE TO BE ORIENTATED TO FACE PREVAILING N-S WIND.
2. PIPED WATER TO MOSQUE, SCHOOLS, MANAGEMENT HOUSES & DISPENSARY.
3. PLANNED POPULATION IS 400 FAMILIES EACH WITH A PLOT OF 400 SQ.m.
4. VILLAGE AREA INCLUDING ACCESS ROADS IS 200 FEDDANS.
5. SURROUNDING AREA OF 350 FEDDANS TO BE PASTURE & VEG. GARDENS.
6. MINIMUM WIDTH OF ROAD IS 15 m.
7. G.R. GOVT. RESERVE.
   O.S. OPEN SPACE.
   D.S. DISPENSARY.
   F.M. FLOUR MILL.
   BY. BAKERY.
   V.S. VETERINARY FIELD STATION.

SCALE

M. 100 0 100 200 300 M.

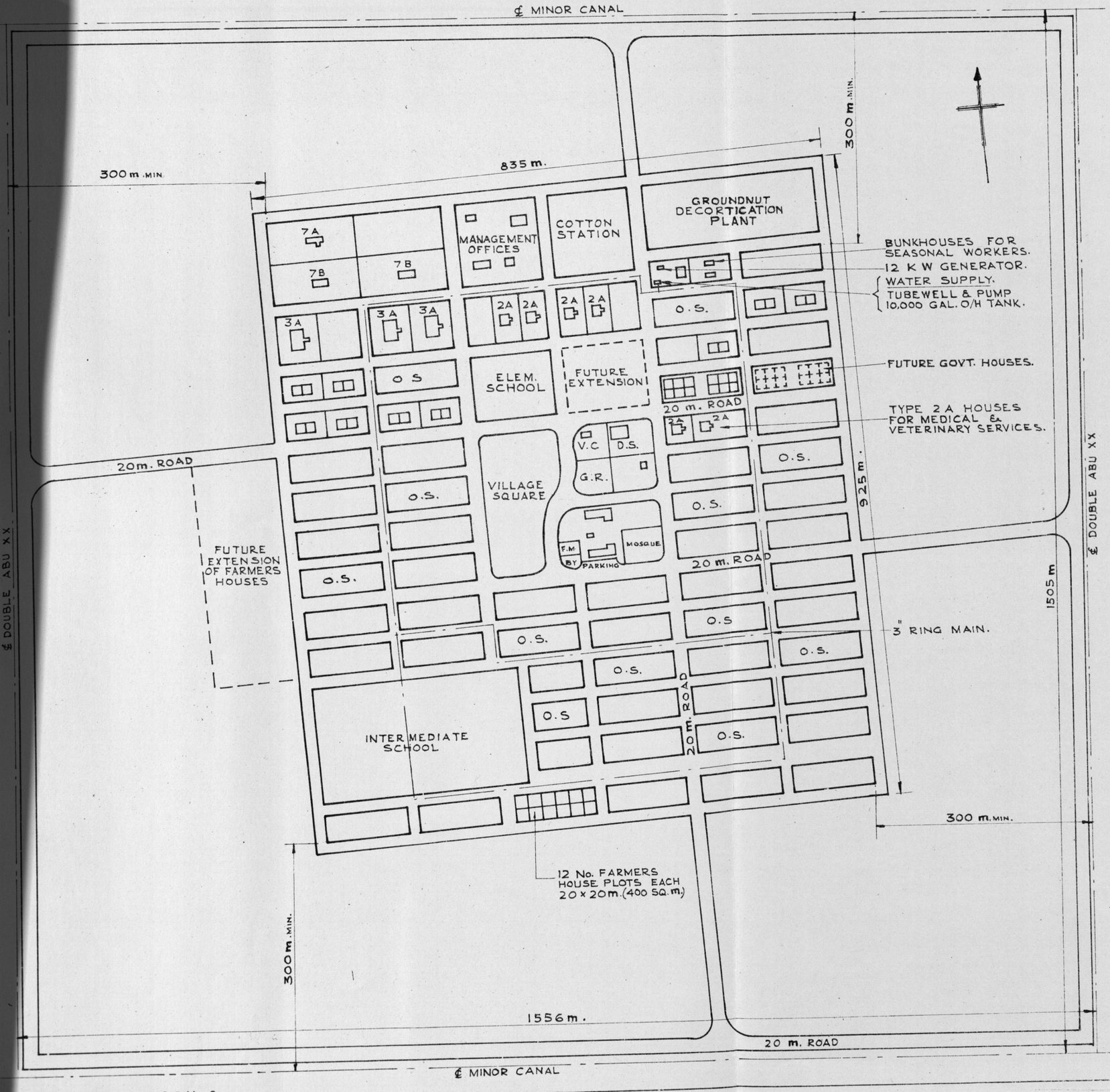
THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

LAYOUT OF BLOCK H.Q. VILLAGE

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

SCALE
AS SHOWN

DRG. No. SN 88
DATE: MAY 1965



NOTES:-

1. VILLAGE TO BE ORIENTATED TO FACE PREVAILING N-S WIND.
2. PIPED WATER TO MANAGEMENT HOUSES, MOSQUE, SCHOOLS & DISPENSARY.
3. MINIMUM ROAD WIDTH 15 m.
4. PLANNED POPULATION IS 400 FARMERS FAMILIES EACH WITH A PLOT 400 SQ.m.
5. THE NOTHERN END OF THE VILLAGE CONTAINS OFFICES & 40 HOUSES FOR MANAGEMENT STAFF.
6. AREA OF VILLAGE INCLUDING ACCESS ROADS IS 220 FEDDANS.
7. SURROUNDING AREA OF 330 FEDDANS TO BE PASTURE & VEG. GARDEN.
8. V.C. VETERINAY CLINIC.
   O.S. OPEN SPACE.
   G.R. GOVT. RESERVE.
   D S. DISPENSARY.
   F.M. FLOUR MILL.
   BY. BAKERY.

SCALE

M. 100 0 100 200 300 M.

THE REPUBLIC OF THE SUDAN
MINISTR OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

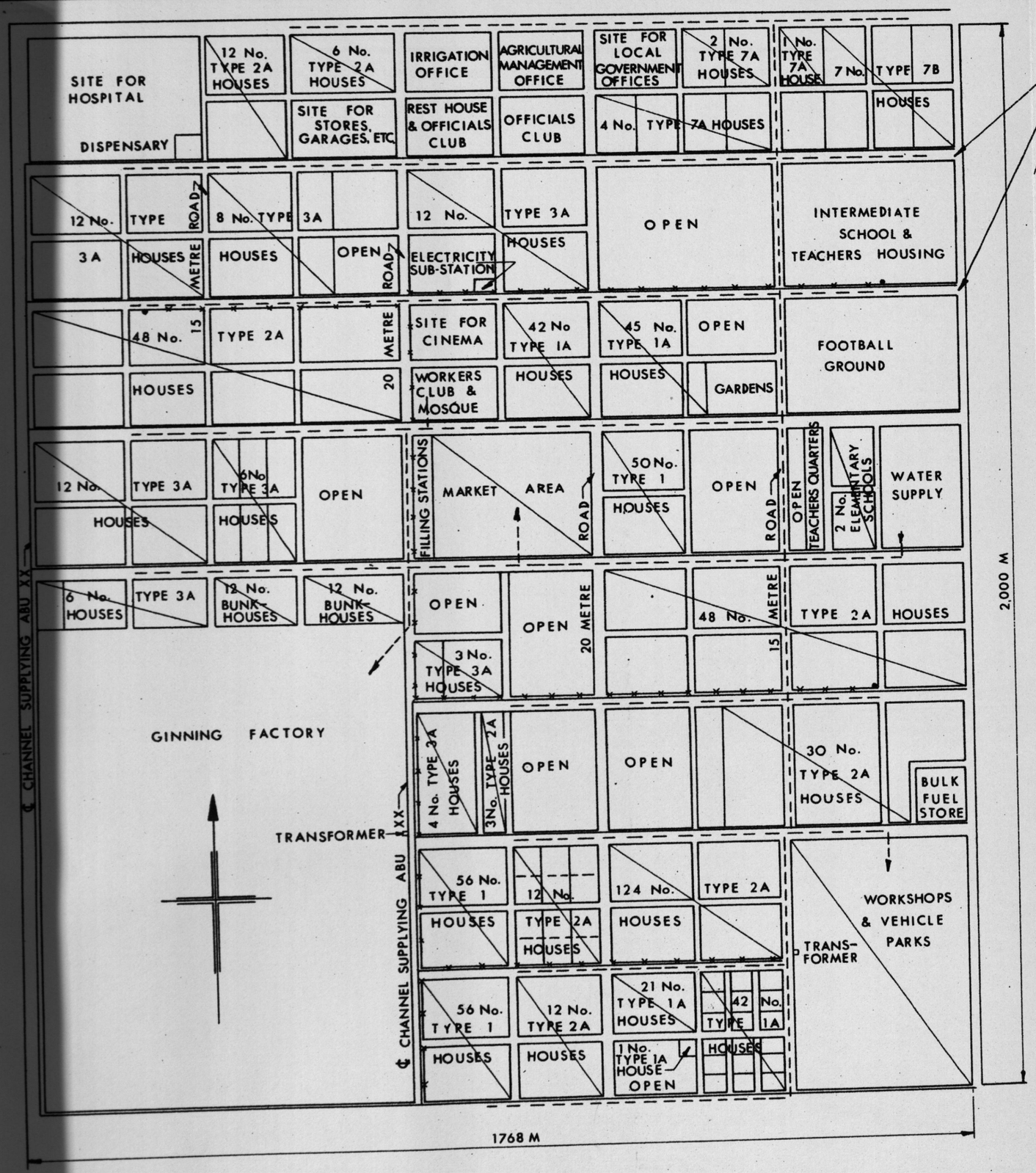
LAYOUT OF GROUP H.Q. VILLAGE

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

SCALE AS SHOWN

DRG. No. SN 89
DATE: MAY 1965

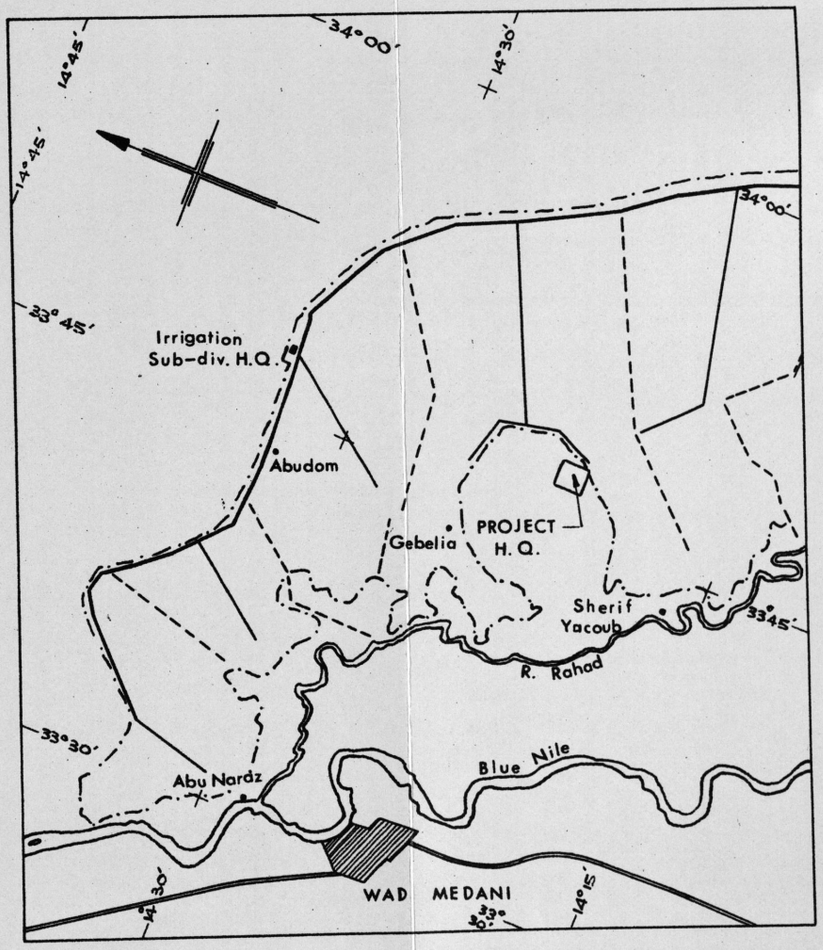
PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2



PLAN OF PROJECT H.Q.

M 100 0 100 200 300 400 500M

17 M. ROADS WITH ABU XXS



LOCATION PLAN

KM 5 0 5 10 15 KM

HOUSING

TYPE 7A	-	7
TYPE 7B	-	7
TYPE 3A	-	60
TYPE 2A	-	195
TYPE 1A	-	151
TYPE 1	-	162
BUNK HOUSE	-	24

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

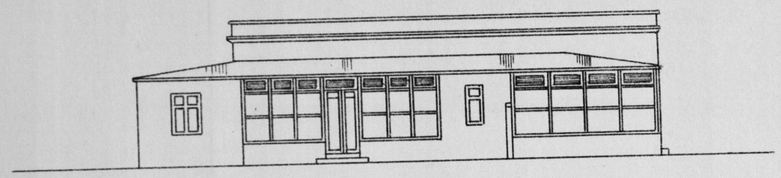
LAYOUT OF PROJECT ADMINISTRATION HEADQUARTERS

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

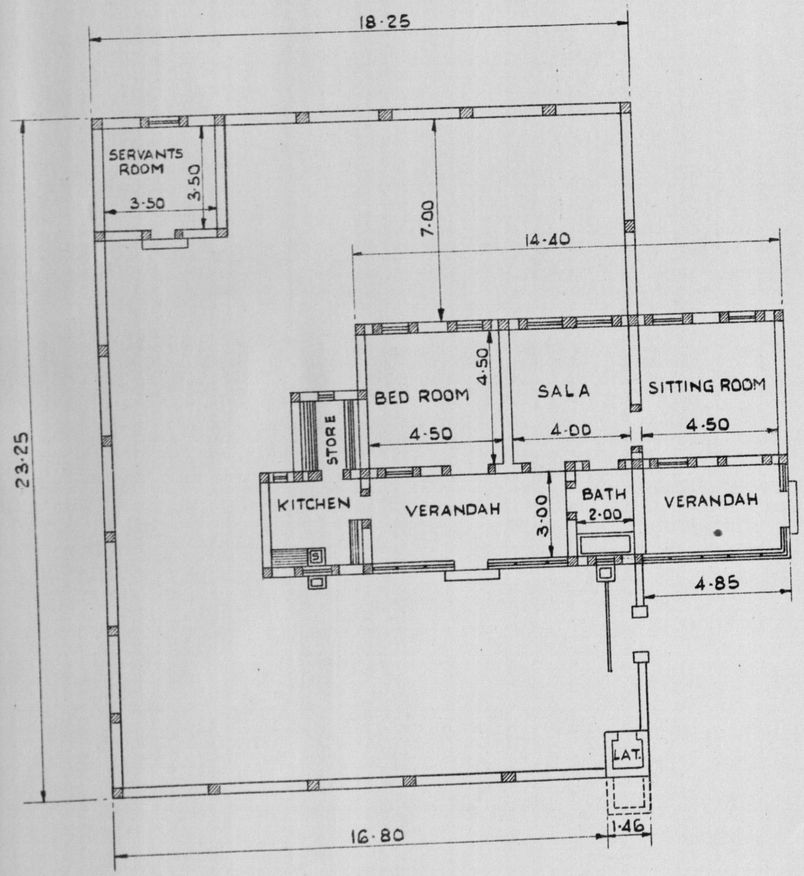
SCALES AS SHOWN

DRG. No. SN 90

DATE: MAY, 1965.

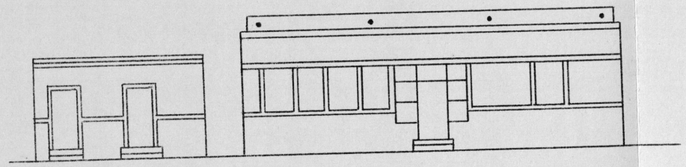


SOUTH ELEVATION

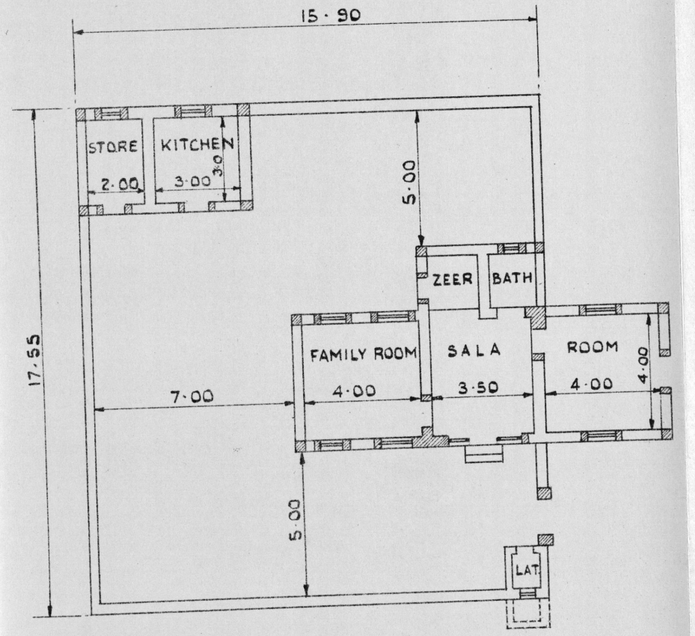


PLAN

TYPE 3A HOUSE



SOUTH ELEVATION



PLAN

TYPE 2A HOUSE

MIO 0 10M

CONSTRUCTION DETAILS TYPE 3A & 2A HOUSES

ROOF : JACK ARCH - 8" × 4" × 18# R.S.J. 4:2:1, P.C. CONC. 4" THICK. INSULATED WITH 10cms. AVERAGE THICKNESS LIME & HOMRA CONCRETE

WALLS : 35 cms. THICK SAND STONE RUBBLE MASONRY IN 8:1 P.C.M. - PARAPET & CORNER JAMBS IN RED BRICK 8:1 P.C.M. INTERNAL P.C. PLASTER 10:1

FLOORS : 2cms. THICK P.C. TILES - 10 cms. LIME & HOMRA, 10cms. SAND & BRICK, 18 cms. RAMMED EARTH FILL

FOUNDATIONS : 50cms. × 70cms. R.C. TOE BEAM 1m BELOW G.L.

VERANDAH : G.C.I. SHEETS WITH CELOTEX CEILING

BOUNDARY WALL: SAND STONE RUBBLE IN MUD WITH 3:1 P.C.M. POINTING BOTH FACES. B.O.E COPING SAND STONE RUBBLE IN 6:1 P.C.M. FOUNDATION

NOTE.

HOUSING DETAILS REPRODUCED FROM SUDAN MINISTRY OF IRRIGATION AND H.E.P. DRAWINGS No. S.I.D/58-12684 AND S.I.D./58-1/6798

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

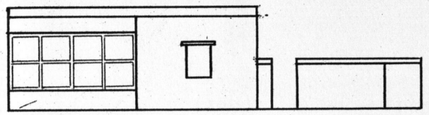
OUTLINE HOUSE PLANS TYPE 3A&2A

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

SCALE AS SHOWN

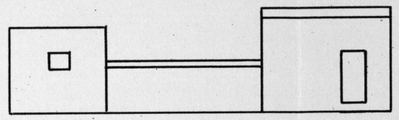
DRG. No. SN 91

DATE : APRIL 1965.



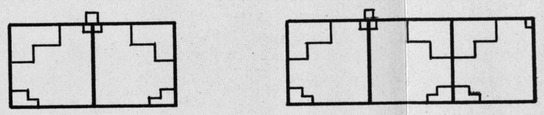
SOUTH ELEVATION OF LIVING QUARTERS

SCALE 'A'



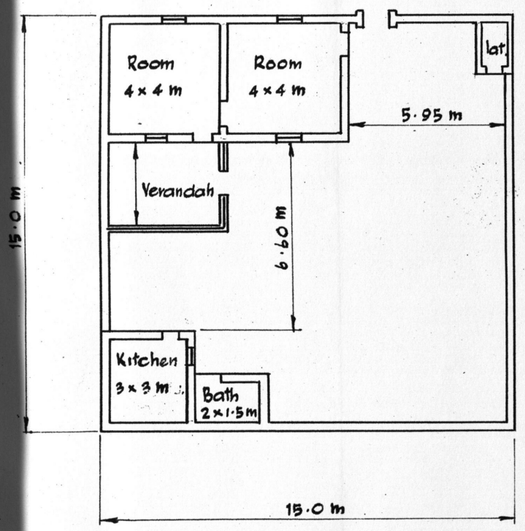
ELEVATION OF KITCHEN & LIVING QUARTERS

SCALE 'A'



LAYOUT OF CLASS IA HOUSES

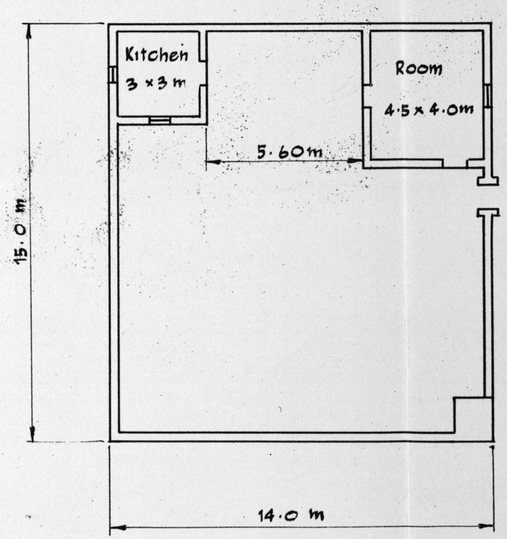
Scale 'B'



PLAN

SCALE 'A'

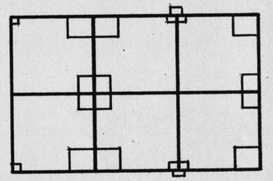
TYPE IA HOUSE



PLAN

SCALE 'A'

TYPE I HOUSE



LAYOUT OF CLASS I HOUSES

Scale - 'B'

TYPES 1A & 1 HOUSES

CONSTRUCTION DETAILS

ROOF - 12 cms. R.C. Slab insulated by 10 cms. lime & homra concrete. Kitchen roof G.C.1 sheets with 5 cms. lime & homra concrete insulation.

WALLS - 35 cms. thick sand stone rubble masonary in mud mortar above G.L. Corner jambs & belt at sill & roof level of red brick in 8:1 P.C.M. Walls cement pointed 3:1 externally & cement plastered internally.

FLOOR - 7 cms. brick on flat grouted with 8:1 P.C.M, 10 cms. sand & brick, 13 cms. rammed earth fill.

FOUNDATIONS - 50 cms. x 70 cms. R.C. Toe beam 80 cms. below G.L. Wall below floor level sand stone rubble masonary in 8:1 P.C.M.

VERANDAH - G.C. 1 sheets roofing. Celotex roofing.

BOUNDARY WALL - 35 cms. thick x 1.75 m. high above G.L. sand stone rubble in mud, cement pointed in 3:1 P.C.M. both faces B.O.E. coping. Foundation of sand stone rubble in 6:1 P.C.M.

NOTE :- Reproduced from Sudan Ministry of Irrigation & H.E.P. Drawings No. SID/61-12868 & SID/58-1/6800.

SCALE 'A'

M. 5 0 5 10 15 M.

'B'

M. 10 0 10 20 30 40 50 60 70 80 90 100 M.

THE REPUBLIC OF THE SUDAN

MINISTRY OF FINANCE AND ECONOMICS

ROSEIRES PRE-INVESTMENT SURVEY

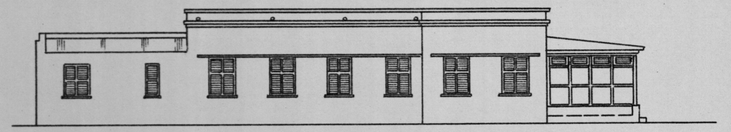
OUTLINE HOUSE PLANS TYPE IA & I

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

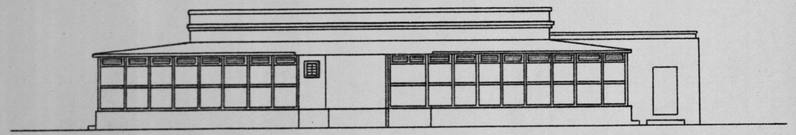
SCALE AS SHOWN

DRG. No. SN 92

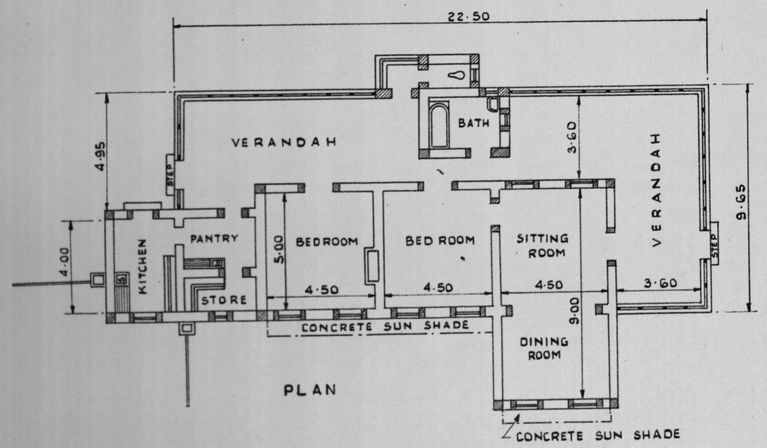
DATE:- SEPTEMBER 1965



SOUTH ELEVATION

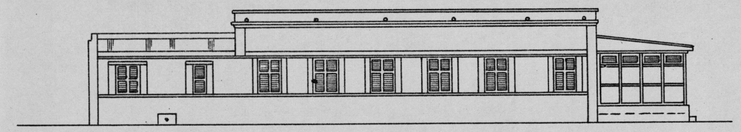


NORTH ELEVATION



PLAN

TYPE 7A HOUSE



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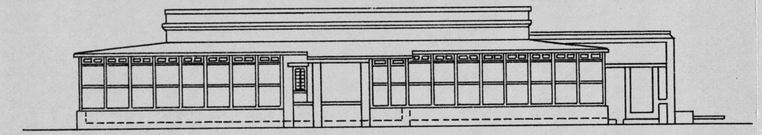
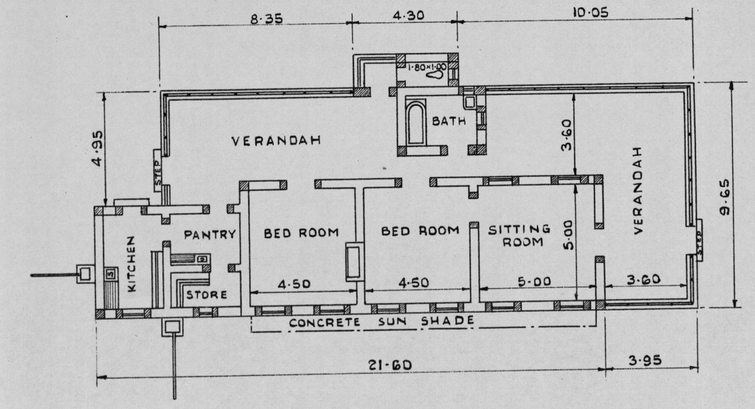


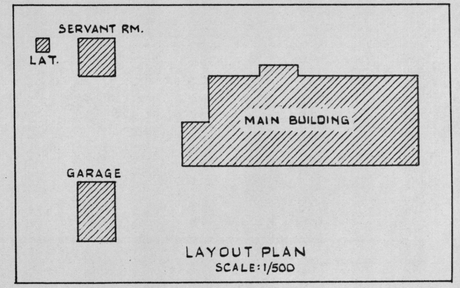
NORTH ELEVATION



PLAN

TYPE 7B HOUSE

M5 0 5 10M



KM1 0 1 2KM.

CONSTRUCTION DETAILS TYPE 7A & 7B HOUSES

ROOF : JACK ARCH WITH 8"×4"×18# R.S.J. & RED BRICK IN 4:1 P.C.M. INSULATED BY 10cms. AVERAGE THICKNESS LIME & HOMRA CONCRETE

WALLS : 35cm. THICK SAND STONE RUBBLE MASONRY IN 8:1 P.C.M. WITH 8:1 P.C.M. BRICK WORK IN CORNER JAMBS & PARAPET. INTERNAL PLASTER 10:1

FLOORS : P.C. TILES ON 10cms. LIME & HOMRA CONCRETE, 10cms. SAND & BRICK, 18cms. RAMMED EARTH FILL

FOUNDATIONS: 50cms. × 30cms. R.C. TOE BEAM 80cms. BELOW G.L.

VERANDAH : ROOF OF G.C.I. SHEETS WITH CELOTEX CEILING

NOTE.

HOUSING DETAILS REPRODUCED FROM SUDAN MINISTRY OF IRRIGATION AND H.E.P. DRAWINGS No. S1D/58-12681 AND S.1.D./58-12682

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE INVESTMENT SURVEY

OUTLINE HOUSE PLANS TYPE 7A & 7B

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

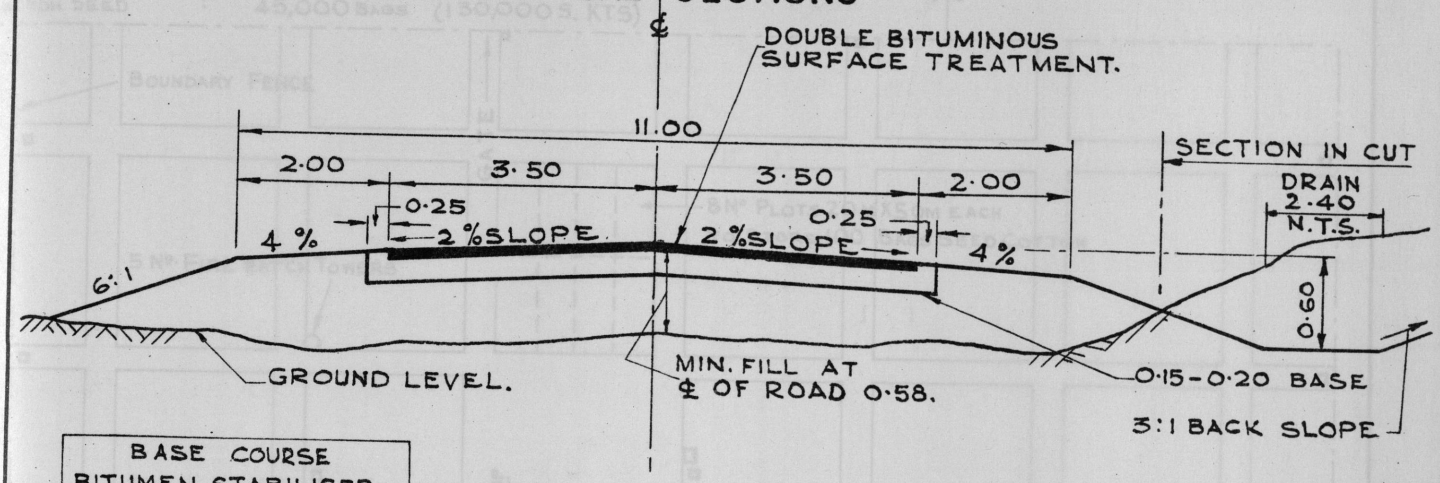
SCALE
AS SHOWN

DRG No S N 93
DATE: APRIL 1965

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

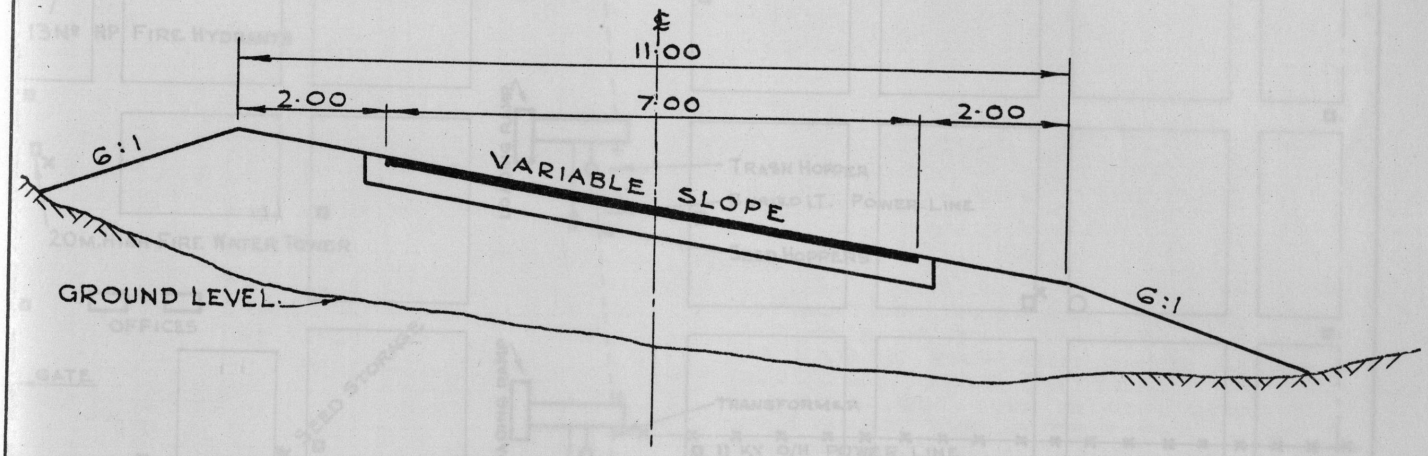
WAD MEDANI PROJECT H.Q. ROAD
TYPICAL SECTIONS

PLATE 25

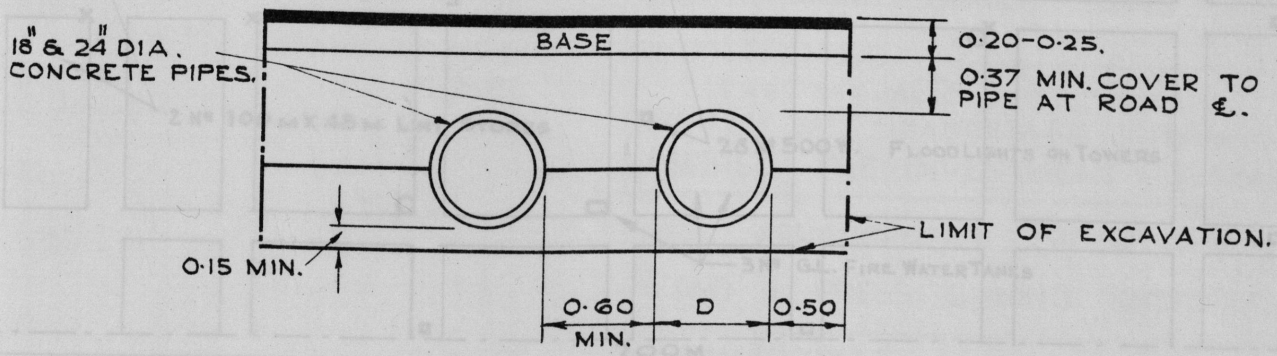


BASE COURSE
BITUMEN STABILISED, CRUSHED GRAVEL, OR CEMENT STABILISED.

NORMAL SECTION



SUPERELEVATED SECTION



TYPICAL CULVERT

DRG. No. SN. 94.
DATE: MAY 1965

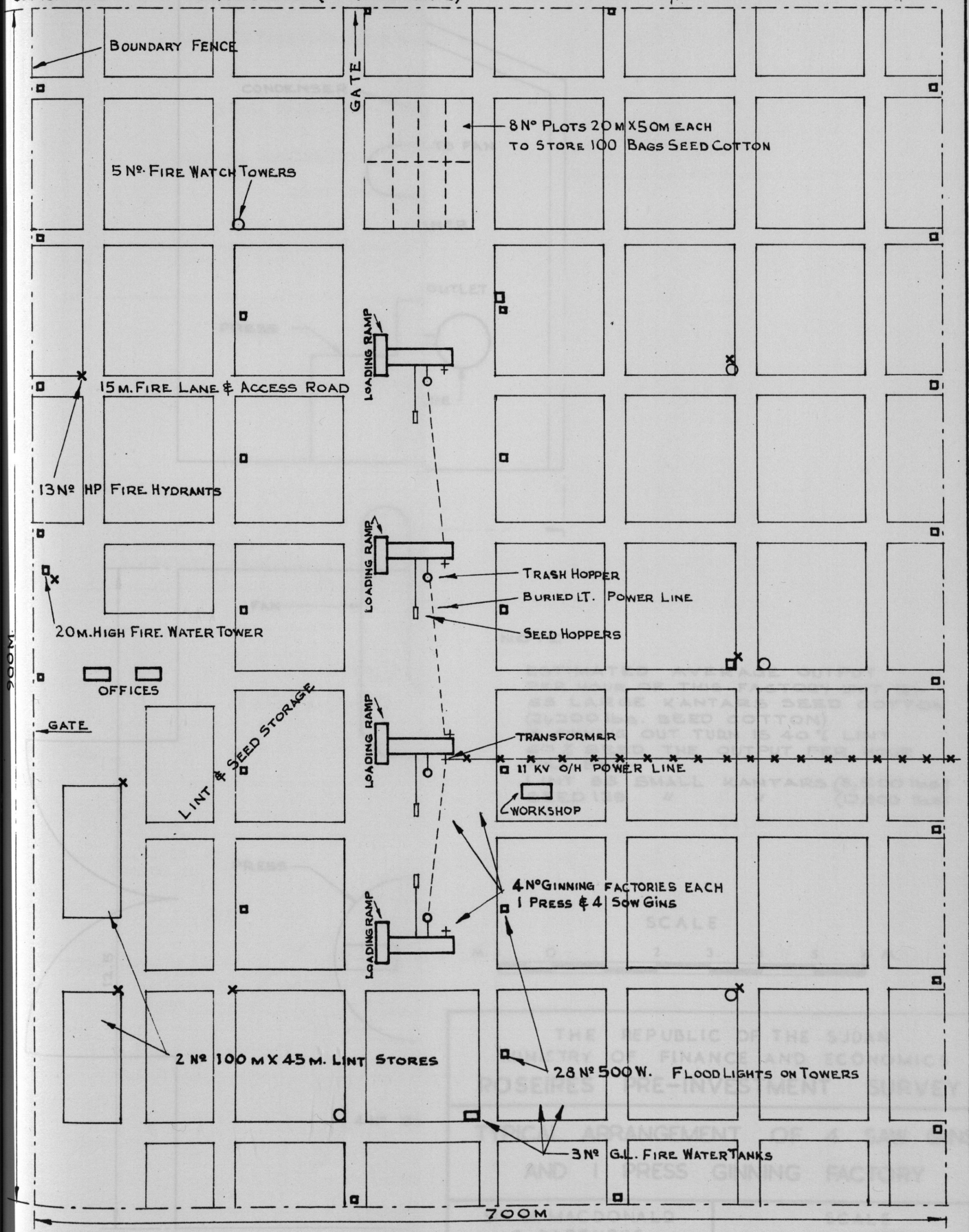
SCALE:- HORIZONTAL - 1:100
VERTICAL - 1:50

SIR M. MACDONALD & PARTNERS

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

PLATE 26

YARD STORAGE
SEED COTTON : 340,000 BAGS (405,000 L.KTS.)
MEAN ANNUAL OUTPUT OF SEED COTTON : 675.000 L.KTS.
LINT COTTON : 60,000 BALES (280,000 S.KTS)
COTTON SEED : 45,000 BAGS (130,000 S.KTS)



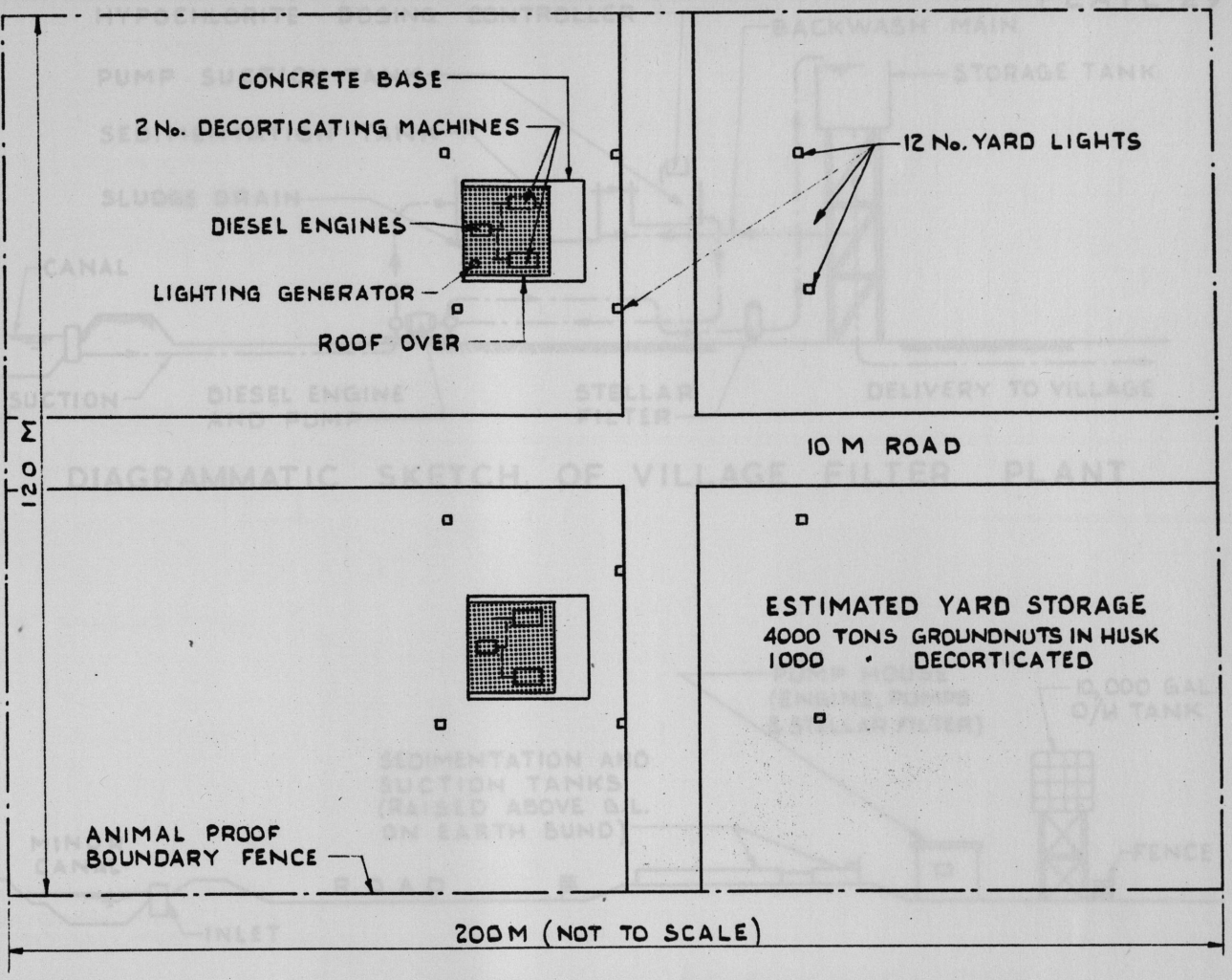
TYPICAL LAYOUT OF GINNING FACTORY AREA

SCALE 1:4,000

DRG. Nº. SN 95

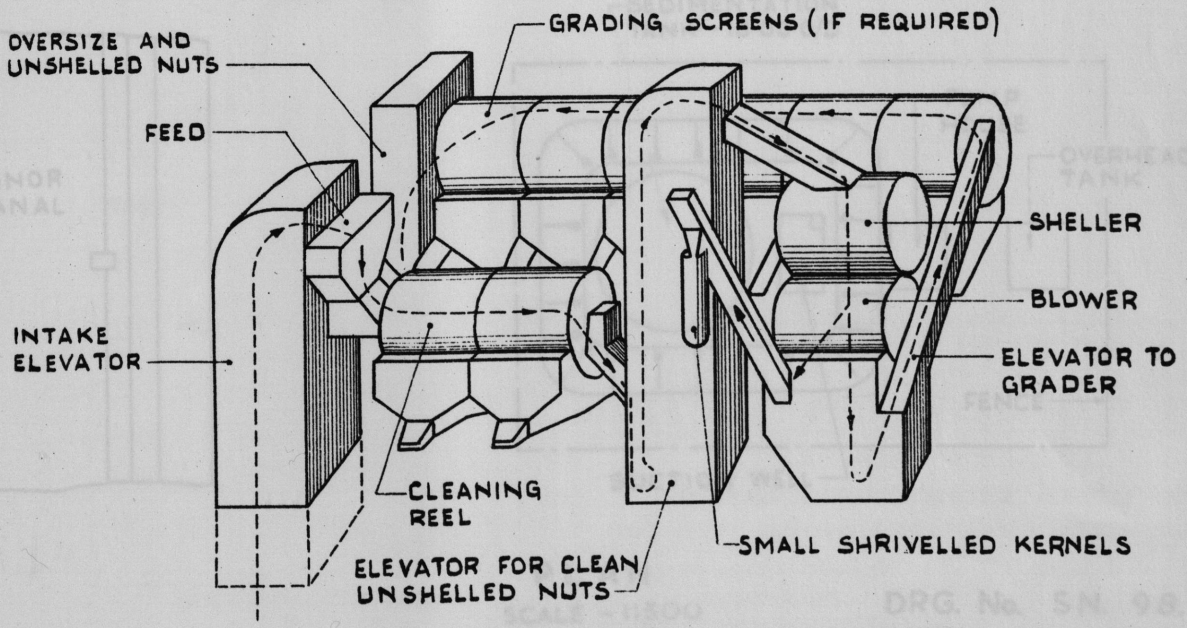
SIR M. MACDONALD & PARTNERS

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2



TYPICAL LAYOUT OF GROUNDNUT DECORTICATION AREA

SCALE : 1/1000

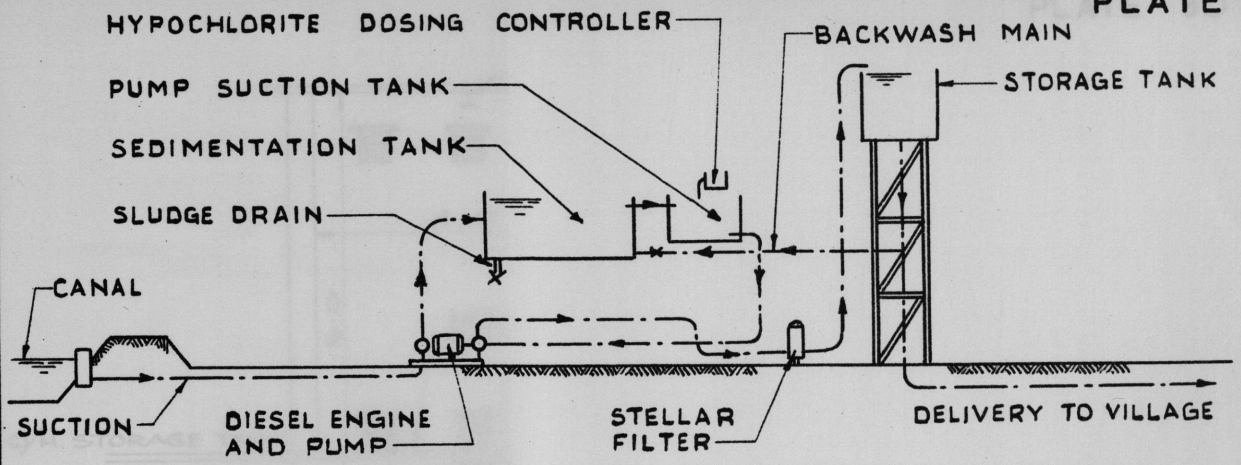


DECORTICATION MACHINE – FLOW DIAGRAM

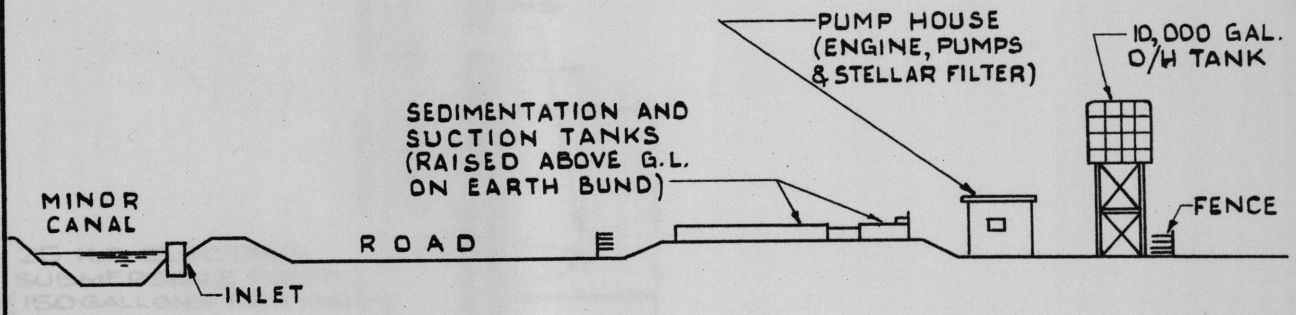
DRG. No. SN. 97
DATE: APRIL 1965

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

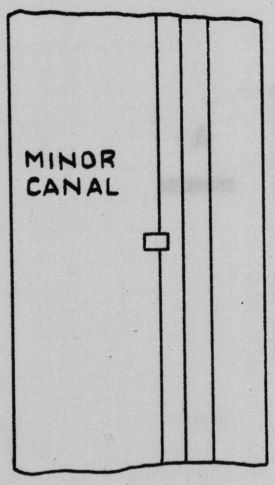
PLATE 29

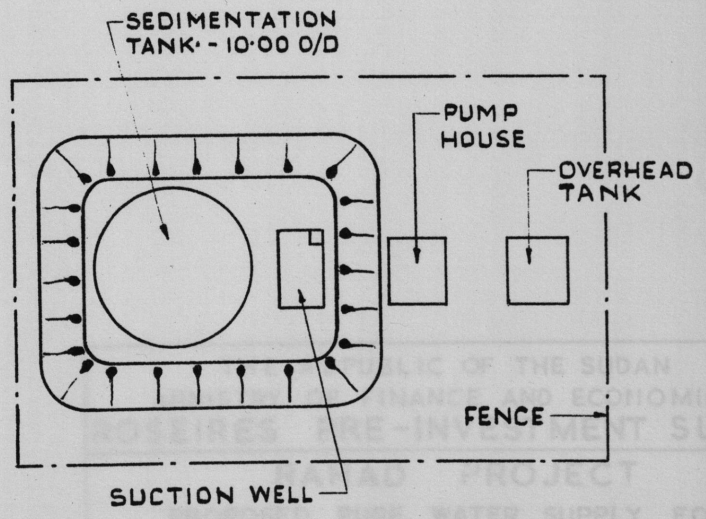


DIAGRAMMATIC SKETCH OF VILLAGE FILTER PLANT



ELEVATION



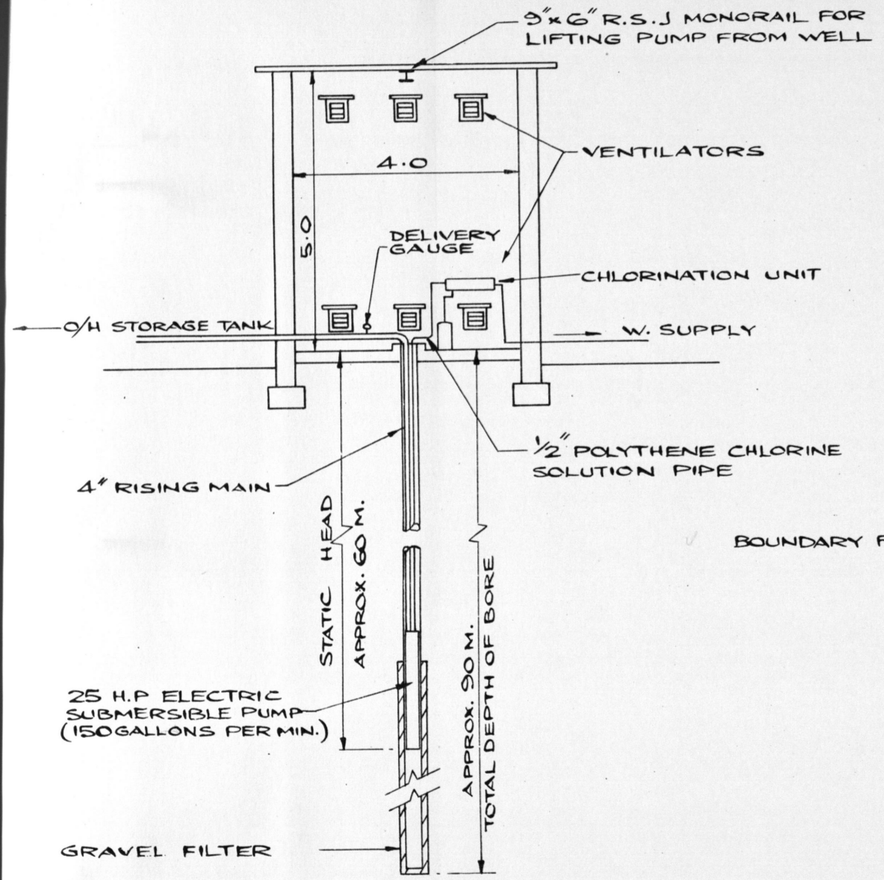


PLAN
SCALE - 1:500

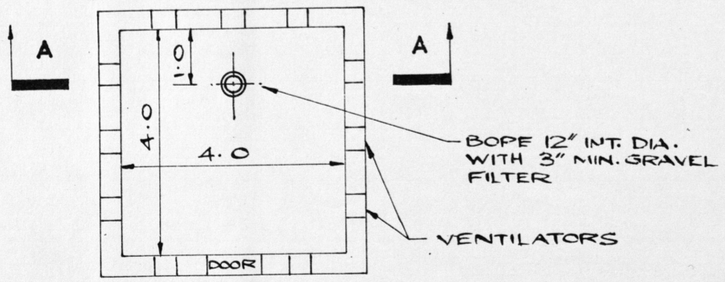
DRG. No. SN. 98.
DATE: APRIL 1965.

PRELIMINARY DRAWING TO ACCOMPANY REPORT N. ?

SIR M. MACDONALD & PARTNERS



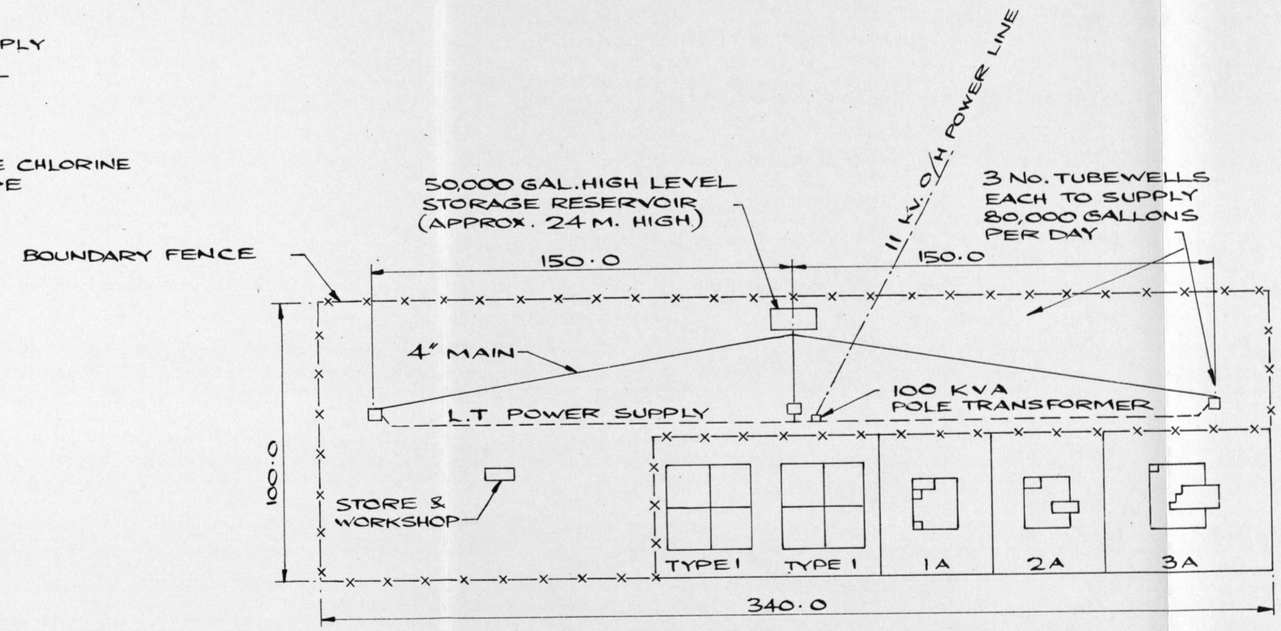
SECTION A-A



PLAN

M1 0 1 2 3 4 5M

DETAIL OF TUBEWELL



LAYOUT PLAN

M50 0 50 100M

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

RAHAD PROJECT

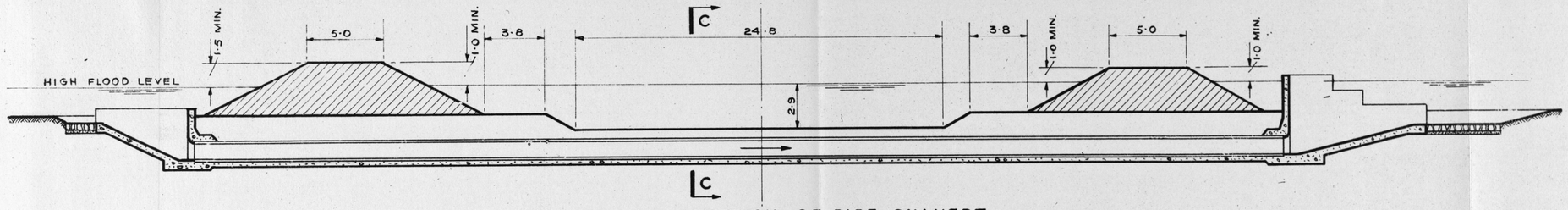
PROPOSED PURE WATER SUPPLY FOR PROJECT ADMINISTRATION HEADQUARTERS

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

SCALES AS SHOWN

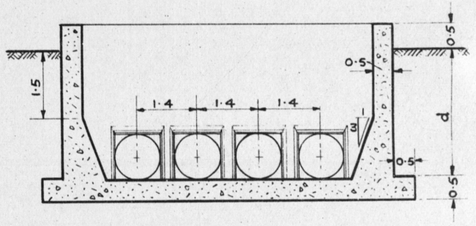
DRG. No. SN 99.
DATE :- APRIL 1965

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

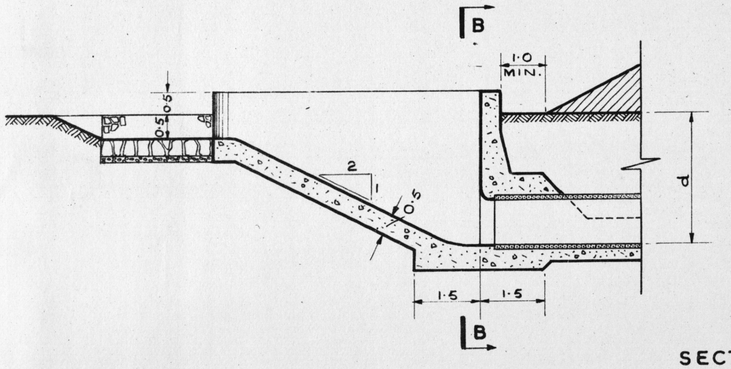


LONGITUDINAL SECTION OF PIPE CULVERT

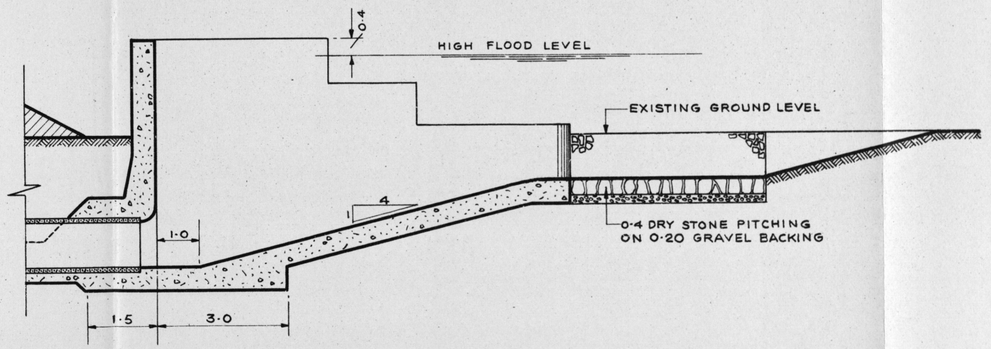
SCALE A

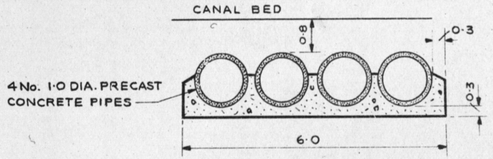


SECTION B-B



SECTION A-A



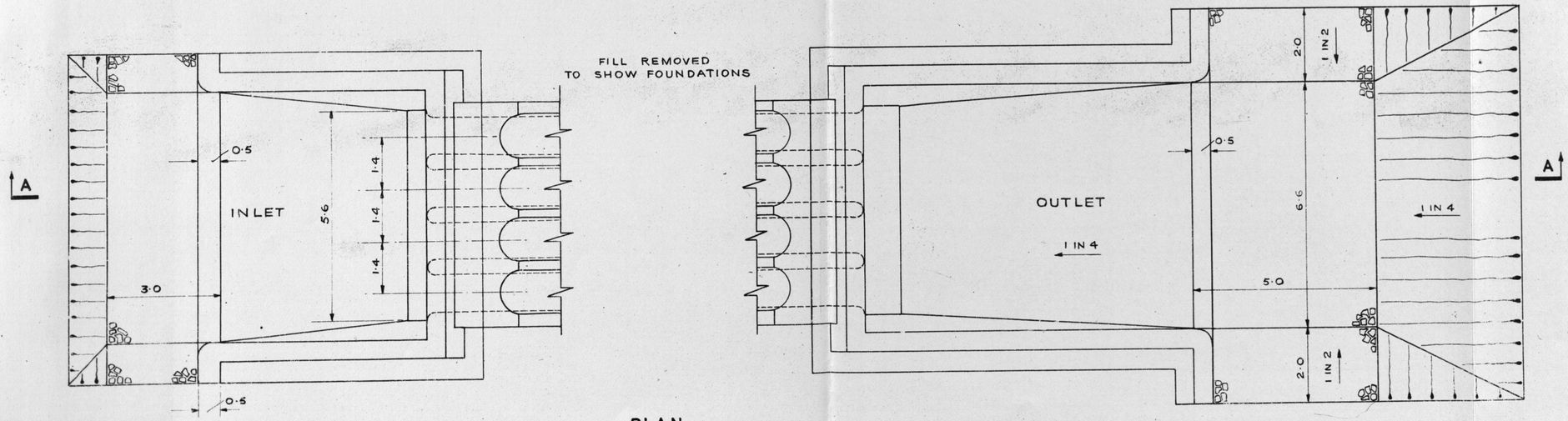


SECTION C-C

SCALE B

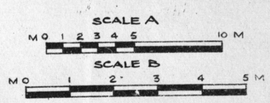
NOTES

1. TYPE CULVERT FOR KHOR AQALIYIN AND KHOR ABU MUHAR. FOR LOCATION SEE DRG. Nº SU 155.
2. FOR SMALLER KHOR CROSSINGS ONLY ONE PIPE CULVERT.



PLAN

SCALE B



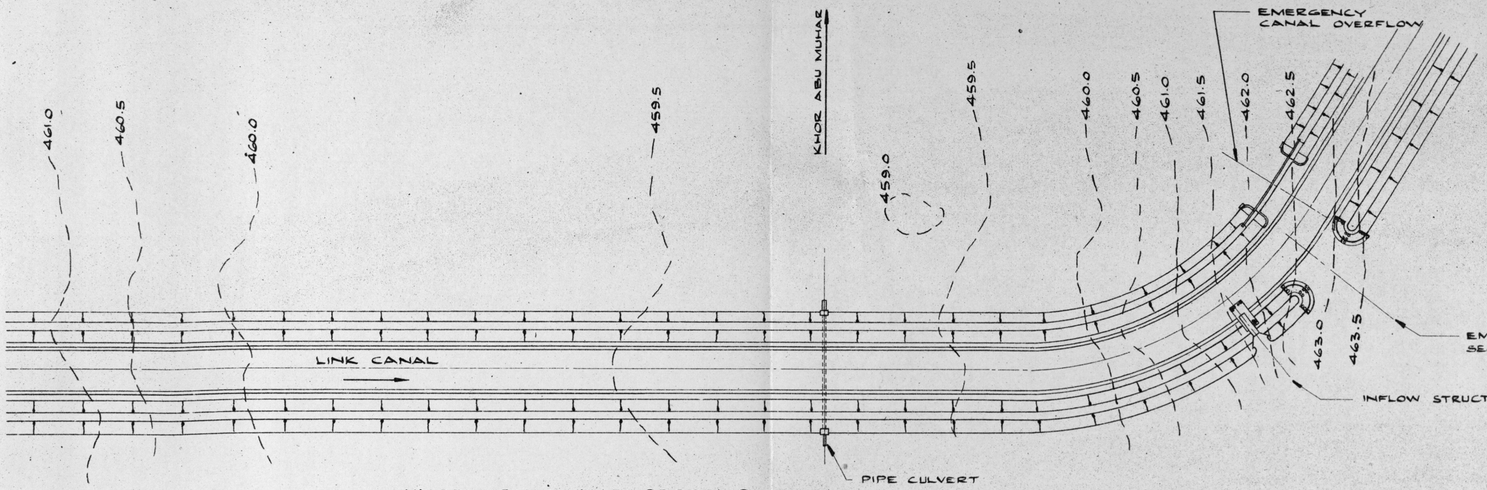
THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE & ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

TYPICAL PIPE SIPHON FOR KHOR CROSS DRAINAGE

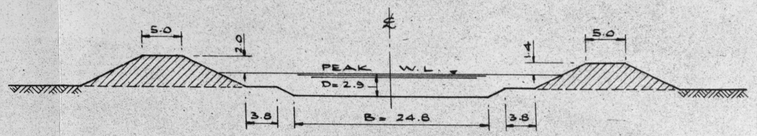
SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS
LION HOUSE
RED LION STREET
LONDON W.C.1

SCALES
AS SHOWN
DRG. No SU 154
DATE MAY 1965

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

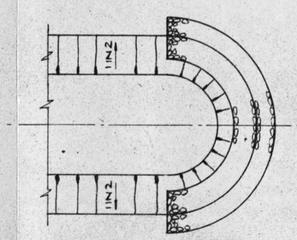


KHOR ABU MUHAR CROSSING

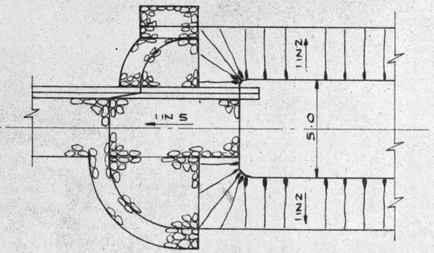


TYPICAL CROSS SECTION OF LINK CANAL AT KHOR CROSSING

M. 10 0 10 20 M.



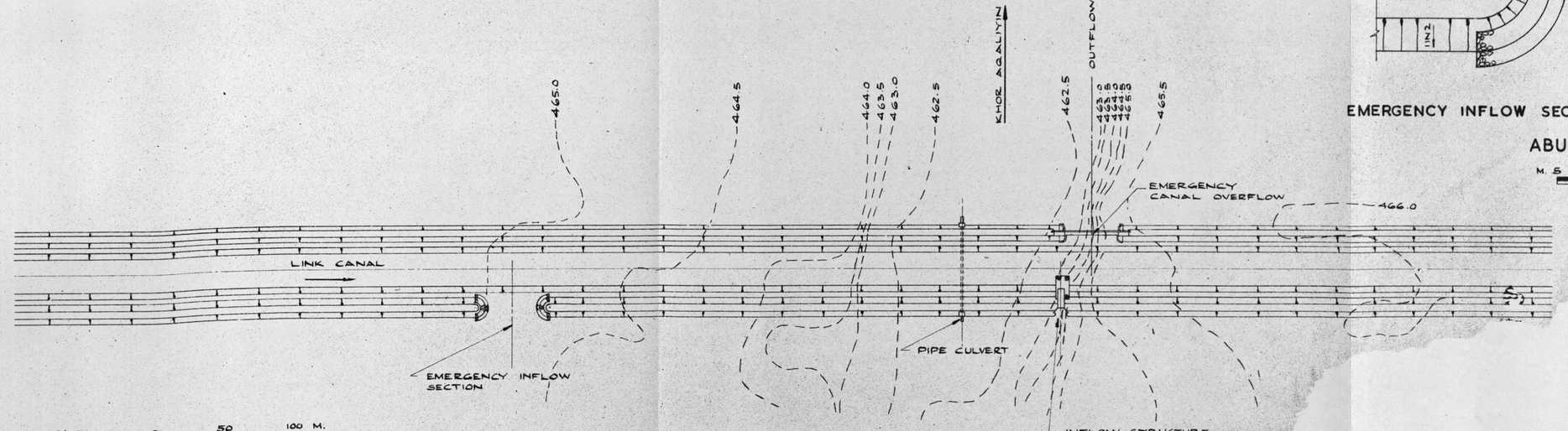
EMERGENCY INFLOW SECTION



EMERGENCY CANAL OVERFLOW

ABUTMENT DETAILS

M. 5 4 3 2 1 0 5 M.



KHOR AQALIYIN CROSSING

M. 50 0 50 100 M.

NOTES :-

1. FOR MAIN DETAILS OF STRUCTURES SEE DRG. No. SU 154.
2. GROUND LEVEL AT INFLOW STRUCTURE PEAK W.L. – 0·30
3. GROUND LEVEL AT EMERGENCY INFLOW SECTION PEAK W.L. + 1·00
4. GROUND LEVEL AT EMERGENCY CANAL OVERFLOW PEAK W.L. + 0·10

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE & ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

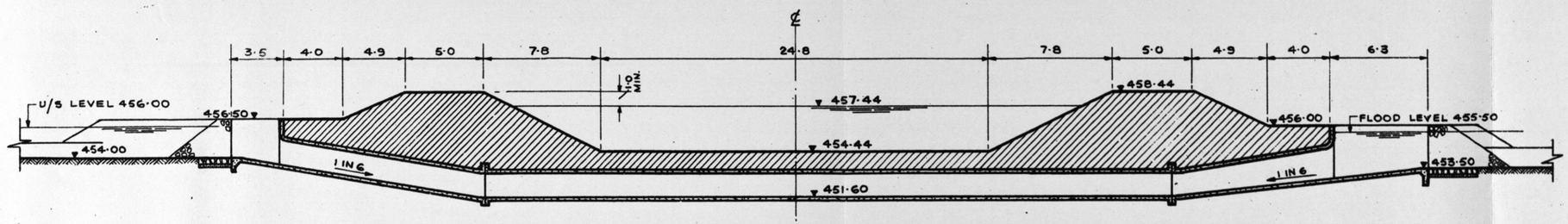
SITE PLAN
KHOR AQALIYIN & KHOR ABU MUHAR

SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS
LION HOUSE,
RED LION STREET
LONDON WC1

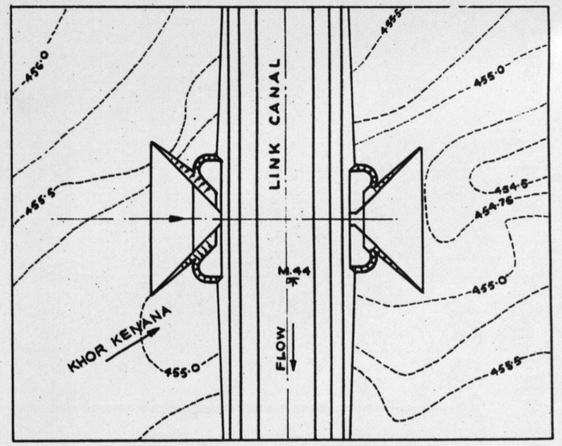
SCALES AS SHOWN
DRG. No. SU 155
DATE: MAY 1965

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

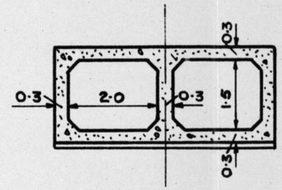
PLATE 33



SECTION A-A



SITE PLAN
SCALE A

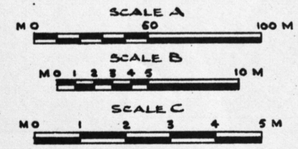


SECTION B-B
SCALE C

PLAN
SCALE B

NOTES

1. DESIGN CAPACITY OF CULVERT 15 CUMECS.
2. LINK CANAL CAPACITY 65 CUMECS.
3. CULVERT DESIGNED FOR REINFORCED CONCRETE CONSTRUCTION.
4. CULVERT ALLOWS FOR FUTURE ENLARGEMENT OF CANAL.



PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

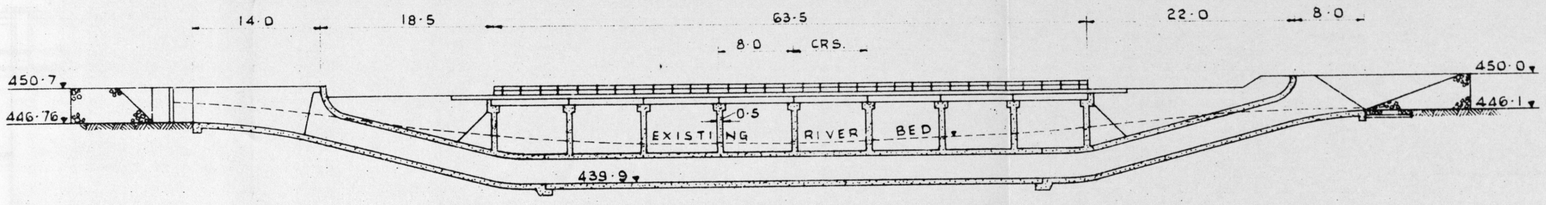
THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE & ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

RAHAD LINK CANAL
KHOR KENANA CROSSING

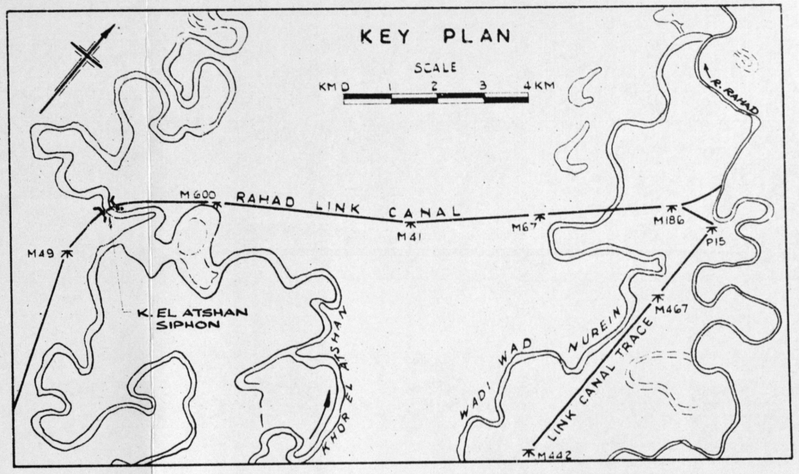
SIR M. MACDONALD & PARTNERS
CONSULTING ENGINEERS
LION HOUSE
RED LION STREET
LONDON W.C.1

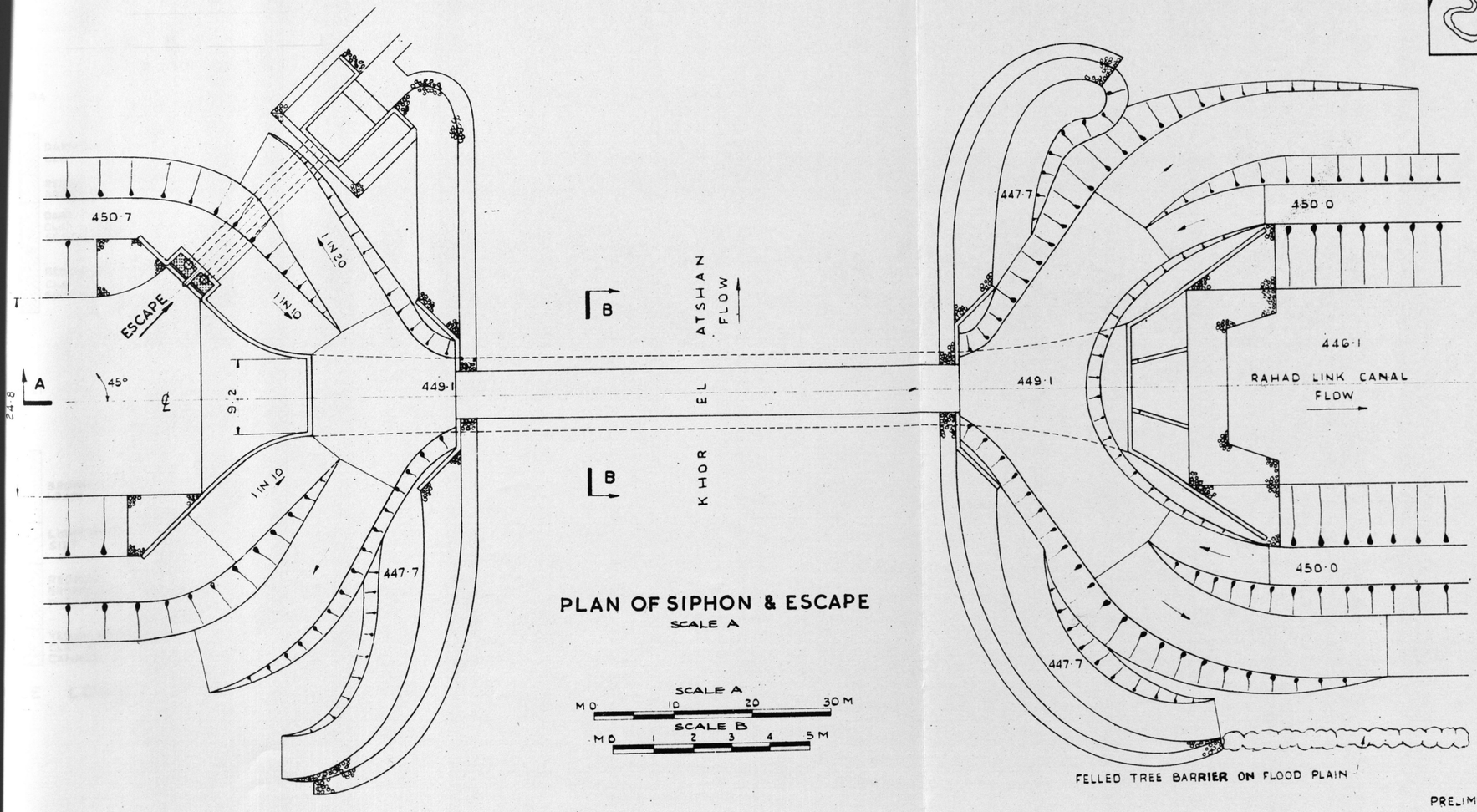
SCALES AS SHOWN
DRG. No SU 156
DATE MAY 1965.

PLATE 35



SECTION A-A

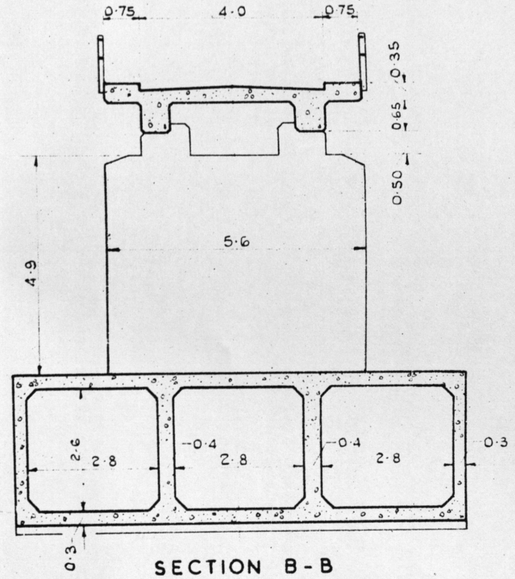




PLAN OF SIPHON & ESCAPE
SCALE A

SCALE A
M 0 10 20 30 M
SCALE B
M 0 1 2 3 4 5 M

FELLED TREE BARRIER ON FLOOD PLAIN



SECTION B-B
SCALE B

NOTES.

1. SIPHON CAPACITY - 83 CUMECS
2. CANAL DESIGN FLOW - 65 CUMECS
3. ESCAPE CAPACITY - 10 CUMECS
4. PITCHING TO BE 0·4M DRY STONE AND PLACED ON 0·2M GRAVEL
5. ALL BANK SLOPES 1 IN 2 UNLESS OTHERWISE STATED

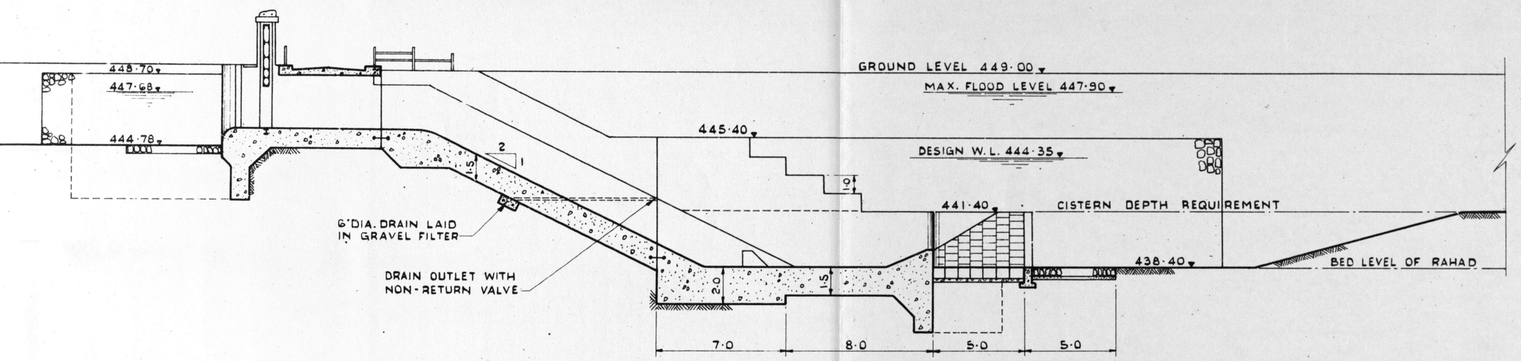
PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE & ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

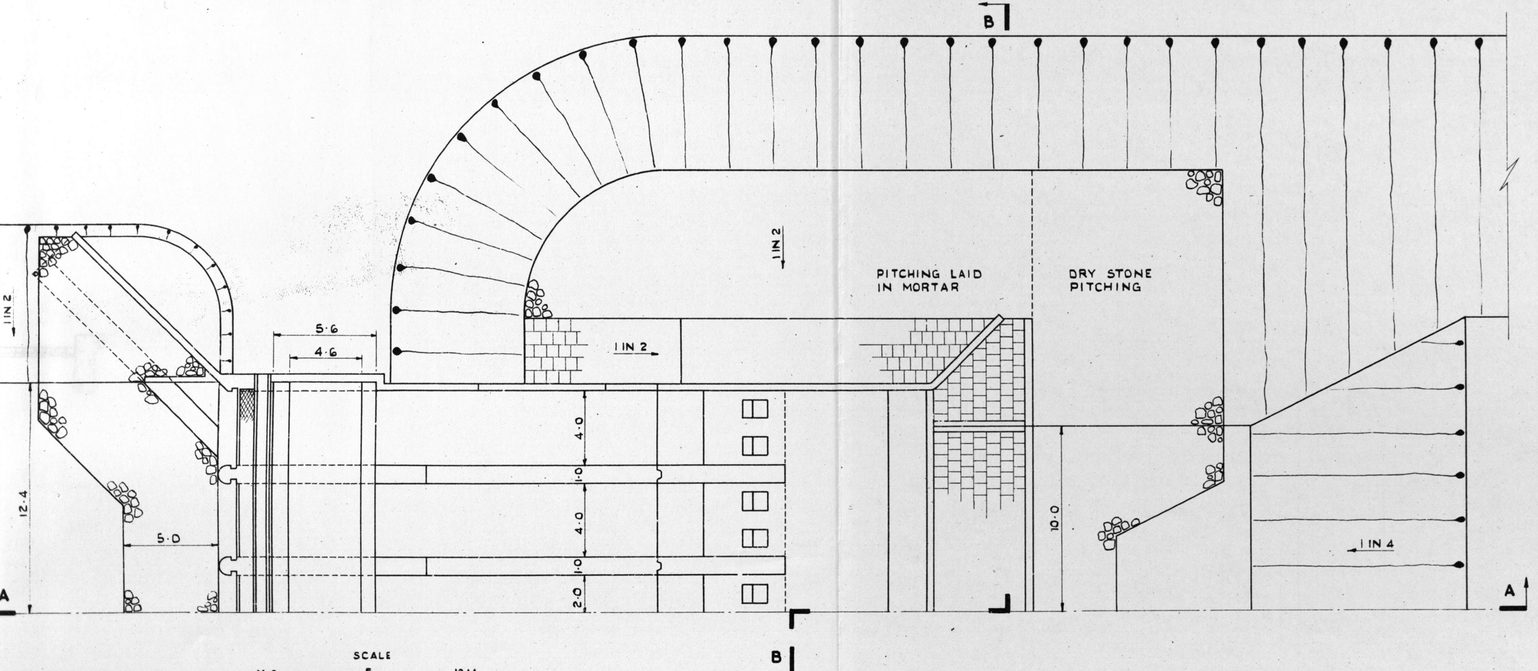
RAHAD LINK CANAL
KHOR EL ATSHAN SIPHON

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

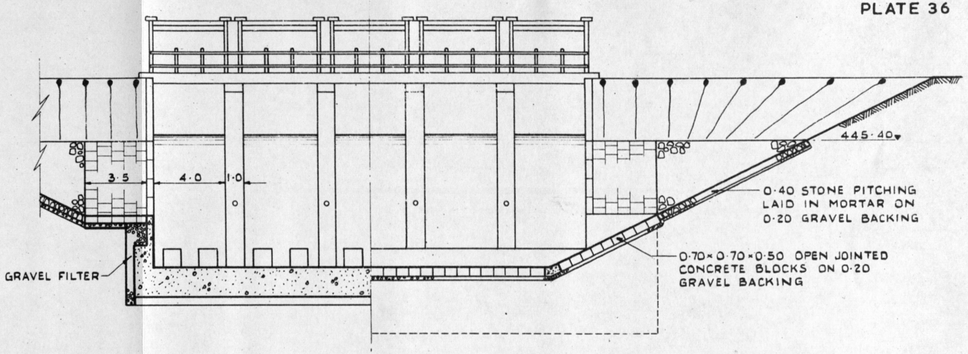
SCALES
AS SHOWN
DRG. No. SU 158
DATE: MAY 1965



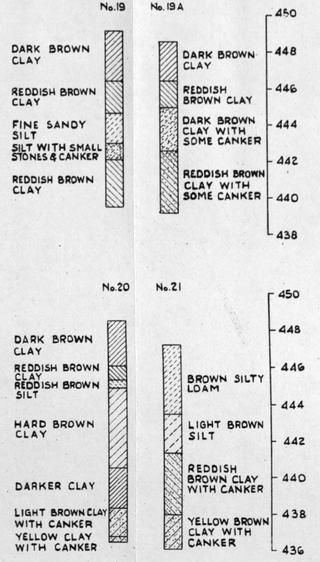
SECTION A-A



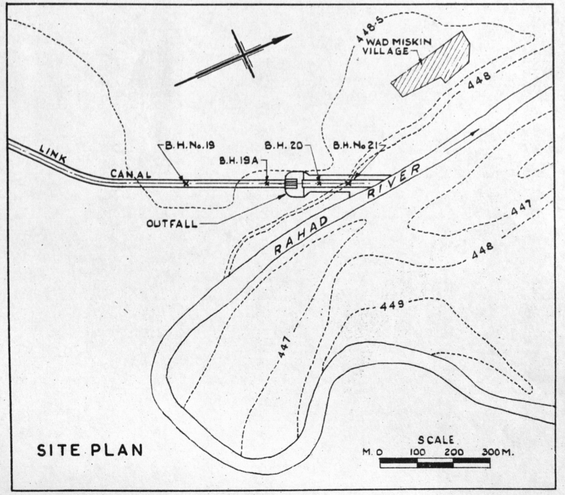
HALF PLAN



SECTION B-B



BOREHOLE LOGS



NOTES.
1. OUTFALL TO BE LOCATED IN HOMOGENEOUS IMPERVIOUS OR SEMI-PERVIOUS COHESIVE MATERIAL
2. LINK CANAL CAPACITY 65 CUMECS
3. FOR ANY ENLARGEMENT OF LINK CANAL ADDITIONAL DOWNSTREAM PROTECTION TO BE ADDED

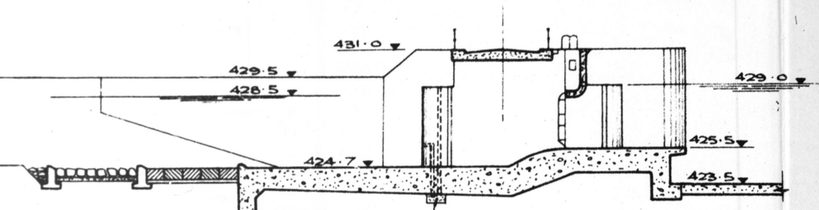
PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE & ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

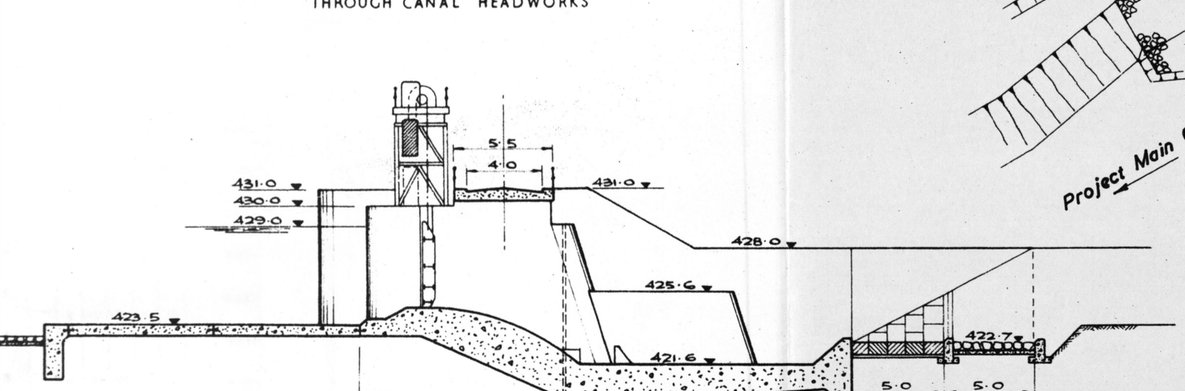
RAHAD LINK CANAL OUTFALL TO RAHAD

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

SCALES AS SHOWN
DRG. No. SU. 159
DATE:- MAY 1965

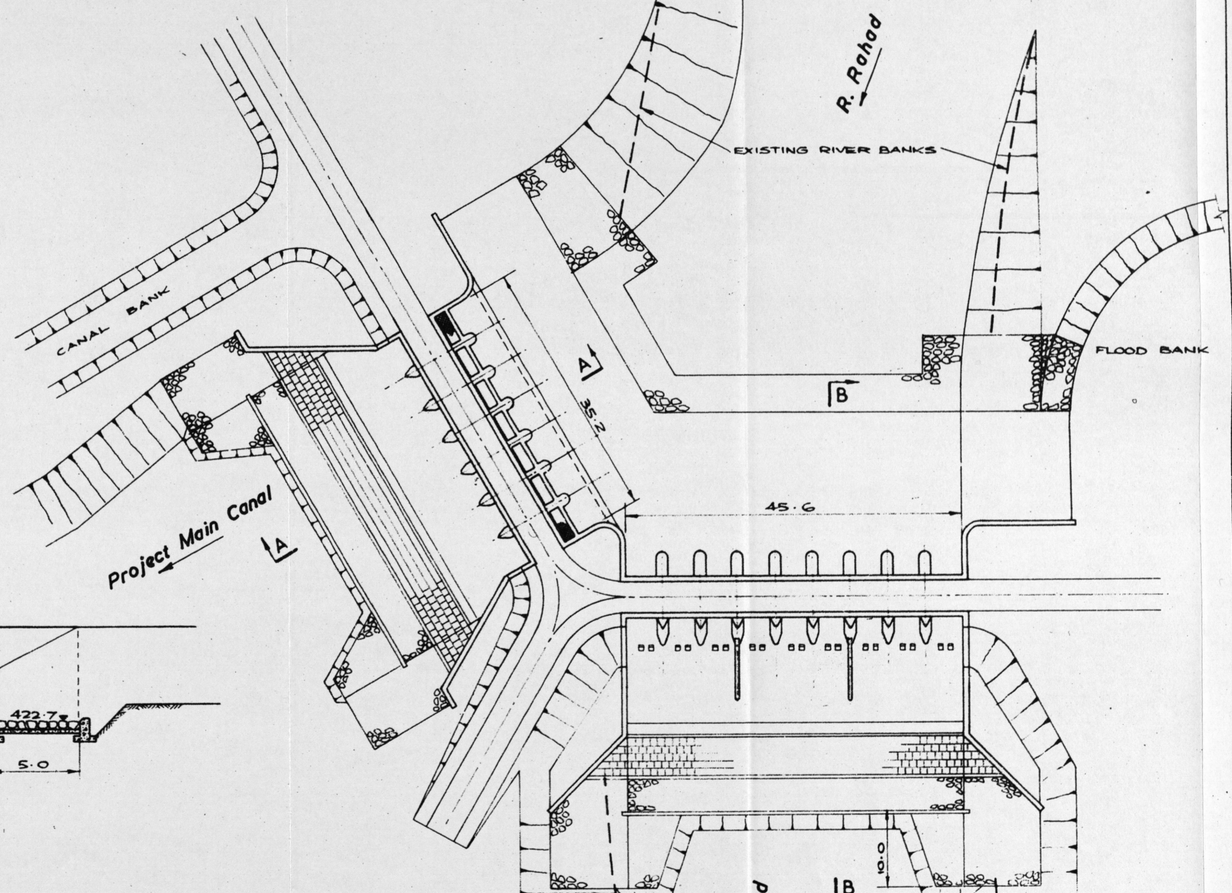


SECTION A-A
THROUGH CANAL HEADWORKS



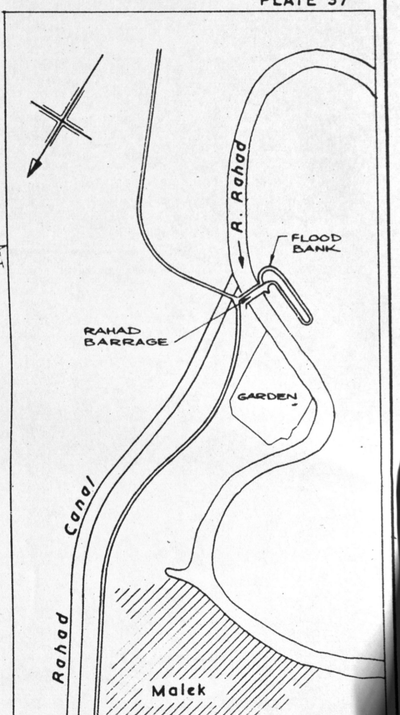
SECTION B-B
THROUGH BARRAGE

M5 0 5 10 15M



PLAN

M10 0 10 20 30 40M



LOCATION PLAN

M100 0 500M

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE & ECONOMICS

ROSEIRES PRE-INVESTMENT SURVEY

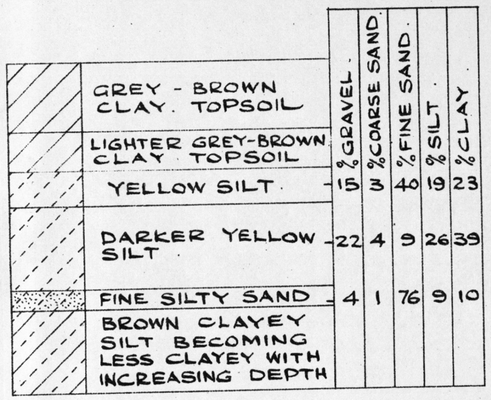
RAHAD BARRAGE

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

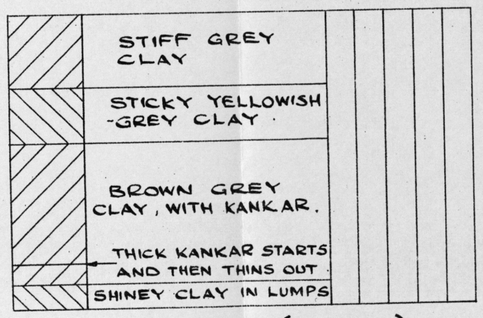
SCALES AS SHOWN
DRG. No. SU.160
DATE. MAY 1965

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

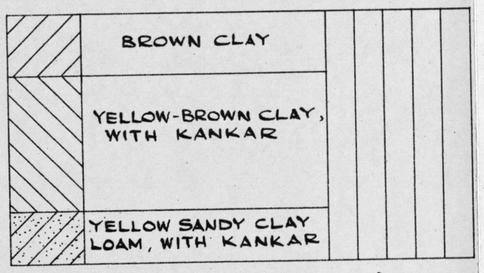
PLATE 39



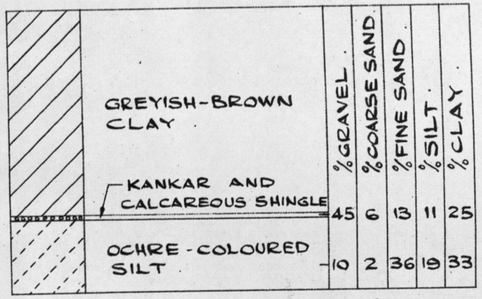
PIT No. 8 (K.31·756)



PIT No. 9 (K.50·447)



PIT No. 10 (K.94·260)



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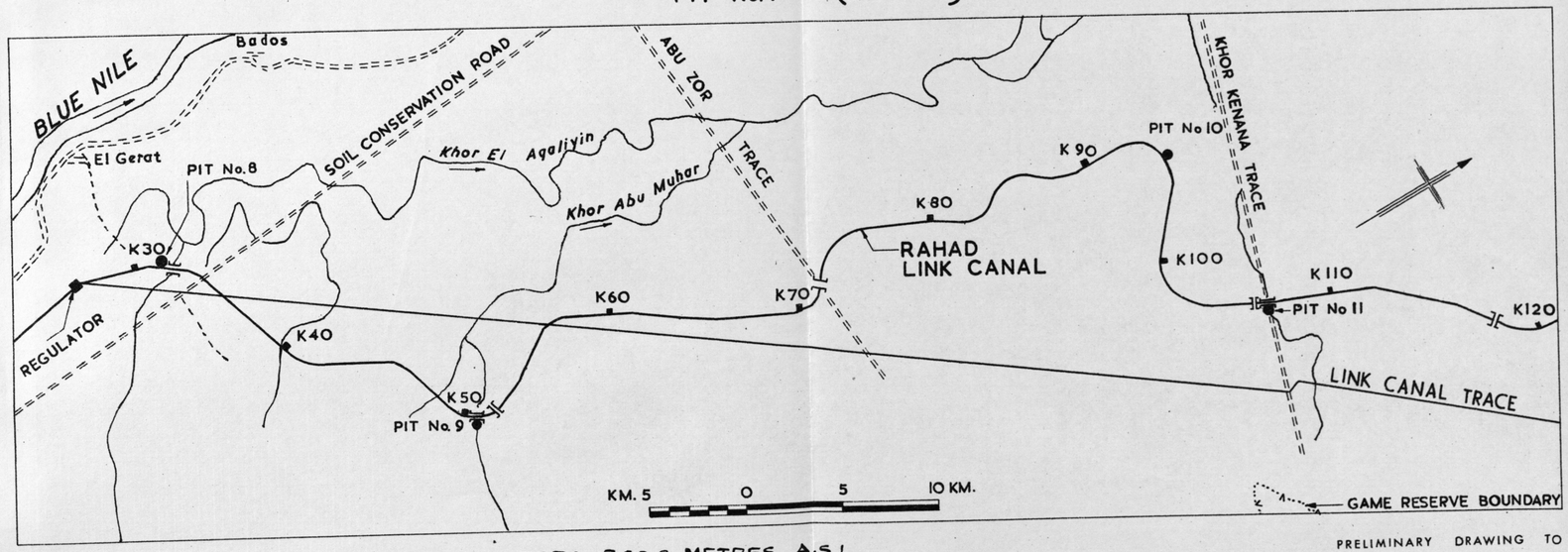


NOTE: ALL LEVELS ARE TO KHARTOUM GAUGE ZERO 360·0 METRES A.S.L.

PRELIMINARY DRAWING TO ACCOMPANY REPORT No.2

METRES: 465 464 463 462 461 460 459 458 457 456 455 454 453 452 451 450 449

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

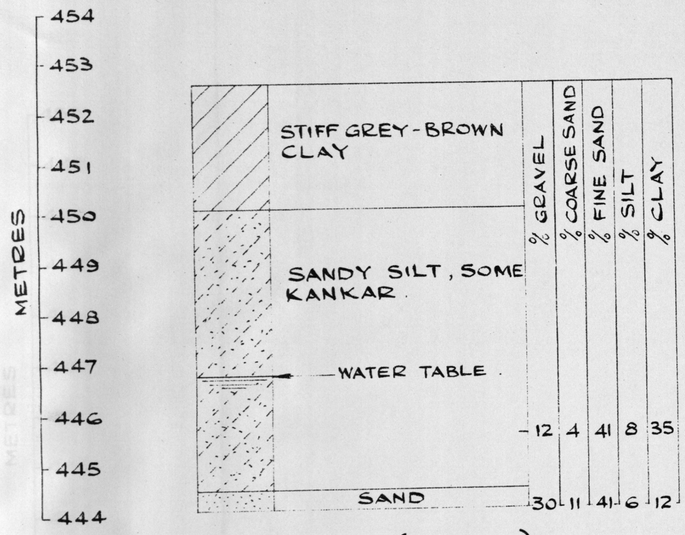
RAHAD PROJECT
RAHAD LINK CANAL
SITE INVESTIGATION — SHEET 2

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

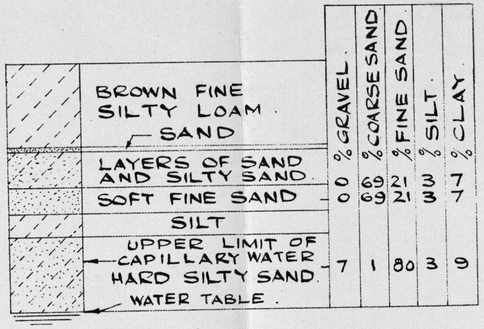
SCALE AS SHOWN

DRG No. SU 232
DATE: APRIL 1966.

PLATE 40



PIT No.12 (K.136·409)



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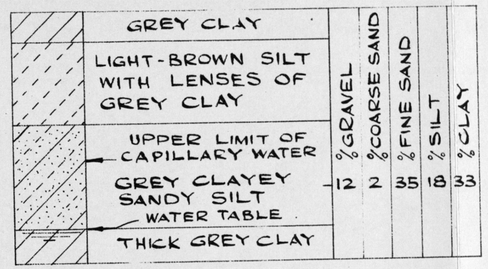

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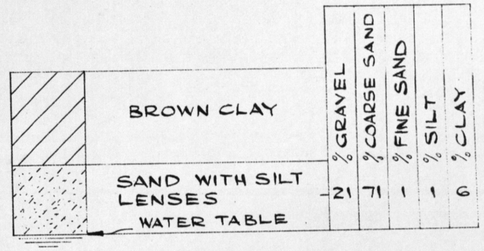
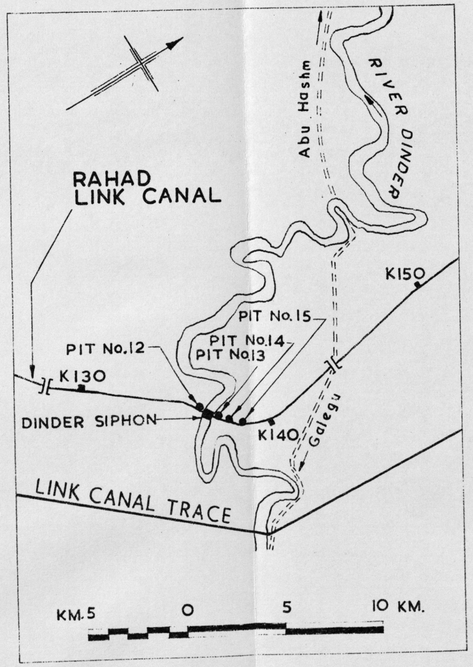
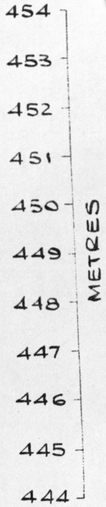


PIT No.15 (K.138·102)





NOTE: ALL LEVELS ARE TO KHARTOUM GAUGE ZERO 360·0 METRES A.S.L.

PRELIMINARY DRAWING TO ACCOMPANY REPORT No.2

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

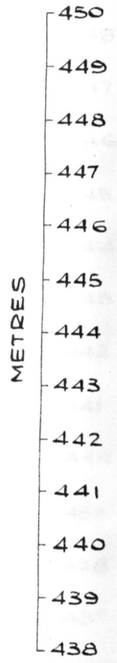
RAHAD PROJECT
RAHAD LINK CANAL
SITE INVESTIGATION — SHEET 3

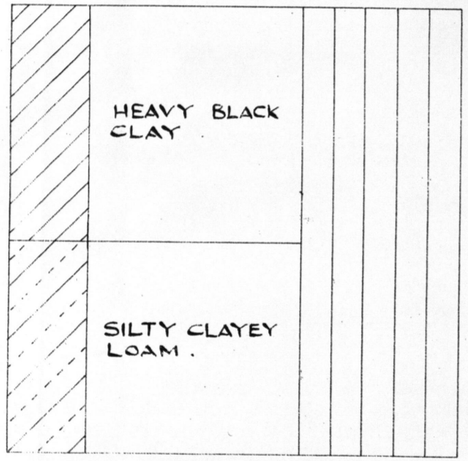
SIR M. MACDONALD & PARTNERS, CONSULTING ENGINEERS, LION HOUSE, RED LION STREET, LONDON W.C.

SCALE AS SHOWN

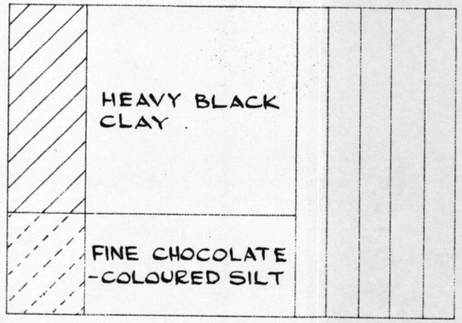
DRG No. SU 233

DATE: APRIL 1966.





PIT No. 16 (K.177·543)



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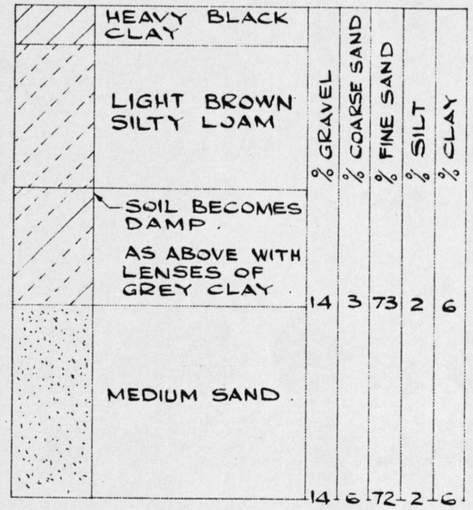

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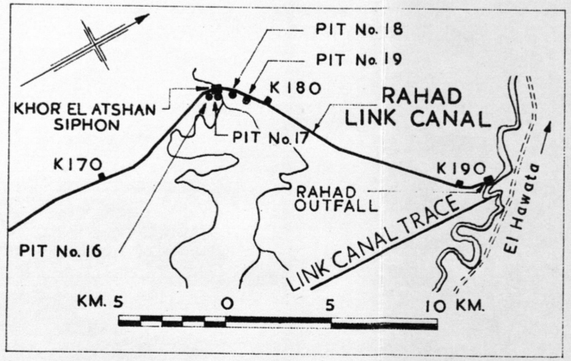

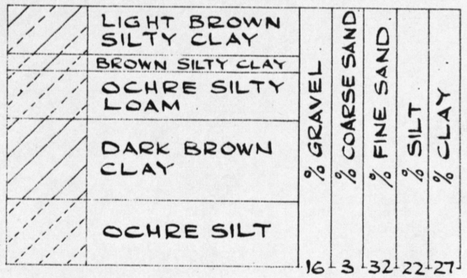

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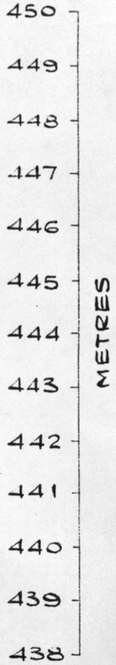


NOTE: ALL LEVELS ARE TO KHARTOUM GAUGE ZERO 360·0 METRES A.S.L.

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

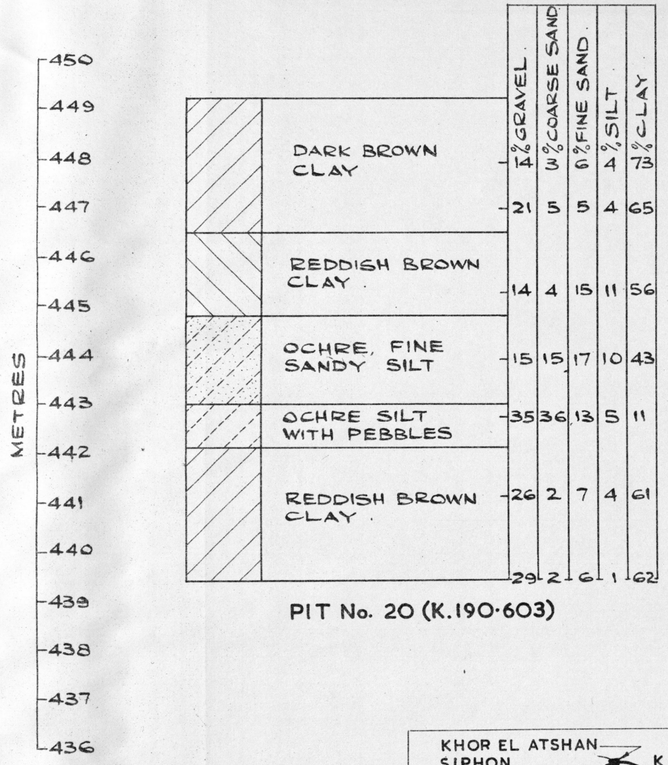
RAHAD PROJECT
RAHAD LINK CANAL
SITE INVESTIGATION – SHEET 4

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

SCALE
AS SHOWN

DRG. No. SU 234
DATE: APRIL 1966.

PLATE 42



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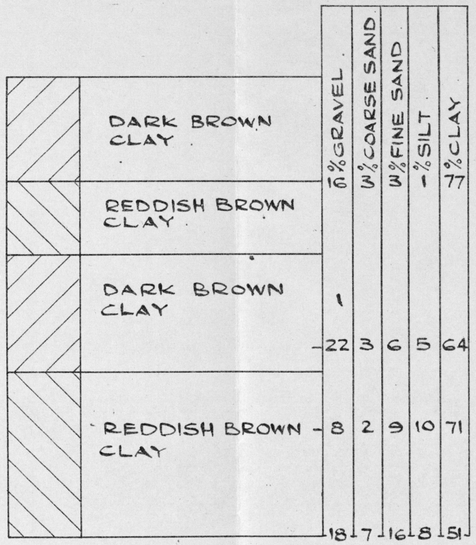

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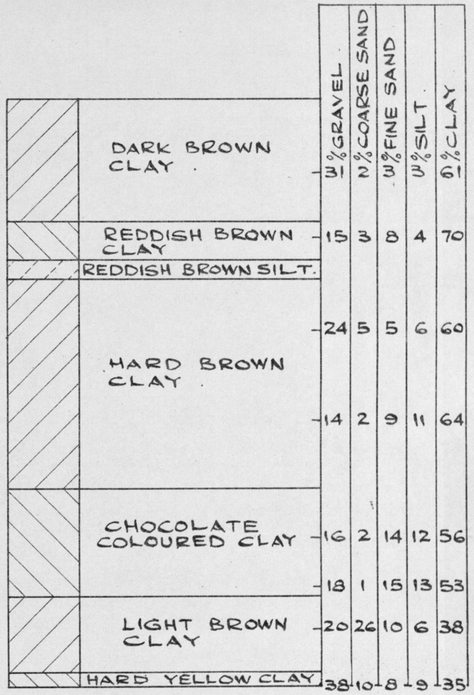

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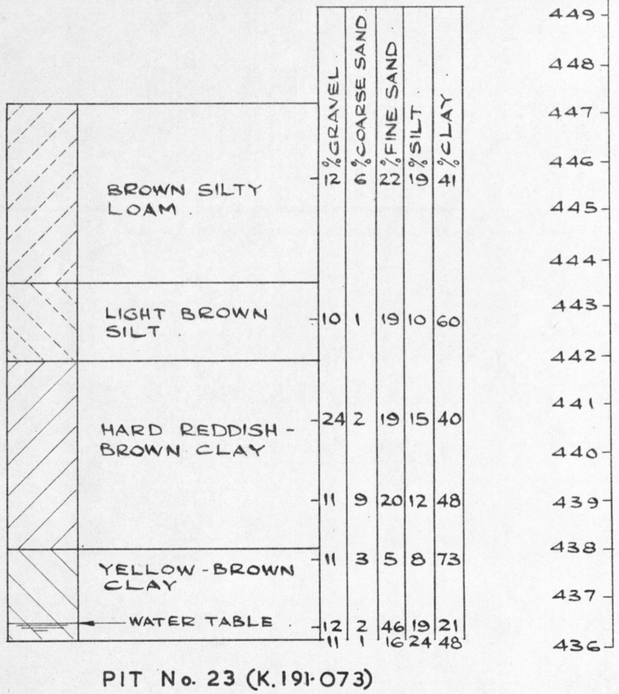
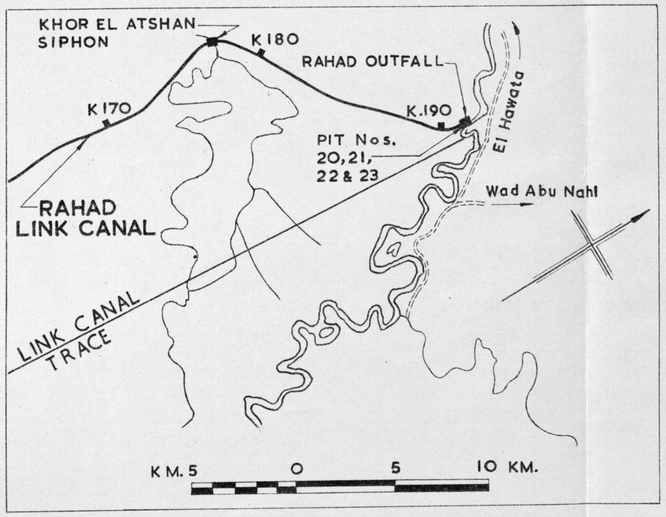


PIT No. 23 (K.191·073)



NOTE: ALL LEVELS ARE TO KHARTOUM GAUGE ZERO 360·0 METRES A.S.L.

PRELIMINARY DRAWING TO ACCOMPANY REPORT No. 2

THE REPUBLIC OF THE SUDAN
MINISTRY OF FINANCE AND ECONOMICS
ROSEIRES PRE-INVESTMENT SURVEY

RAHAD PROJECT
RAHAD LINK CANAL
SITE INVESTIGATION – SHEET 5

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

SCALE AS SHOWN

DRG. No. SU 235
DATE: APRIL 1966