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جمهورية السودان
THE REPUBLIC OF THE SUDAN

MINISTRY OF FINANCE AND ECONOMICS

MEMORANDUM ON
UTILISATION OF WATER FROM
ROSEIRES RESERVOIR

JANUARY 1966

SIR ALEXANDER GIBB & PARTNERS

SIR M. MACDONALD & PARTNERS
In association with Hunting Technical Services

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CHAPTER I - THE ROSEIRES IRRIGATION PROJECT

1. In June 1961 the International Bank for Reconstruction and Development, the International Development Association and Kreditanstalt fur Wiederaufbau jointly agreed to make loans available to the Government of the Republic of the Sudan to assist in financing the construction of the Roseires Dam as part of the Roseires Irrigation Project.
2. The Project was defined as the construction of the dam together with irrigation works and farm development to enable the water stored in the reservoir to be effectively used.
3. The headworks for a future gravity irrigation canal on the west bank of the river, with a maximum capacity of 360 cumecs for reservoir levels at or above 467.2 metres was to be incorporated in the dam structure. Provision was also made for intakes for a future hydro-electric power station with an ultimate capacity of 7 sets of a nominal power output of 25 MW. each.
4. At the time the loans were made the total volume of storage which would be available to the Sudan as a result of the construction of the Roseires Dam was assessed as follows:-

TABLE 1

STORAGE - MILLIARDS

1 milliard = 1,000 million cubic metres

Reservoir	1962-63		Roseires Stage I (TWL. 480 m)		Roseires Stage II (TWL. 490 m)	
	Gross	Net	Gross	Net	Gross	Net
Sennar	0.93	0.79	0.93	0.79	0.93	0.79
Jebel Aulia equivalent		0.85	-	-	-	-
Roseires	-	-	3.02	2.72	7.62	6.91
TOTAL (milliards)	0.93	1.64	3.95	3.51	8.55	7.70

- Notes: (i) In the above Table "Net" represents "Gross" volume of storage less estimated evaporation losses, but with no deduction for dead storage.
- (ii) The 6.91 milliard figure under Roseires Stage II was not computed in 1961 but represents the gross volume less 0.71 milliards evaporation losses.
5. Uses for the additional water stored in Roseires Stage I were proposed as follows:-
- (a) Conversion of restricted pump schemes to unrestricted pumping.
 - (b) Intensification of cropping of the Gezira area.
 - (c) New pump schemes.
 - (d) Extension of the Gezira-Managil area.
 - (e) Increasing supplies for existing schemes.
 - (f) Expansion of sugar cane production in the Guneid area.
6. It was considered that the above proposals would absorb about 1.9 milliards of Roseires Stage I storage and that a research programme would determine the most economic use of the balance.

CHAPTER II - PROGRESS IN IRRIGATION AND POWER DEVELOPMENT
SINCE 1961

Dams and Reservoirs

Roseires Dam.

7. Construction of the dam is well advanced, and substantial completion should be achieved by 1st July, 1966 to enable water to be stored to Stage I level of 480 metres during the following flood. This is an advance of 12 months on the programme envisaged when the loan Agreement was signed and the main contract awarded in 1961.

8. During the course of construction of the dam it was found necessary to incorporate headworks for a future gravity canal on the east bank, of similar capacity to that on the west bank. The working drawings were, therefore, revised to accommodate the change.

9. In addition design work is now proceeding to enable construction of the foundations for the main hydro-electric power station to be started during the 1965/66 working season. It has been possible, within the spacing of buttresses adopted, to increase the specified power output of each set to 30 MW. at 29 metre head.

Khashm el Girba Dam.

10. Since 1961 the Khashm el Girba dam on the Atbara river has been completed and is now in operation, with a gross reservoir capacity of 1.3 milliards and an effective storage of 1.0 milliard cu.m.

Sennar Dam.

11. A hydro-electric power station with a capacity of 15 MW. in two sets has been completed and is now in operation, linked to thermal power plant in Khartoum and Wad Medani through a 110 kV. transmission line.

Conversion of Existing Pump Schemes to Unrestricted Pumping.

12. In June 1961 the gross area of pump schemes under restricted licences was 395,500 feddans, equivalent to approximately 341,000 feddans gross irrigable area as recorded by I.B.R.D. in 1961. By 1964 the gross area under restricted licences had increased to 407,700 feddans. As soon as additional water becomes available from Roseires storage all restrictions to seasonal irrigation will be finally removed.

Intensification of cropping in the Gezira and Managil areas.

13. Progress in intensification of cropping in the Gezira can be seen from Table 2A which indicates changes in gross area and in cropping pattern between the 1960/61 and 1964/65 seasons, together with the proposed cropped areas for 1965/66. Similar information dating from the 1962/63 season is given for Managil in Table 2B.

TABLE 2A
INTENSIFICATION OF GEZIRA SCHEME (WITH ABDEL MAGID)
1961 to 1966

	1960/61		Cropped Areas			
	%	Fed.	1964/65		1965/66	
			%	Fed.	%	Fed.
Cotton	25.1	246,154	25.0	245,400	25.0	245,400
Dura	12.7	124,496	12.8	125,806	12.8	125,806
Wheat	-	-	7.4	73,277	10.2	100,000
Lubia	4.8	47,229	2.8	27,185	2.6	26,000
Groundnuts	2.1	20,734	1.8	17,561	2.0	20,000
Phillipesara	-	-	0.1	1,532	.1	1,000
Rotation Gardens	1.0	10,213	1.7	16,630	1.8	17,400
Total	45.7	448,826	51.6	507,391	54.5	535,606
Gross Area (Feddans)		982,800		982,800		982,800

TABLE 2B
INTENSIFICATION OF MANAGIL SCHEME - 1962 to 1966

	1962/63		Cropped Areas			
	%	Fed.	1964/65		1965/66	
			%	Fed.	%	Fed.
Cotton	31.7	249,468	32.6	273,151	32.6	273,151
Dura	13.8	108,605	16.4	137,018	16.4	137,018
Groundnuts	2.7	21,399	5.0	42,400	9.6	80,000
Wheat	-	-	0.2	1,788	-	-
Lubia	7.9	62,466	6.6	54,950	5.0	42,000
Phillipesara	-	-	-	089	-	-
Rotation Gardens	0.6	4,965	1.0	8,495	1.2	10,000
Total	56.7	446,903	61.8	517,891	64.8	542,169
Gross Area (Feddans)		787,678		837,678		837,678

14. Although no large scale intensification requiring water after December can be contemplated until stored water from Roseires becomes available, the figures indicate that progress is being made, and that cropping intensity in the Gezira has increased to 51.6% in 1964/5, which figure may be further increased to 54.5% in 1965/66. In 1964/5 season 73,000 feddans of wheat were grown against a reduction since 1960/61 of 20,000 feddans in the area of lubia. In addition 1,500 feddans of phillipesara (*phaseolus trilobus*) were grown and rotation gardens increased by 6,400 feddans. The corresponding figures planned for 1965/6 as compared with 1960/61 are:-

Wheat	+ 100,000 feddans.
Lubia	- 21,000 "
Phillipesara and rotation gardens	+ 8,200 "

This will bring the intensity of cultivation in the Gezira up to 54.5% and achieve an increase in the cultivated areas of 86,800 feddans since 1960/61.

15. Changes in the Managil cropping pattern since 1962/63 (the first year of full development) are generally due to substitutions of groundnuts and wheat for lubia. Thus the area of groundnuts has increased from 21,000 to 42,000 feddans and the area cropped with lubia has been reduced from 62,000 to 55,000 feddans. It is planned to extend this substitution during 1965/66 so that the area under groundnuts will be 80,000 feddans and the area under lubia 42,000 feddans, increasing the % cropped from 56.7% in 1962/63 to 64.8% in 1965/66

New Pump Schemes and Extensions to Existing Pump Schemes.

16. Progress made on pump schemes can be seen in Table 3 which sets out the gross areas in feddans under pump irrigation, by Provinces.

TABLE 3.

DEVELOPMENT OF PUMP SCHEMES

Year	Blue Nile Province	Khartoum Province	Northern Province	Upper Nile, Equatoria, Bahr-el-Ghazal and Kassala Provinces.	TOTAL
1961	851,047	37,663	229,209	64,048	1,181,967
1964	867,574	44,619	249,673	87,691	1,249,557

Again, some progress has been made but only on a small scale pending the provision of over year storage in the High Aswan Dam and further annual storage on the Blue Nile at Roseires.

Extensions of the Gezira-Managil Area.

17. As a result of semi-detailed soil surveys an area of nearly 70,000 feddans was canalised in 1962/63. In addition a further 132,000 feddans may be available as follows:-

	<u>Feddans</u>
Gezira Scheme Extensions	42,800
Managil Scheme Extensions	57,200
Fringe Areas,	<u>32,000</u>
Total	<u>132,000 feddans</u>

These areas are subject to confirmation after completion of semi-detailed soil surveys.

Agricultural Research.

18. A summary of progress in agricultural research and experiment is given in an Appendix to this Memorandum.

Surveys of Irrigable Areas.

19. Scope of the Soil Surveys.

The 1961 Roseires Dam Financing Agreement made reference to increasing the Gezira-Managil irrigated area by 200,000 feddans together with a further 670,000 feddans of pump schemes. In 1962 the Republic of the Sudan started reconnaissance and semi-detailed soil surveys to locate suitable areas on the Blue and White Niles and in the Gezira. These areas are shown in Figures 1 and 2. The riverain areas were limited to land within 20 metre lift of low rivers. A semi-detailed soil survey was also carried out on the land lying on the East of the River Rahad which might be irrigated from the river; a further area between the rivers Rahad and Dinder which could be irrigated by pumping from the Blue Nile at Sennar was also included.

20. The field work and investigation have continued since 1962. A total area of 3.8 million feddans has been covered by reconnaissance soil survey and 3.5 million feddans by semi-detailed soil survey. The areas are detailed in Table 4 together with 0.9 million feddans due for survey in 1965/66.

TABLE 4.

EXTENT OF RECONNAISSANCE AND SEMI-DETAILED SOIL SURVEYS

<u>Reconnaissance Survey</u>	<u>Feddans</u>
Main Nile - Khartoum to Kareima	1,000,000
Kareima to Third Cataract	600,000
Blue Nile - Guneid to Khartoum	395,000
White Nile - Renk to Khartoum (Right Bank)	<u>1,787,000</u>
Total	<u>3,782,000</u>

<u>Semi-detailed Soil Survey</u>	<u>Feddans</u>
Extensions to Gezira Scheme and Managil Scheme.	462,000
Main Nile - Khartoum to Kareima	202,000*
Kareima to Third Cataract	87,000
White Nile - Rabak to Khartoum (Right Bank)	169,000
- Renk to Rabak	158,000*
Blue Nile - Guneid to Khartoum	186,000
Rahad/Dinder	134,000
Blue Nile Right Bank - Roseires to Dinder Confluence	879,000
Blue Nile Left Bank - Abu Hugar to Sennar	58,000
Rahad East Bank -	
Rahad Project	630,000
Guneid Project	120,000*
Hawata Project	<u>450,000*</u>
Total	<u>3,535,000</u>

* For survey in 1965/66 season.

Estimate of Irrigable Areas.

21. The outcome of the survey is that the soils adjacent to the existing Gezira area are generally of poor quality and only 70,000 of the estimated area of 200,000 feddans has so far been found and brought under cultivation. Surveys are in hand to find the balance on the Gezira fringes and by pumping ⁱⁿ the vicinity of Sennar. There is a little suitable land on the Main Nile between Khartoum and the Third Cataract where development will be by comparatively small pumped projects. Similarly on the White Nile between Jebelain and Khartoum and on the Blue Nile between Guneid and Khartoum no sizeable areas are available for development.

22. On the other hand large project areas have been found on the East Bank of the River Rahad (the Rahad Project) and on the Right Bank of the Blue Nile between Roseires and Sennar (the Roseires Project). Exploratory surveys also show that there may be further projects on the River Rahad (the Hawata and Guneid Projects), on the West Bank of the Blue Nile (the Kenana Project) and in the Dinder area.

23. The estimated areas for development based on the results of the soil survey now available are as follows:-

TABLE 5
ESTIMATED AREAS FOR DEVELOPMENT - GROSS IRRIGABLE AREA

	<u>Feddans</u>	<u>Feddans</u>
<u>Main Nile</u>		
Kareima - Third Cataract	17,000(2)	
Khartoum - Kareima	<u>43,000(1)</u>	60,000
<u>White Nile</u>		
Khartoum - Rabak	7,000(1)	
Rabak - Melut	<u>200,000(1)</u>	207,000
<u>Blue Nile - Sennar to Khartoum</u>		
Extensions to Guneid Sugar Scheme	12,000(2)	
Pump Schemes	<u>8,000(2)</u>	20,000
<u>Blue Nile - Roseires to Sennar</u>		
Gezira and Managil Extension	132,000(1)	
Khartoum Green belt (Forest and fodder)	25,000	
Abu Hugar - Sennar		
New Pump Schemes	<u>32,000(2)</u>	<u>189,000</u>
	Carried forward,	476,000

	<u>Feddans</u>	<u>Feddans</u>
Brought forward,		476,000
<u>Blue Nile Upstream Roseires Dam.</u>		
(a) Roseires Project (Blue Nile Right Bank)	500,000 (2)	
(b) Kenana Project (Blue Nile Left Bank)	1,500,000 (3)	
Dinder Project,	350,000 (3)	
Rahad System		
Rahad Project,	430,000 (2)	
Guneid Project	120,000 (1)	
Hawata Project	<u>300,000 (3)</u>	850,000
		<u>3,200,000</u>
	Total	<u>3,676,000</u>

- Notes: (1) Estimated after Reconnaissance Soil Survey
 (2) Based on Semi-detailed Soil Survey.
 (3) Estimated after Exploratory Soil Survey.

24. In addition developments are being planned and carried out on the River Atbara to utilise the storage provided by the Khashm el Girba Dam.

Development of hydro-electric power project.

25. Early in 1963, Consulting Engineers were appointed by the Minister of Works to survey the existing and potential market for electricity in the Sudan and to plan the development of power supplies within the country over a period of fifteen years. The report, a comprehensive power market survey, together with a review of the potential thermal and hydro-electric projects, was submitted in November 1963.

26. The first recommendation of the report was that, to meet demands in the Khartoum area in the immediate future, the diesel generating capacity at the Burri thermal power station in Khartoum should be increased. This extension is under way and will increase the system capacity by 15 MW.

27. The second recommendation was that work on the Roseires power project should be started so that the first generating set and a transmission line to Khartoum could be in commercial service by 1st March 1969 with the second set in service three months later, and a third in the following year.

28. As a result of the second recommendation, the Central Electricity and Water Administration (C.E.W.A.) appointed Consulting Engineers to prepare a Project Report on the Roseires Power Station and the Roseires - Khartoum Transmission Line. This Report was submitted in December 1964 and included a programme of works for commissioning three sets at Roseires by 1st March 1970.

29. In order to achieve this objective, it is necessary to start construction of the power house foundations early in 1966. It was agreed that, subject to satisfactory rates, this work would be incorporated as an extension to the main contract for the construction of the Roseires dam. Negotiations to effect this have been completed and work has started. In addition, tender documents have been prepared for contracts covering the supply and erection of turbo-generators, gate equipment and penstocks, and also for the transmission line. Tenders are due to be received shortly for the draft tube gates and equipment. Further documents are being prepared for transformers and switchgear, and will be prepared for the power station superstructure when detailed design has been further advanced.

CHAPTER III - PLANS FOR FUTURE USE OF NILE WATERS.

Sudan's share in Nile Waters.

30. Although the main objective of this Memorandum is to consider the use of the water to be stored at Roseires, it is of value first to examine the limits of the Sudan's present overall share in Nile Waters as defined in the Nile Waters Agreement of 1959. After 1977 this share will amount to 18.5 milliards annually, assessed as at Aswan. The construction of the High Aswan Dam by The United Arab Republic as well as of the Roseires Dam by the Sudan is also covered by this Agreement. With the provision at Aswan of over year or long term storage, it will no longer be necessary, as heretofore, for the Sudan to consider the incidence of The United Arab Republic's requirements at the different seasons of the year in relation to the varying rates of flow in the river. The Sudan will, of course, ensure that the total amount abstracted by her from the river in any one year does not exceed her agreed share and up to 1977 has agreed to restrict her share to 17.0 milliards at Aswan.

Physical Factors within the Sudan.

31. On the White Nile and on the Main Nile, North of Khartoum, natural flows at all times of year and in all years will be more than sufficient to meet the prospective local abstractions, even with the ultimate prospective extent of irrigation development. For such abstractions, storage on these reaches of the river will not be required. On the Blue Nile and the Atbara, however, conditions are different; annual storage of part of the flood flows is essential to ensure sufficient supplies in the low season to meet local abstractions at that time. Therefore, the use of stored water from Roseires reservoir, with that also from Sennar reservoir, is in the first place to be considered in relation to the rates of flow, and the requirements, on the Blue Nile only. The rates of flow vary widely from flood season to low season in any year, and also from year to year at corresponding seasons.

32. Similar considerations apply to the Atbara. But each of these two rivers must in the first place be considered separately.

Irrigation Water Requirements within the Sudan.

33. 18.5 milliards at Aswan is equivalent to 20.55 milliards as at Sennar taking into account natural transmission losses between these two points. Similarly 17.0 milliards at Aswan corresponds to 18.9 milliards as at Sennar. From these quantities must be deducted evaporation losses from reservoirs within the Sudan, storing water for the Sudan's use. For the two stages of Roseires construction these losses are estimated as shown in Table 6.

TABLE 6.

ESTIMATED EVAPORATION LOSSES

Reservoir	Stage I TWL. 480 m. milliards	Stage II TWL. 490 m. milliards
Roseires	0.38	0.73
Sennar	0.34	0.34
Khashm el Girba	0.15	0.15
Total	0.87 (0.9 approx.)	1.22 (1.2 approx.)

34. The completion of the Khashm el Girba Dam with an effective reservoir storage capacity of one milliard has made possible the utilisation for irrigation from the River Atbara of 1.9 milliards per annum.

35. On the Main Nile between Khartoum and the Third Cataract, as will be seen from Table 5, it is planned to extend the area irrigated by pumps from 272,000 to 332,000 feddans as a vital contribution to the development of the Northern Sudan. Based on a water requirement of 3,300 cubic metres per gross feddan this area will require an annual allocation of 1.1 milliards.

36. Plans for the White Nile, also shown in Table 5, envisage an increase in pump schemes from 503,000 to 710,000 feddans. Assuming an average of 2,800 cubic metres per gross feddan this total development would require an annual amount of 2 milliards. In addition it is advisable to hold in reserve an allocation of 0.5 milliards of White Nile water, pending a decision on the future of Jebel Aulia reservoir, either to meet evaporation losses from the reservoir surface or to irrigate land made available by the permanent lowering of the reservoir level.

37. The above figures are summarised in Table 7 which indicates the balance of Nile waters available to the Sudan for developments based on the Blue Nile for both Stage I and II for the periods up to and after 1977.

TABLE 7.
WATER AVAILABLE FOR USE ON THE BLUE NILE.
(All figures in Milliards)

	UP TO 1977				AFTER 1977			
	Stage I TWL. 480		Stage II TWL. 490		Stage I TWL. 480		Stage II TWL. 490	
Sudan's share of Nile Waters as at Sennar		18.9		18.9		20.55		20.55
Evaporation losses from reservoirs	0.9		1.2		0.9		1.2	
Developments from Khashm el Girba (River Atbara)	1.9		1.9		1.9		1.9	
Pump schemes on Main Nile North of Khartoum	1.1		1.1		1.1		1.1	
Pump Schemes on White Nile	2.0		2.0		2.0		2.0	
Allowance pending decision on Jebel Aulia	0.5	6.4	0.5	6.7	0.5	6.4	0.5	6.7
Balance for use on Blue Nile (assuming all the above developments are carried out.)		12.5		12.2		14.15		13.85

38. As will be seen from the tables and notes which follow, plans for development on the Blue Nile as listed in Table 5 call for an annual irrigation water requirement of approximately 17.7 milliards.

39. The limit of development from Roseires Stage I (TWL.480 m) is reached when the annual water requirement from the Blue Nile becomes a little more than 11 milliards. It will be seen from Table 7 that up to 1977 irrigation from Roseires Stage I can be developed to the full, with a margin enabling some use of additional storage from Stage II to be utilised.

40. It can, therefore, be said that the Sudan is in the process of developing plans for the use not only of her present allocation of Nile Waters, but also of the additional share which will become available when further water conservation schemes are implemented. The implementation in the Sudan of the Jonglei Project which, in accordance with the 1959 Nile Waters Agreement is the concern of the Permanent Joint Commission for Nile Waters, should bring an annual benefit to the Sudan and Egypt of 3 milliards each.

41. Further ahead lie the possibilities of canalising the Machar Marshes east of Malakal and the Bahr el Ghazal, both of which receive the run off from large areas but make little or no contribution to the present discharge of the Nile. Very preliminary estimates have put the possible future annual contribution from these two sources as high as 18 milliards.

CHAPTER IV - FUTURE DEVELOPMENTS BASED ON THE BLUE NILE.

General.

42. The gross irrigable areas now under consideration for future development based on water from the Blue Nile are recorded in Table 5. These areas are briefly described in the paragraphs which follow. Their locations are indicated on Figs. 1 and 2.

Sennar to Khartoum.

43. The project lands are part of the Blue Nile plain sloping gently towards the river. They experience a monsoon type rainy season with maximum rainfall in July and August and an average annual rainfall of about 300 mm. The soils are dark coloured cracking clays similar to those of the Gezira area, but with appreciably lower clay contents. They are virtually non-drainable so that rotations would be of the non-intensive types similar to those practiced in the Gezira and Managil projects. The principal climatically adapted crops, tested on the clay soils of the Central Sudan, are cotton, sugar cane, groundnuts, wheat, dura, safflower and the forage crops lubia, phillipesara and clitoria.

Roseires to Sennar.

Further intensification of cropping in Gezira and Managil areas.

44. A Working Party is at present investigating the further development of agriculture, including intensification in the Gezira, and is to report in 1966. Senior officials of the Sudan Gezira Board, the Ministry of Agriculture and the Ministry of Irrigation & Hydro-Electric Power have told us of the various rotations and possible range of watering periods which are under consideration for both the Gezira and Managil.

45. Appreciating that investigations continue and that long term plans have yet to be finalised, we have prepared Tables 8 and 9 as a means of calculating future monthly water requirements for the two areas, with due

regard to the capacity of the two main canals. It will be seen from Table 8 that 75% intensity in the Gezira calls for maximum irrigation of 56 1/4% during September and early October, and represents a total cropped area of 737,000 feddans as compared with 448,800 in 1960/61, an increase of 288,200 feddans. The cropping pattern for Managil shown in Table 9 provides for a 66.2/3 intensity and differs little from present conditions. There is a maximum irrigation demand in September and early October of 66.2/3%.

46. Discussions with the Ministry of Irrigation & Hydro-Electric Power indicate that the following supplies are available in the Gezira and Managil areas.

	<u>Mill.M³/day</u>	<u>Area Irrigated</u> (1965/66) (feddans)	<u>% of Gross</u> Area
Gezira area	15.9	536,000	54.5
Managil area	14.7	542,000	64.8

The above quantities are carried by the Gezira Main Canal (14.5 million M³/day) and the Managil Main Canal (16.1 million M³/day). A discharge of 1.4 million M³/day can be passed from the Managil Main Canal to the Gezira area. The practice in the Gezira Scheme was to maintain the major and minor canal systems to irrigate 50% of the area (15 M³/day/feddan of the gross irrigable area). In the Managil System the corresponding factor for canal design was Factor 18 (18 M³/day/feddan of the gross irrigable area).

Extensions to Gezira and Managil Schemes.

47. To the north and west the Gezira plain shows an increase in salinity and alkalinity and a decrease in clay content. Permeability remains very low so that the soils are virtually undrainable and the arable lands are suitable for a rotation of the Gezira-Managil type. The crops proposed are cotton, dura, wheat, groundnuts, lubia and phillipesara.

TABLE 8

GEZIRA INTENSIFIED

982,000 Feddans, including Abdel Magid,

Crop	% of Gross Area	April	May	June	July	August	Sept.	October	Nov.	Dec.	Jan.	Feb.	March	Full Year
Cotton	25													
Wheat	12½													
Dura	12½													
Groundnuts and Gardens	12½													
Lubia or Phillipisara	12½						← 6¼% only →							
Total % Irrigated	75	12½	12½	12½	25	50	56¼	56¼	50	50	50	50	37½	2
Feddans (thousands)		123	123	123	246	491	552	552	491	491	491	491	368	20
M3 per feddan		800	800	800	800	600	810	920	850	850	800	800	750	800
M3 (Millions)		99	99	99	198	295	477	254	208	416	393	393	276	16
+ Domestic		18	18	18	-	-	-	-	-	-	-	-	-	-
TOTAL M3 (Millions)		117	117	117	198	295	477	462	416	393	393	276	16	3277

TABLE 9.

MANAGIL

838,000 Feddans

Crop	% of Gross Area	April	May	June	July	August	Sept.	October	Nov.	Dec.	Jan.	Feb.	March	Full Year
Cotton	33.1/3													
Dura	16.2/3													
Wheat	-													
Lubia	7													
Groundnuts	8.1/3													
Gardens	1.1/3													
Total % Irrigated	66.2/3	8.1/3	8.1/3	8.1/3	26.1/3	59.2/3	66.2/3	66.2/3	41.2/3	41.2/3	41.2/3	41.2/3	34.2/3	1.1/3
Feddans (Thousands)		70	70	70	221	500	559	559	349	349	349	349	291	11
M\$ per feddan		800	800	800	800	600	785	840	850	850	800	800	800	800
M\$ (Millions)		56	56	56	177	300	438	234	149	297	279	279	233	9
+ Domestic		15	15	15	-	-	-	-	-	-	-	-	-	45
TOTALS M\$ (Millions)		71	71	71	177	300	438	383	297	279	279	233	9	2608

Khartoum Green Belt.

48. A further area which will take water from the Gezira canal system is the Khartoum green belt, a project of 25,000 feddans in extent for development of forest and fodder crops. A part of this project has already been canalised and the remainder will probably have early priority for development. This area has mostly saline-alkali soils of relatively high sand content and poor structure. The trees and fodder crops to be grown on this land should be tolerant of these unfavourable soil conditions.

Blue Nile Left Bank. Abu Hugar to Sennar.

49. An engineering reconnaissance has been completed on the Left Bank of the Blue Nile from Abu Hugar to Sennar. It is thought that the semi-detailed soil survey will show 32,000 feddans suitable for development and this area has, therefore, been included in Table 5. The lands are part of the Blue Nile clay plain. They are virtually non-drainable soils of the Gezira type and are suitable for a non-intensive cotton rotation of the Gezira-Managil type.

50. A project of about 15,000 feddans might be supplied by pumping from the Blue Nile at Singa and the remainder of the area will be developed by eight small pump schemes. The static lift is high varying from 11 to 19 metres. It is probable that the soils compare with those on the Right Bank of the Blue Nile (the Roseires Project). Development could best be achieved by encouraging private enterprise.

Blue Nile - Dinder Area.

51. A semi-detailed soil survey has been carried out on the lands lying north of Sennar and between the Blue Nile and Dinder Rivers. There has been extensive private development of the areas adjacent to the Blue Nile and downstream of Sennar. The remaining lands suitable for development (163,000 feddans) lie inland from the river. The area might be commanded by gravity from Roseires or by low-lift pumping from upstream Sennar. The area has, therefore, been included in the Roseires Project which is described below.

Dinder - Rahad Area.

52. A semi-detailed soil survey has also been carried out on 134,000 feddans of land between the Rivers Rahad and Dinder lying north of latitude $13^{\circ} 45'$. This is a fairly level plain of cracking clay soils superficially similar to those of the Gezira plain. However, soil analyses show that alkalinity is everywhere high and that one quarter of the soils are also slightly saline. It is possible that this was once an area of blocked drainage on the Blue Nile flood plain and that evaporation of impounded flood waters caused an accumulation of salts and exchangeable sodium. Because the soils are virtually non-drainable, leaching to remove salts and to exchange calcium for sodium is not feasible, and development of these lands would depend on the use of alkali and salt tolerant crops. Until research work shows that this is feasible, it is reasonable to leave these land undeveloped whilst better lands are developed elsewhere. The semi-detailed soil surveys showed that there are 82,000 feddans of irrigable lands, but of this area 77,000 feddans is Class 4.

53. The area might be irrigated by pumping from upstream Sennar. The pump lifts would vary between two to 6.5 metres according to the time of the year. A syphon about 2.5 kilometres long would be required to cross the River Dinder, and it is probable that there will be extensive earthworks for the feeder canal. In view of the marginal quality of the soils this area has not been included in the estimate of irrigable areas.

Above Roseires.

54. Of the possible areas for development on the Blue Nile, the greater part, some 3.2 million feddans, will take water from upstream the Roseires Dam. The areas are summarised in Table 5. A description, together with a summary of the surveys and investigations of each project, is given in the paragraphs which follow.

Roseires Project -500,000 feddans - See Figure 3.

55. The Roseires Project on the Right Bank of the Blue Nile extends from Roseires to the Dinder confluence. The extensive north-south spread of these lands places them in a zone of steadily increasing rainfall from about 450 mm. at Hag Abdullah to about 800 mm. at Roseires. The great majority of the soils are "cracking clays" and are classed as Vertisols. In the north, where the clays have the friable surface mulch and other profile characteristics of the Gezira soils, they are classed as Grumusterts. To the south, however, the friable surface mulch becomes thinner and less well defined. The soil pattern here consists partly of Grumusterts (friable surface) and Mazusterts (crusty surface) and partly of the poorly drained Grumaquerts and Mazaquerts.

56. The semi-detailed soil survey of this area shows a total of 624,000 feddans suitable for irrigation out of a gross surveyed area of 878,000 feddans. The distributions of the land classes within this area are as follows:-

Class 2	220,000 feddans.
Class 3	303,000 feddans.
Class 4	101,000 feddans.

Because the soils are virtually non-drainable, they must be used for a relatively non-intensive rotation of the Gezira-Managil type. Long staple cotton is already successfully established as a commercial crop on pump projects within the confines of the project area. Market studies indicate that the future prospects for the sale of a medium staple (Acala 442) variety are better than for the long staple cotton. The rotation is, therefore, based on medium staple cotton and groundnuts for the cash crops, and dura. Although dura is included in the rotation to encourage settlers, it is not an economic crop for cultivation on an irrigated project, and the farmers should be encouraged to substitute some other climatically suited crops.

57. The proposed Roseires Project is made up of a comparatively compact area in the south of 380,000 feddans which can be supplied by gravity from Roseires Dam and the remaining northern area of about 120,000 feddans which can either be supplied by an extension of the gravity canal system or by one or two large pumping stations taking from the Blue Nile between Es Suki and Sennar. In compiling the Tables of Water Use (Tables 10 - 15 inclusive) we have assumed that the area is served by gravity canal.

58. In the southern area, having a comparatively high rainfall, a number of arable crops can be grown without irrigation. In addition to dura and sesame these include the Barberton variety of groundnut, short staple cotton, imported sorghums, maize, safflower and some forage crops. A detailed contour survey of the area has not yet been made. A study of three sample areas in the southern area shows that the contours are irregular and that the plain is intersected by drainage channels which will complicate the layout of canalisation. This, combined with the high rainfall, means that a full system of surface water drainage will be required. A pre-investment report for the project has been completed and submitted in December 1965.

Kenana Project - 1,500,000 feddans - See Figure 4.

59. The net irrigable area of this project on the left bank of the Blue Nile is now assessed at 1,500,000 feddans. The southern section extends from Roseires to Abu Na'ama, the central and north eastern section lies inland from the Blue Nile between Abu Na'ama and Sennar and extends northward along the eastern side of the Managil ridge. The north western section extends across the plain from Jebel Dali to the White Nile and also northward along the western side of the Managil ridge.

60. Initial investigation of this area carried out in 1951/53 was included in the Report on "Estimation of Irrigable Areas in the Sudan" submitted in February 1954. The recommendations contained in this Report were based upon survey lines taken across the area at 10 minute

intervals of latitude and from tests on soil samples carried out at the Gezira Research Farm. At that time the Roseires reservoir was planned to store 1 milliard only with a top water level of 471.5 metres and with a full supply level in the Kenana Main Canal of 462.5 metres. The net irrigable area recommended was 1,220,000 feddans, of which all but 44,500 feddans were supplied by gravity and the balance by pumping from the Kenana Main Canal.

61. As a result of the subsequent decision to provide increased storage at Roseires the full supply level in the main canal was raised to 466.5 metres and with the additional land brought under command, the estimated net irrigable area increased to approximately 1,500,000 feddans.

62. Between 1958 and 1962 1.3 million feddans of the Kenana area have been demarcated and levelled by the Sudan Survey Department. Permanent beacons at one minute intervals of latitude and longitude have been established and the area has been covered by a grid of levels from which 90 maps to a scale of 1/20,000 have been prepared with spot height and contours at $\frac{1}{2}$ metre intervals. Part of the area was also covered by air photographs in 1962/63 to a scale of 1/25,000.

63. During the 1965/66 season a detailed soil survey of the area is to be commenced as part of the Special Fund Project - with F.A.O. as the Executing Agency - for assisting the Government of the Republic of the Sudan in strengthening the Soil Survey Section of the Research Division of the Department of Agriculture.

64. The 1954 Report proposed two rotations, the first a three course rotation based on cotton, dura and legume requiring 3,170 cubic metres per gross feddan per annum and the second based on the Gezira four course rotation of cotton - legume or fallow - fallow - cotton - dura - fallow - fallow, requiring 2,300 cubic metres per gross feddan per annum. As a result of the more detailed investigations subsequently carried out on the East Bank in areas of comparable soils and climate the water requirements have been re-assessed for the time being as 3,300 cubic

metres per gross feddan per annum and this figure has been used in compiling the tables in this Memorandum.

Dinder Project - 350,000 feddans - See Figure 5.

65. This project lies to the north of the Rahad Link Canal and between the Khor El Aqaliyin and the River Rahad. Exploratory Soil Survey of the area indicates that there may be lands suitable for irrigation. The soils are similar to the Roseires Project, having comparatively high clay content and low salinity. No contours are available. From traverses it is possible that the area might be served from the Rahad Link Canal (see description of the Rahad Project) by main canals running adjacent to the River Dinder. The area is one of high rainfall, the annual precipitation being about 700 mms. As for the southern part of the Roseires Project, dura, sesame, groundnuts and short staple cotton could be grown without irrigation.

66. For the purpose of assessing water requirements, a project area of 350,000 feddans has been assumed with a Roseires Project rotation based on medium staple cotton and groundnuts. Although the area is close to the source of irrigation supply, Roseires Dam, it suffers from the disadvantages of high rainfall and lack of population which is accentuated by the distance from established centre of population.

The Rahad Projects - 850,000 feddans - See Figure 6.

67. An area of 240,000 feddans was included in the Roseires Soil Survey Contract for semi-detailed survey and land classification. The first intention was to develop this area using water from the River Rahad which flows from mid-July through November. The results of the semi-detailed land classification showed the area to be largely Class 2.

68. A Reconnaissance Engineering Survey indicated that by constructing a barrage on the River Rahad an area of nearly 600,000 feddans could be commanded and that a supply channel from the Roseires Dam to the River Rahad (the Rahad Link Canal) was a feasible and profitable proposition. The Rahad Project area had certain advantages for early development. There

is already an established population. The average annual rainfall in the area is about 400 mm. corresponding to the conditions in the existing Gezira and Managil schemes, and only 7% of the area presents any serious problems in connection with forest clearance. Moreover, a semi-detailed type soil survey has shown that the greater part of the area is irrigable (516,000 feddans). In 1964, therefore, it was decided to proceed with a pre-investment survey for the Rahad project and after certain preliminary studies the full pre-investment survey was started in October 1964.

69. The project lands, which are part of the vast clay plain of the Central Sudan, lie on a very gently undulating land surface between elevations of 380 and 450 metres above sea level. The clay plain which extends uniformly over an old flood plain and low upland has gentle slopes which are ideal for good surface drainage and irrigated use of the land. Average annual rainfall ranges from about 300 mm. in the extreme north to about 500 mm. in the south east.

70. The greater part of the project area is covered by dark-coloured cracking clays similar to those of the Gezira area. The clay content is mostly between 60 and 75 per cent. There is a well developed granular mulch at the surface and deep wide cracks extend to 50 cm. when the soil is dry. These clay soils belong to the great group of Grumusterts of the soil order of Vertisols. Because they are virtually impermeable, these soils must be used for a relatively non-intensive rotation of the Gezira-Managil type. The climatically adapted crops at present grown commercially on clay soils in Central Sudan are cotton (long, medium and short staple), dura, sesame, wheat, groundnuts, pigeon pea, onions, garlic, sugar cane and forage crops. Other potentially important crops, not yet grown on a commercial scale, are jute, kenaf, sunn hemp, maize, rice, safflower, sunflower and new fodder crops.

71. The Pre-Investment Report which covers engineering, agriculture, economics and ancillary subjects such as management, population, forestry and animal husbandry has been finally submitted in October 1965. The cropping pattern proposed is a three course rotation based on medium staple cotton (one third), groundnuts (one third) and dura (one sixth). By cultivating groundnuts between June and November thus making use of the River Rahad waters for this crop, the link canal from Roseires is required only to supply the cotton rotation and perennial crops. The Project Area is as follows:

Rotation area	430,000 feddans
Forestry and fodder	<u>45,000</u> feddans
	<u>475,000</u> feddans

72. The greater part of the area has been covered by a detailed contour survey, which shows the ground slopes to be regular and the area ideal for a gravity irrigation system. A surface drainage system will not be required throughout the whole project; drains may have to be constructed where the natural drainage is impeded by canals.

73. The project shows a return to the Government of 12.9% on its capital at the maturity of the project. This indicates that the economics of the project are viable. It is proposed that the administration of the project should follow the method which has been established in the Gezira and Managil schemes, where the project is controlled by a semi-autonomous Board and the cultivation is in the hands of smallholders. The holding size recommended is 12 feddans providing a cropped area for each farmer of 10 feddans corresponding to $7\frac{1}{2}$ feddans in the Managil Extension and 15 to 20 feddans in the Gezira Scheme.

74. If development of the Rahad project proceeds, then an area adjacent to the Guneid pump scheme can be irrigated from an extension of the Rahad Main Canal. This area, which lies approximately 50 kms. north

of the Rahad project, is 200,000 feddans in extent; a part of this area has already been covered by a semi-detailed soil survey and shows a block of 40,000 feddans of Class 2 and 3 lands. The soil survey of the remaining area has still to be completed, but it is expected to provide a rotation area of 40,000 feddans. Similarly, on the east bank of the River Rahad and to the south of the main project, an exploratory soils and engineering survey has indicated a block of 550,000 feddans which might be commanded either by pumping or gravity from the River Rahad. This area (the Hawata Project) together with irrigable lands on the west bank of the River Rahad, might provide a further 340,000 feddans of net irrigable area.

75. The full development of the Rahad projects might, therefore, be as follows:-

	<u>Feddans</u>	<u>Feddans</u>	<u>Total</u>
(i) Rahad East Bank Project			475,000
Rotation lands,	430,000		
Fodder and pasture,		45,000	
(ii) Hawata Project	340,000	}	420,000
Guneid Project	<u>80,000</u>	}	
Total rotation lands	850,000		
Fodder and pasture,		<u>45,000</u>	
Projects area,			<u>895,000</u>

Of these areas the pre-investment survey or feasibility studies have been completed for the Rahad east bank project. The soils survey and pre-investment surveys for the Hawata and Guneid Projects are in hand. It is probable that the cropping pattern, system of management and cultivation will follow the recommendations for the Rahad Project with such alterations as may be necessary on account of local conditions. An allowance of water for the fodder and pasture area has been made in the Tables of Water Use (Tables 10 to 15).

CHAPTER V - UTILISATION OF ROSEIRES WATER ON COMPLETION
OF STAGE I.

Areas.

76. For determining the area of irrigation which the combined storage of the Roseires and Sennar reservoirs can support, it has been decided that a suitable criterion is the 80% year. From the records of river flow, each 10 day period has been considered individually, and a flow determined such that in forty years out of fifty one years of record the recorded flow is greater than that selected for the 80% year. Then on average, if irrigation is developed based on this criterion, in four years out of five there will be sufficient water to support the proposed rotations to their full extent, with a variable surplus which can be used to improve power production or if convenient to allow extra watering.

77. In the remaining one year out of five there will be a shortage on the planned watering, which will become assessable as the river falls after the annual flood, and storage is drawn upon. In such a year it will be necessary to restrict watering in a manner which will bring crops to maturity, but with a reduced yield.

78. On this basis we have estimated that Stage I of Roseires Reservoir, in conjunction with Sennar Reservoir can support a total net irrigable area of 3,512,000 feddans, watered from the Blue Nile. The areas in which the water would be used, and the monthly amounts of water required, are shown on Table 10 with the exception of 772 million cubic metres of water supplied from the River Rahad to the Rahad-Hawata-Guneid Scheme from July to November inclusive. Since this water does not enter either reservoir it is not necessary to consider it further in the analyses of reservoir operation.

79. The area of 3,512,000 feddans is made up as follows:-

	<u>AREA</u>
	Feddans (1,000)
<u>Areas already irrigated</u>	
Guneid (sugar)	38
Other pump projects,	
Sennar - Khartoum	62
Roseires - Sennar	289
Gezira with Abdel Magid,	982
Managil,	838
Sub Total	2,209
 <u>New Developments - Immediate future</u>	
Pump Projects,	-
Sennar- Khartoum,	8
Abu Hugar - Sennar	32
Extensions to Gezira and Managil,	132
Guneid Extension and Khartoum Green Belt,	<u>31</u>
Sub Total	203
 <u>Major Irrigation Projects,</u>	 <u>1,100</u>
Grand Total	<u>3,512,000 feddans</u>

80. Under "New Developments - Immediate Future" have been included the areas which can be developed without major works such as main feeder canals or large pumping stations. The lands can either be irrigated from existing gravity systems or by pumping. Under "Major Irrigation Projects" we have included the whole of the Rahad Projects (850,000 feddans) and a part of the Roseires Right Bank Project, the water requirements for which have already received detailed investigation.

81. The total annual water requirement of the existing schemes, with new rotations, is 7,326 milliards, and of the new schemes 3,704 milliards from the Blue Nile plus 0.772 milliards from the Rahad, a total demand of 11.8 milliards.

Reservoir Capacity.

82. In considering the operating regime for both Stages I and II we have made the following allowances for evaporation losses and for dead storage in calculating the effective storage at Roseires and Sennar, as shown in Table 16.

TABLE 16.
RESERVOIR STORAGE (Milliards of M³)

Reservoir	Roseires Stage I (480m.)				Roseires Stage II (490m.)			
	Gross	Evap. losses (median)	Dead Storage	Effective	Gross	Evap. losses (median)	Dead Storage	Effective
Sennar	0.93	0.34	0.33	0.26	0.93	0.34	0.33	0.26
Roseires	3.02	0.38	0.64	2.00	7.59	0.73	0.64	6.22
Total	3.95	0.72	0.97	2.26	8.52	1.07	0.97	6.48

83. It will be noted that dead storage of 0.33 milliards has been allowed at Sennar. Subject to considerations of gate maintenance and of irrigation water requirements arising from intensified cropping in the Gezira and Managil areas, it is proposed to modify the regime of operation of the reservoir so that a minimum level is maintained to permit a continuous supply of water to the Gezira and Managil main canals by gravity and to enable the hydro-electric station to produce power all the year round. The effective storage in Sennar could be increased by 0.1 milliard if it should prove possible to reduce the minimum level from 417.2 m. to 415.9 m. and accept a greater limitation on the energy available from the hydro station at low reservoir.

Reservoir operation.

84. Table 11 shows the detailed analysis of the operation of the two reservoirs in combination, supporting the irrigation of 3.512 million feddans in an 80% year. Filling of the reservoirs is arranged in accordance with the criteria set out in Appendix I of the Roseires Power Station Project Report of December 1964, which ensures that even in the worst years of record the reservoirs will fill completely. The entire pattern of operation from November 20th to the end of May is determined by the irrigation demands, and the necessity for ensuring a minimum flow in the river below Guneid of 5 million cubic metres per day.

85. Of the total flow at Deim near the border with Ethiopia (40.11 milliards in the 80% year) 11.03 milliards are used for irrigation purposes, 0.71 milliards are lost by evaporation from the reservoirs and 27.64 milliards are passed onwards below Guneid. The difference of 0.73 milliards represents natural transmission losses between Roseires and Sennar. Evaporation losses are larger than those visualised in 1961 as reservoir levels are generally higher later in the season to allow for increased watering after March.

86. When a median year is considered, the natural flows in the period of shortage are greater than those of the 80% year, and there is a consequent surplus of stored water available from the reservoir. This surplus can be released in a manner which improves power production, without detriment to the irrigation supply. Table 12 sets out the proposed method of operation for a median year. In such a year 37.54 milliards are passed onwards below Guneid, out of a total of 50.25 milliards passing at Deim.

Power.

87. The power and energy output for the full development of Roseires Stage I is shown on Fig. 7 for either 5 or 7 sets installed. This can be compared with Plate No.3 of the Roseires Power Station Project Report.

There is little significant difference in a median year except in the period March to May inclusive. The cessation of cotton watering at the end of February means that there is an extra month where energy output is low, although kW. capacity can be maintained a month longer, until mid April. Conditions at Sennar improve slightly, particularly in March.

88. The power and energy output for an 80% year is also shown on Fig. 7 (there called a dry year). Again the difference is most marked in the period March to May inclusive. By comparison with the Roseires Power Station Project Report it will be seen that the continuous power during that period has increased from 20 MW. to 29 MW. at Roseires, and from 6.4 MW. to 8.0 MW. at Sennar. This is a result of the revised rotations now proposed, and does not represent any attempt to improve the power situation at the expense of irrigation potential.

89. If all available energy can be absorbed by the system, then 5 sets could produce 759 million units in an 80% year, and 809 million units in a median year. If 7 sets were installed before the Roseires dam is raised to its second stage then the energy potential would be 906 million units in an 80% year and 961 million units in a median year. For years when the flow is worse than that of the 80% year, there would be a falling off of available energy, which would be dependant on the restrictions applied to the irrigation pattern. For years when the flow is above that of a median year, then the surplus could be used to improve the energy output in the period March to May inclusive, when it is normally at its lowest.

BLUE NILE REGULATION

TABLE 10

FORECAST OF WATER REQUIREMENTS FOR FULL USE OF ROSEIRES STAGE I.

TOTAL IRRIGABLE AREA 3,512,000 FEDDANS

	Gross Irrigable Area Feddans (1,000)	Water Demand - million m ³												
		July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June	Total
<u>Taking water from Downstream Sennar</u>														
Guneid (Sugar)	44	37	27	35	36	25	22	21	20	24	28	30	30	335
Pumps (Existing)	62	28	20	24	31	29	23	19	16	13	-	-	-	203
Pumps (Extensions)	8	3	3	3	3	3	3	3	3	3	-	-	-	27
Total	114	68	50	62	70	57	48	43	39	40	28	30	30	565
<u>Taking water from Roseires - Sennar</u>														
Existing Gezira (intensified) inc. Abdel Magid	982	198	295	477	462	416	393	393	276	16	117	117	117	3277
Existing Managil,	838	177	300	438	383	297	279	279	233	9	71	71	71	2608
Gezira Extensions	97	19	29	47	45	41	39	39	27	3	12	12	12	325
Managil Extensions	35	7	13	18	16	12	12	12	10	3	3	3	3	112
Green belt (Forest and fodder)	25	15	15	15	15	15	15	15	14	15	15	15	15	179
Pumps (Existing)	289	131	94	111	145	136	107	89	75	61	-	-	-	949
Pumps (Extensions)	32	14	11	12	16	15	12	10	8	7	-	-	-	105
Total	2298	561	757	1118	1082	932	857	837	643	114	218	218	218	7555
<u>Taking water from Upstream Roseires</u>														
Rahad - Hawata - Guneid	850	133	-	157	313	309	308	257	73	74	90	237	244	2195
Roseires (Right Bank)	250	43	37	35	92	96	92	59	9	48	85	65	54	715
Total	1,100	176	37	192	405	405	400	316	82	122	175	302	298	2910
GRAND TOTAL	3,512													11030

* Rahad-Hawata-Guneid is supplemented from River Rahad in July - November inclusive.

TABLE 11
ROSEIRES STAGE I
AND SENNAR
80% YEAR.

BLUE NILE REGULATION
ROSEIRES STAGE I - FULL USE OF AVAILABLE STORAGE

TOTAL IRRIGABLE AREA 3,512,000 FEDDANS

All amounts in millions of cubic metres in stated period

Period	ROSEIRES - STAGE I							SENNAR					SENNAR-KHARTOUM			
	Natural Flow 80% Year at Deim.	Irrig. Reqs. from Reservoir	Evap. loss	Change in Contents	Contents at end of period	Level at end of period metres	Release down- stream	Inflow (2% loss) from Roseires	Irrig. Reqs.	Evap. loss	Change in Contents	Contents at end of period	Level at end of period metres	Release down- stream	Irrig. Reqs.	Min. flow Down- stream Gareid
July 1-10	811	82	3	-	638	467.0	726	711	186	4	-	330	417.2	521	25	50
11-20	1410	68	3	-			1339	1312	186	4	-			1122	22	50
21-31	2760	26	3	-			2731	2676	189	5	-			2482	21	55
Aug. 1-10	3983	12	2	-			3969	3890	247	3	-			3640	17	50
11-20	4380	12	2	-			4366	4279	241	3	-			4035	16	50
21-31	4950	13	2	-			4935	4836	269	3	-			4564	17	55
																Surplus water
Sep. 1-10	3933	38	2	-			3893	3815	372	3	-			3440	20	50
11-20	3440	77	2	-	638	467.0	3361	3294	373	3	-	330	417.2	2918	21	50
21-30	3176	77	3	+ 936	1574	473.7	2160	2117	373	4	+ 234	564	419.2	1506	21	50
																Filling starts
Oct. 1-10	2260	115	7	+ 716	2290	477.2	1422	1394	355	8	+ 179	743	420.45	852	22	50
11-20	1570	145	8	+ 440	2730	478.95	977	957	366	9	+ 110	853	421.2	472	22	50
21-31	1144	145	10	+ 240	2970	479.8	749	734	361	10	+ 60	913	421.6	303	26	55
Nov. 1-10	891	131	16	+ 54	3024	480.0	690	676	312	12	+ 17	930	421.7	335	20	50
11-20	693	137	16	-	3024	480.0	540	529	313	12	-	930	421.7	204	19	50
21-30	540	137	16	- 6	3018	480.0	393	385	307	12	- 2	928	421.7	68	18	50
																Filling com- pleted.
Dec. 1-10	442	133	18	- 61	2957	479.75	352	345	281	12	- 15	913	421.6	67	17	50
11-20	363	129	18	- 119	2838	479.3	335	328	281	11	- 30	883	421.4	66	16	50
21-31	320	138	19	- 177	2661	478.7	340	333	295	12	- 44	839	421.1	70	15	55
																Withdrawals 1/5th from Sennar 4/5th from Roseires throughout.
Jan. 1-10	257	121	17	- 194	2467	477.9	313	307	277	13	- 48	791	420.75	65	15	50
11-20	213	118	16	- 219	2248	477.0	298	292	271	12	- 55	736	420.4	64	14	50
21-31	199	77	17	- 218	2030	476.0	323	317	289	13	- 54	682	420.0	69	14	55
Feb. 1-10	157	32	16	- 165	1865	475.2	274	269	232	14	- 41	641	419.75	64	14	50
11-20	131	27	15	- 180	1685	474.3	269	264	232	13	- 45	596	419.45	64	14	50
21-28	91	23	11	- 150	1535	473.5	207	203	179	10	- 37	559	419.15	51	11	40
Mar. 1-10	105	27	15	- 41	1494	473.2	104	102	36	14	- 10	549	419.1	62	12	50
11-20	86	34	15	- 63	1431	472.9	100	98	36	14	- 15	534	419.0	63	13	50
21-31	89	61	15	- 93	1338	472.3	106	104	42	15	- 23	511	418.8	70	15	55
Apr. 1-10	73	56	13	- 115	1223	471.6	119	117	73	13	- 29	482	418.6	60	10	50
11-20	71	54	12	- 113	1110	470.85	118	116	73	12	- 28	454	418.3	59	9	50
21-30	70	65	12	- 122	988	470.0	115	113	72	12	- 30	424	418.1	59	9	50
May 1-10	69	116	9	- 159	829	468.7	103	101	72	10	- 40	384	417.7	59	9	50
11-20	99	99	9	- 122	707	467.65	113	111	72	10	- 31	353	417.4	60	10	50
21-31	167	87	10	- 67	640	467.0	137	134	74	11	- 17	336	417.25	66	11	55
June 1-10	245	74	6	- 2	638	467.0	167	164	73	8	- 6	330	417.2	89	11	50
11-20	369	112	5	-	638	467.0	252	247	73	7	-	330	417.2	167	10	50
21-30	551	112	5	-	638	467.0	434	425	72	7	-	330	417.2	346	9	50
Totals	40,108	2910	368				36830	36095	7355	338				28202	565	

TABLE 15

ROSEIRES STAGE II
AND SENNAR
MEDIAN YEAR

BLUE NILE REGULATION

ROSEIRES STAGE II - FULL USE OF AVAILABLE STORAGE

TOTAL IRRIGABLE AREA 6,127,000 FEDDANS

All amounts in millions of cubic metres in stated period

Period	ROSEIRES - STAGE II							SENNAR							SENNAR-KHARTOUM		
	Natural Flow Median Year at Deim.	Irrig. Reqts.	Evap. Loss	Change in Contents	Contents at end of period	Level at end of period metres	Release down- stream	Inflow (2% loss) from Roseires	Irrig. Reqts.	Evap. loss	Change in Contents	Contents at end of period	Level at end of period metres	Release down- stream	Irrig. Reqts.	Min. Flow Down- stream Gueid	
July 1-10	1045	265	3	-	638	467.0	777	761	186	4	-	330	417.2	571	25	50	
11-20	1900	219	3	-			1678	1644	186	4	-			1454	22	50	
21-31	3652	191	3	-			3458	3389	189	5	-			3195	21	55	
Aug. 1-10	4600	171	2	-			4427	4338	247	3	-			4088	17	50	Surplus water
11-20	5240	181	2	-			5057	4956	241	3	-			4712	16	50	
21-31	5999	218	2	-			5779	5663	269	3	-			5391	17	55	
Sept. 1-10	4980	304	3	-	638	467.0	4673	4580	372	3	-			4205	20	50	Roseires filling starts
11-20	4270	405	5	+ 2360	2998	479.9	1500	1470	373	3	-			1094	21	50	
21-30	3839	469	9	+ 1930	4928	485.1	1402	1402	373	4	-			1025	21	50	
Oct. 1-10	2876	544	18	+ 1680	6608	488.35	634	621	355	5	-	330	417.2	261	22	50	Sennar filling starts
11-20	2220	550	20	+ 600	7208	489.4	1050	1029	366	8	+ 365	695	420.1	290	22	50	
21-31	1650	533	23	+ 315	7523	489.9	779	763	361	9	+ 193	888	421.4	200	26	55	
Nov. 1-10	1110	471	34	+ 65	7588	490.0	540	529	312	12	+ 42	930	421.7	163	20	50	Filling completed
11-20	822	478	34	- 87	7501	489.9	397	389	313	12	- 5	925	421.7	69	19	50	
21-30	734	471	34	- 151	7350	489.6	380	372	307	12	- 15	910	421.6	68	18	50	
Dec. 1-10	553	452	39	- 279	7071	489.15	341	334	281	11	- 25	885	421.4	67	17	50	
11-20	452	433	37	- 353	6718	488.55	335	328	281	11	- 30	855	421.2	66	16	50	
21-31	394	465	40	- 455	6263	487.75	344	337	295	12	- 40	815	420.9	70	15	55	
Jan. 1-10	299	403	36	- 461	5802	486.9	321	315	277	13	- 40	775	420.6	65	15	50	
11-20	251	376	34	- 472	5330	486.0	313	307	271	12	- 40	735	420.4	64	14	50	
21-31	233	224	35	- 372	4958	485.15	346	339	289	11	- 30	705	420.2	69	14	55	
Feb. 1-10	183	97	35	- 245	4713	484.6	296	290	232	14	- 20	685	420.0	64	14	50	
11-20	164	83	34	- 248	4465	484.05	295	289	232	13	- 20	665	419.9	64	14	50	
21-28	114	69	26	- 206	4259	483.55	225	221	179	11	- 20	645	419.75	51	11	40	
Mar. 1-10	123	83	33	- 163	4096	483.15	170	167	36	15	-	645	419.75	116	12	50	
11-20	106	127	32	- 226	3870	482.55	173	170	36	15	-	645	419.75	119	13	50	
21-31	111	284	33	- 402	3468	481.4	196	192	42	17	-	645	419.75	133	15	55	
Apr. 1-10	92	258	26	- 376	3092	480.2	184	180	73	15	- 40	605	419.5	132	10	50	Surplus water used for improvement of power production.
11-20	81	246	23	- 384	2708	478.85	196	192	73	14	- 40	565	419.2	145	9	50	
21-30	89	251	20	- 386	2322	477.3	204	200	72	14	- 40	525	418.9	154	9	50	
May 1-10	112	384	15	- 502	1820	475.0	215	211	72	12	- 40	485	418.55	167	9	50	Surplus water
11-20	165	327	13	- 415	1405	472.7	240	235	72	11	- 40	445	418.25	192	10	50	
21-31	243	290	12	- 351	1054	470.4	292	286	74	12	- 40	405	417.9	240	11	55	
June 1-10	318	254	6	- 232	822	468.65	290	284	73	8	- 40	365	417.5	243	11	50	Surplus water
11-20	510	352	5	- 184	638	467.0	337	330	73	7	- 35	330	417.2	285	10	50	
21-30	695	350	5	-	638	467.0	340	333	72	7	-	330	417.2	254	9	50	
Totals	50,225	11278	734				38213	37446	7555	345				29546	565	1825	

CHAPTER VII - COSTS, BENEFITS AND PRIORITY OF DEVELOPMENT
OF MAJOR AREAS.

Estimated Capital Costs.

103. The costs of construction for the Rahad and Roseires Projects have been estimated for the pre-investment reports. Estimates have been made for the Kenana and Dinder based on the results of the Rahad and Roseires Projects and estimates for the cost of the feeder canals. The comparative estimates are given in Table 17 and are summarised below in Table 18.

TABLE 18.

SUMMARY OF CAPITAL COST ESTIMATES

	Area Feddans 1000	Ministry of (1) Irrigation & Hydro-Electric Power.		Project (2) Board Costs		TOTAL	
		£S Mill.	£S per Feddan	£S Mill.	£S per Feddan	£S Mill.	£S per Feddan
Kenana	1,500	95.8	63.8	12.8	8.6	108.6	72.4
Roseires	500	35.0	69.9	4.3	8.6	39.3	78.5
Dinder	350	25.3	72.4	3.0	8.6	28.3	81.0
Rahad	850	60.1	70.8	7.3	8.6	67.4	79.4

(1) Covers the cost of headworks, canalisation and drainage, land preparation, housing including schools, etc. services and communications.

(2) Covers cost of processing and agricultural plant.

TABLE 17

APPROXIMATE ESTIMATE OF PRESENT COSTS.

Net Cultivable Area (feddans)	KENANA		ROSEIRES		DINDER		RAHAD, HAWATA & GUNEID	
	1,500,000		500,000		350,000		850,000	
	(Thou. £S)	(£S/feddan)	(Thou.£S)	(£S/feddan)	(Thou.£S)	(£S/feddan)	(Thou.£S)	(£S/feddan)
Preliminary Works, including land	600	0.4	190	0.4	150	0.4	360	0.4
Headworks, etc.	1,200	-	710	-	490	-	1,200	-
Main and Branch Canals	26,400	17.6	8,610	17.2	6,200	17.7	21,000	24.7
Distributary Canals	12,350	8.2	4,290	8.6	3,150	9.0	6,710	7.9
Escapes and Drains	2,300	1.5	1,190	2.3	810	2.3	1,020	1.2
Land preparation	5,650	3.8	2,720	5.4	2,270	6.5	1,660	2.0
Excavating plant	-	-	950	-	690	-	700	-
Agric. and Irrig. buildings,	15,900	10.6	5,280	10.6	3,710	10.6	8,300	9.8
Other buildings (schools, etc.)	5,310	3.5	1,770	3.5	1,240	3.5	3,080	3.6
Water and Electricity	5,170	3.4	1,720	3.4	1,210	3.4	2,220	2.6
Communications	4,340	2.9	1,450	2.9	1,010	2.9	3,450	4.1
Contingencies	7,920	-	2,890	-	2,090	-	4,970	-
Eng. Supervision and Min. of Irrigation establishment.	8,710	-	3,180	-	2,300	-	5,470	-
Total Ministry of Irrigation Costs.	95,850	63.8	34,950	69.9	25,320	72.4	60,140	70.8
Processing Plant	3,550	2.4	1,490	3.0	830	2.4	2,010	2.4
Agricultural Plant	8,070	5.5	2,420	4.8	1,900	5.5	4,610	5.5
Contingencies	1,160	-	390	-	270	-	660	-
Total Project Board Costs	12,780	8.6	4,300	8.6	3,000	8.6	7,280	8.6
GRAND TOTAL	108,630	72.4	39,250	78.5	28,320	81.0	67,420	79.4

Notes:

- Rahad and Roseires:** Estimates of costs for these projects have been made for pre-investment surveys. The cost of canal headworks has been distributed between all the Right Bank Projects. As a result, the Grand Total Cost for the Roseires Project is less than that quoted in the Pre-Investment Report, where the whole cost of the headworks was included. The cost of excavating plant required for the construction of drains and distributary canals is shown as a separate item.
- Kenana:** An estimate of cost for a net area of approximately 1,000,000 feddans was prepared in 1958. A revised estimate for 1,500,000 feddans has been prepared and includes additional information derived from the Rahad and Roseires estimates.
- Dinder:** The estimate of costs has been based on the Roseires estimated rates. Adjustments have been made to take into account conditions which differ from Roseires.
- Hawata:** The estimate has been made in a similar way to that for Dinder, but also based on Rahad costs.
- Guneid:** The estimate has been based on Rahad costs.

APPROXIMATE ESTIMATE OF PRESENT COSTS.

Net Cultivable Area (feddans)	KENANA		ROSEIRES		DINDER		BAHIG, HAWATA & QUNEID	
	1,500,000		500,000		350,000		850,000	
	(Thou. £S)	(£S/feddan)	(Thou.£S)	(£S/feddan)	(Thou.£S)	(£S/feddan)	(Thou.£S)	(£S/feddan)
Preliminary Works, including land	600	0.4	190	0.4	150	0.4	360	0.4
Headworks, etc.	1,200	-	710	-	490	-	1,200	-
Main and Branch Canals	26,400	17.6	8,610	17.2	6,200	17.7	21,000	24.7
Distributary Canals	12,350	8.2	4,290	8.6	3,150	9.0	6,710	7.9
Escapes and Drains	2,300	1.5	1,190	2.3	810	2.3	1,020	1.2
Land preparation	5,650	3.8	2,720	5.4	2,270	6.5	1,660	2.0
Excavating plant	-	-	950	-	690	-	700	-
Agric. and Irrig. buildings,	15,900	10.6	5,280	10.6	3,710	10.6	8,300	9.8
Other buildings (schools, etc.)	5,310	3.5	1,770	3.5	1,240	3.5	3,080	3.6
Water and Electricity	5,170	3.4	1,720	3.4	1,210	3.4	2,220	2.6
Communications	4,340	2.9	1,450	2.9	1,010	2.9	3,450	4.1
Contingencies	7,920	-	2,890	-	2,090	-	4,970	-
Eng. Supervision and Min. of Irrigation establishment.	8,710	-	3,180	-	2,300	-	5,470	-
Total Ministry of Irrigation Costs.	95,850	63.8	34,950	69.9	25,320	72.4	60,140	70.8
Processing Plant	3,550	2.4	1,490	3.0	830	2.4	2,010	2.4
Agricultural Plant	8,070	5.5	2,420	4.8	1,900	5.5	4,610	5.5
Contingencies	1,160	-	390	-	270	-	660	-
Total Project Board Costs	12,780	8.6	4,300	8.6	3,000	8.6	7,280	8.6
GRAND TOTAL	108,630	72.4	39,250	78.5	28,320	81.0	67,420	79.4

Notes:

- Bahig and Roseires:** Estimates of costs for these projects have been made for pre-investment surveys. The cost of metal headworks has been distributed between all the Right Bank Projects. As a result, the Grand Total Cost for the Roseires Project is less than that quoted in the Pre-Investment Report, where the whole cost of the headworks was included. The cost of excavating plant required for the construction of drains and distributary canals is shown as a separate item.
- Kenana:** An estimate of cost for a net area of approximately 1,000,000 feddans was prepared in 1958. A revised estimate for 1,500,000 feddans has been prepared and includes additional information derived from the Bahig and Roseires estimates.
- Dinder:** The estimate of costs has been based on the Roseires estimated rates. Adjustments have been made to take into account conditions which differ from Roseires.
- Hawata:** The estimate has been made in a similar way to that for Dinder, but also based on Bahig costs.
- Quneid:** The estimate has been based on Bahig costs.

104. The following qualifications should be noted regarding these approximate estimates:-

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Kenana Project:	No semi-detailed soil survey, part of topo survey completed but not available for estimate.
Roseires Project:	Semi-detailed soil survey completed <u>but</u> no detailed topographical survey. The unevenness of the micro-relief in the southern area of the Project which constitutes the major part of the total project area may increase the cost per feddan to the £S 79.4 level of Rahad.
Dinder Project:	No semi-detailed soil survey or topographical survey.
Rahad Project:	There are possibilities of some reduction of the rate per feddan of £S 79.4 by revising the standard of housing and social services. These services are presently being worked out by Government. In addition to the total project area for Rahad, Hawata and Guneid of 850,000 feddans described above recent exploratory survey indicates that the Hawata area can be extended and may increase the total project area to 1.2 million feddans. This should result in some further economy in the cost of the supply canals and administration, and a reduction in the cost per feddan.

Profitability of Crops.

105. A variety of crops were considered for the Roseires and Rahad Projects to form the basic cash crops of the rotation. Based on estimated yields and forecasted market prices the returns from these crops are as follows:-

TABLE 19

RELATIVE PROFITABILITY OF CROPS PER FEDDAN

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Description	Yield	Price f.o.b. Port Sudan	Output (1) £S.	Gross (2) Margin £S
Long Staple Cotton 1 BAR 1425 (G.O.T. 30%)	4.3 SK	12.26 LK	60.1	46.5
Medium Staple Cotton Acala 4.42 (G.O.T. 39.5%)	5.0 SK	9.57 LK	66.9	53.6
Groundnuts Ashford Variety (S.O.T. 70%)	1.25 M tons in shell	54.4 p.ton shelled	44.9	37.5
Barberton Variety (S.O.T. 70%)	1.00 M tons in shell	54.4 p.ton shelled	35.8	29.7
Dura	0.6 M tons	18.0 p.ton	10.8	8.0
Sesame	0.3 M tons	67.3 p.ton	20.2	18.1
Wheat	0.8 M tons	27.0 p.ton c.i.f.	23.2	14.4

Notes: SK = Seed Kantars (315 lbs.)
 LK = Lint Kantars (100 lbs.)
 M = Metric
 S.O.T. = Shelling out turn
 G.O.T. = Ginning out turn

- (1) The 'Output' is the value of the crops sold in Port Sudan or Khartoum.
- (2) The Gross Margin is the 'Output' less the following costs:

Seed, root pulling (depreciation on equipment),
spraying, fertilisers, ginning including sacks,
freight, insurance, marketing etc.

Details are given in Appendix 7 of the Rahad Pre-Investment Report, Part III.

106. From the comparison of Output and Gross Margin for the various crops, it is evident that Medium Staple Cotton and Groundnuts (Ashford Variety) are the two most profitable crops, and these form the basis of the rotation recommended for the Rahad and Roseires Projects. The cropping pattern recommended for the Rahad Project has been referred to in paragraph 71 as cotton $33.1/3\%$, groundnuts $33.1/3\%$ and dura $16.2/3\%$. This cropping pattern has been formulated to give the maximum return and to conform with the restrictions imposed on account of soil permeability, crop hygiene, minimum fallow, etc., and the economy of the supply channels. In addition to the rotation area of 12 feddans for each holding there is a garden area adjacent to the village of 0.75 feddans for fruit, vegetables and the farmers' livestock. In spite of the differing cost of feeder canal and increase in rainfall, the agricultural investigation for the Roseires Project has produced the same cropping pattern. In the Rahad Project, an area of 45,000 feddans is proposed for fodder and forestry. In the Roseires Project 18,000 feddans are allocated for a sugar plantation and 5,000 feddans for rice cultivation.

107. The purpose of the analysis is to compare the various major irrigation projects, and it will be assumed that the basic Roseires and Rahad rotations will apply to the Kenana and Dinder Projects. The northern area of the Kenana project is similar to the Rahad Project and the southern area compares with the Roseires Project. The Dinder Project

- (1) The 'Output' is the value of the crops sold in Port Sudan or Khartoum.
- (2) The Gross Margin is the 'Output' less the following costs:

Seed, root pulling (depreciation on equipment),
spraying, fertilisers, ginning including sacks,
freight, insurance, marketing etc.

Details are given in Appendix 7 of the Rahad Pre-Investment Report, Part III.

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107. The purpose of the analysis is to compare the various major irrigation projects, and it will be assumed that the basic Roseires and Rahad rotations will apply to the Kenana and Dinder Projects. The northern area of the Kenana project is similar to the Rahad Project and the southern area compares with the Roseires Project. The Dinder Project

is similar to the southern part of the Roseires Project. The 'special areas', such as fodder, forest, sugar and rice in the Roseires and Rahad Projects will be ignored, as they relate to a limited area consideration of which would only complicate the comparison of the benefits.

Benefits of Development.

108. A full economic appraisal has been included in the Rahad and Roseires Pre-Investment Report by Sir Murdoch MacDonald & Partners and Hunting Technical Services. This covers all factors affecting development, namely land, water, management, skilled and unskilled labour and settlement etc. The object of this Memorandum is to compare four major irrigation projects. From the information now available it is probable that the cropping pattern, agricultural management and irrigation techniques will be similar in all the projects. The input management labour, land and water can be assessed to be much the same for all the projects. The financial assessment, therefore, will be based on a simple "Output: Capital Ratio" of the various projects.

109. The 'Output' per feddan with the proposed cropping pattern is as follows:-

TABLE 20.
ESTIMATED INCOME PER FEDDAN

	£S per feddan
Revenue from Crops - Cotton, Groundnuts, Dura	36.8
Farmers' Benefit from Vegetables and Animals	<u>3.3</u> ⁽¹⁾
	40.1
Loss of Output due to Movement of Farmers into irrigation schemes	4.4 ⁽²⁾
Total value of Output	35.7
Less Foreign Exchange expenditure	<u>5.2</u> ⁽³⁾
Net annual increase in National Income	£S <u>30.5</u> per feddan

Notes (1) This is based on the conclusion of the Rahad Report Part III - Table 5.12 - estimated benefit to farmer from vegetables (£S 12) and from animals (£S 30) for 12.75 feddan irrigated area.

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(2) Reference Rahad Report Part II - paragraph 5.531 - farmers' previous income from dura (£S 21.6) and cash earnings (£S 34.0)

(3) Reference Rahad Report Part II Table 5.23.

Output: Capital Ratio.

110. From the estimate of the benefits of development it is possible to compare the output with the capital cost to get a simple comparison of economics of the various projects.

TABLE 21

OUTPUT: CAPITAL RATIO FOR MAJOR PROJECTS

	Capital Cost per feddan £S	Output per feddan		Output: Capital ratio	
		Gross £S	Less Foreign Exchange £S	Gross %	Less Foreign Exchange %
Kenana	72.4	35.7	30.5	50	42
Roseires	78.5	35.7	30.5	45	39
Dinder	81.0	35.7	30.5	44	38
Rahad	79.4	35.7	30.5	45	38

Thus the output: capital ratio varies from 42% for the Kenana Project to 38% for the Rahad Project if the foreign exchange element in the cost of production is taken into account.

Priority of Development (Stage 1).

111. As will be seen in Table 10 it is estimated that Roseires Stage I, in conjunction with Sennar, will irrigate a total area of 3,512,000 feddans, of which 1,100,000 feddans represents the priority areas chosen for the major projects taking water direct from the Roseires reservoir. In considering the selection of these major areas for first stage development it is necessary to take into account the fact that pre-investment or feasibility studies are nearing completion for the Rahad and Roseires areas whereas assumptions have had to be made through lack of detailed knowledge in assessing the output: capital ratios for the Kenana and Dinder areas.

Dinder.

112. There is a considerable growth of established forest in the Dinder areas and it is possible that the area could be developed more profitably by expansion of rainland agriculture using a gravity supply from the Rahad Link Canal for domestic water supplies. The estimated cost of development per feddan is £S 81.0 which is more costly than either the Roseires, Rahad or Kenana Project. The Dinder Project is not, therefore, considered further for use of the Roseires Stage I water.

Kenana.

113. During the early planning of the Roseires Dam it was generally assumed that the Kenana Project would provide the major irrigation development. A railway is available from Roseires to Sennar and topographical survey for 1.3 million feddans has been completed. No semi-detailed soil surveys have yet been carried out. The comparatively high rainfall in the south might prove to be a limitation for irrigation development on account of the unknown problems in connection with controlled agriculture under such conditions. On the other hand, the northern area of nearly 1 million feddans is similar to the Gezira and Managil Schemes, and subject to the confirmation of the soils and topography could be developed for irrigation.

The estimated cost of construction is the most economical of the four projects considered. The I.B.R.D. Report number 204a of April 17, 1959, did not recommend the Kenana Project for the use of Roseires Stage I water. It was recorded at the time that settlement of the area would be a major operation due to lack of any appreciable resident population. The southern part of the area has a rainfall similar to the Roseires Project, is fairly heavily timbered, and could support a raingrown crop.

Roseires.

114. The southern part of this area carries a heavy growth of timber and could support rain grown crops. The pattern of rainfall is such that completion of agricultural operations to a rigid timetable might be difficult to achieve, and communications for supervision of the agriculture could be disrupted for considerable periods. The practice now is to close all roads from 15th July to 15th October.

115. A semi-detailed soil survey has confirmed the irrigable area, but indicates that the soils are variable. The topographical survey for close contouring has not been completed. A survey of a number of sample areas has shown that the micro-relief is uneven, which precludes regular layout of canalisation, as practiced in the Gezira Scheme, and may increase the cost of canalisation to the level of the Rahad Project, or reduce the effective irrigable area. The pre-investment survey and feasibility report is about to be completed. As described above, the major limitations for development are the comparatively high rainfall in the southern area and the possibility of difficulties in canalisation as a result of uneven topography, the extent of which cannot be defined until a detailed contour survey has been completed.

Rahad, including Guneid and Hawata.

116. The climate is similar to the Gezira Scheme. The soils in the main Rahad Project (430,000 feddans) and part of the Guneid Project (60,000 feddans) are good. The semi-detailed soil survey of the remaining

areas is in hand. There is already a resident population, and although settlers from other districts will be needed to develop the irrigation projects, the area is known to the inhabitants of the Sudan, and this will ease the problems of settlement. The detailed contour survey of the main Rahad Project shows the topography and land slopes to be even, and ideal for the regular layout of canalisation practiced in the Sudan. The agricultural operations could follow the Gezira pattern, and the experience gained in that Project can be used in the Rahad area. These advantages outweigh the disadvantage that the estimated capital cost per feddan is greater for the Rahad Project than for the Kenana Project. Furthermore, as already mentioned, possibilities for some reduction in capital cost of the Rahad Project are being investigated, and if they materialise may result in a reduction of the estimated cost per feddan to that of the Roseires Project or even lower.

Recommended Priorities for Stage I.

117. In September 1964, when the Sudan Government initiated pre-investment and feasibility studies on the Rahad and Roseires Projects, the former was considered favourable for development, in spite of the distance from Roseires, the major source of irrigation supplies, because there was every indication that the soils would be suitable for irrigation, the rainfall not excessive and the topography most suitable for irrigation development, together with the further advantage that there was a sizeable resident population. From the information available to date there is no doubt that these general conditions still favour priority development of the Rahad Projects, in spite of the additional cost as compared with development in the Kenana area.

118. The pre-investment study and feasibility report for the Roseires Project has been submitted. It is possible that early development of about 120,000 feddans might be achieved by pumped irrigation in the northern area. The southern area of 380,000 feddans suffers from the limitations of high rainfall and irregular surface topography. From the

information now available, the Rahad Project is preferred for first development.

119. A full pre-investment survey and feasibility study is required to formulate the plan of development for Kenana. A research station has been established to study the problems of irrigation in the rainland areas. In addition we repeat the recommendation made in the Estimation of Irrigable Areas Report of February 1954 that further agricultural research on the response of crops to the higher rainfall and special soil conditions of the southern area should be undertaken on a sizeable pilot project.

Stage II Development.

120. The difference between the total irrigable areas in Table 10 (3,512,000 feddans) and Table 13 (6,127,000 feddans) of 2,615,000 feddans represents Roseires Stage II development. The length of the period before Stage II storage is required is dependent on the rate of development of irrigated agriculture which the Sudan can successfully sustain over the next 10 years and thereafter. This will depend on the supply of capital, management, skilled and unskilled labour.

CHAPTER VIII - RATE OF DEVELOPMENT

Introduction.

121. A large and sustained rate of development is desired, not only to realise and possibly increase the projected growth rate of the Sudan's economy, but to utilise fully the appreciable investments which have already been spent on infrastructure in the shortest possible period. However, a large and sustained rate of development makes great demands on capital, management and skills. In the Sudan, capital is in short supply and, although management and skills are improving and increasing, yet their supply may be inadequate to satisfy the needs of a large and sustained rate of development, unless positive and energetic steps are taken now. From a constructional point of view economies of scale, which can be substantial, can be achieved mainly by large irrigation works and rapid rates of construction. To achieve these economies, however, supplies of management, skills and labour must be made available in large numbers over a relatively short period of time so that the optimum level of output can be achieved as quickly as possible after construction is complete. The larger the project and the greater the engineering economies of scale that can be achieved, the greater the demands for these other factors become.

122. As the full utilisation of the waters of both stages of the Roseires reservoir will take some time, it should be possible, in the interim period, to increase the supply of these factors substantially. It is apparent that the Government is aware of the factors associated with large scale development of irrigation and their implications on the phasing of one or more projects. In consultation with senior members of the Civil Service, the Consultants were advised that the Government was actively examining resources which would be required with a view to ensuring their availability at the time of implementation and in order to achieve the maximum sustained rate of development.

Managil as a guide to long term rates of development.

123. The Managil Extension (800,000 feddans) was originally planned to be developed over a period of eight years. After Independence, it was decided and found feasible, from a planning point of view, to aim at the phasing and execution of the project within a period of four years. However, due to financial stringency and the time required to prepare and negotiate the required loan to cover external costs, the phasing was extended to five years. If the additional year (which also came about mainly as a result of financial circumstances during which the main duplicate feeder canal was started) is taken into consideration, the whole scheme took six years, averaging 133,000 feddans per annum involving an average capital investment of £S 6.5 m (including duties) annually. Although it would have been possible to crop up the 264,000 feddans of cotton over five years, or an average of 53,000 feddans annual increase, it took six years to crop the whole area under cotton, an annual increase of 133,000 feddans gross area (44,000 feddans of cotton). The annual average requirement of labour in households was 9,000 of whom the majority were resident.

124. In Table 22 various rates of development and their demands for capital and labour are given. It will be noted that the rates given under Column C, viz. 400,000 feddans maximum rate of canalisation of which 266,000 feddans per annum is the actually completed construction rate, exceed the maximum possible average rate of development (130,000 to 164,000 feddans per annum) in terms of availability of irrigation water as discussed in Paragraphs 126 to 128. The phasing of development has an important bearing on world commodity supply, demand and prices over a short period. It follows that although some of the production will be consumed locally, a close watch should be maintained on world market trends and if necessary adjustments in the rate of development may have to be made towards the end of the development programme. In addition, agricultural research in respect of alternative crops and improved techniques should be intensified.

TABLE 22.

RATES OF DEVELOPMENT COMPARED WITH MANAGIL (PER ANNUM)

	(Short Term) Managil	New Projects (Long Term)		
		A	B	C
Maximum rate of Canalisation 000 feddans	200	200	300	400
Actual completed construction rate 000, feddans	133	133	200	266
Annual average capital requirement excluding duty £S million	(1) 6.0	(2) 9.3	(2) 14.0	(2) 18.6
Annual average requirement of labour in households.	9,000	10,500	16,000	20,800
	Mainly Resident	Mainly Non Resident		

- Notes: 1. Capital requirement of Managil assumed at £S 45.0 per feddan
2. Capital requirement of new projects on average assumed at £S 70.0 per feddan.

Limitation of Rate of Development

125. Experience gained during the execution of Managil, Khashm el Girba and extensions to the Gezira indicate that the Sudan's capacity for the implementation of irrigation projects has been appreciably enhanced over the past eight years. Notwithstanding this increase in ability and physical resources, a major constraint becomes operative when the rate of

development exceeds about 150,000 feddans annually, namely the availability of water. It is calculated that an average annual increment of 130,000 feddans in the Blue Nile area over a period of eleven years will fully utilise the share of water available to the Sudan by 1977 if all other developments also proceed as foreseen in Paragraphs 34 to 36. Although it may be possible to achieve higher rates of development in one or more years it would be inadvisable to incur capital expenditure on plant and equipment greatly in excess of that deemed necessary to achieve a sustained average rate of development over the whole period.

126. We have considered ways in which the average rate of development of 130,000 feddans per year in the Blue Nile area can be increased in the period up to 1978 during which the loan to The United Arab Republic of 1.5 milliards per annum is applicable.

127. On the Atbara River storage is already available at Khashm el Girba and, therefore, developments based on this storage must obviously proceed until full development from the storage has been obtained. It has also been established that pump schemes on the Main Nile north of Khartoum must also have high priority. If, therefore, additional water is to be made available on the Blue Nile during the interim period this can only be done by a reduction in the area of pump schemes to be developed on the White Nile.

128. In Table 5 0.58 milliards is allocated for the development of 207,000 feddans in this area. In addition an allowance of 0.5 milliards has been made pending a decision on the future of Jebel Aulia. Assuming that no further developments take place on the White Nile until after 1977 and that the Jebel Aulia allowance can also be utilised, the average rate of development on the Blue Nile during this period could be increased from 130,000 to 164,000 feddans per annum. As the development of pump schemes on the White Nile is unlikely to stop all together, the rate of development on the Blue Nile will, therefore, lie between the two figures quoted above.

CHAPTER IX - PROJECTION OF INCOME AND EXPENDITURE

Roseires Stage I.

129. The increases in gross national income are mainly in foreign exchange earnings, with the exception of wheat in the Gezira which is in terms of foreign exchange saved. Allowances have been made for loss of production of subsistence and other crops that the settlers will have caused by moving into the new schemes, but no allowances have been made for loss in transferring management and skills from other activities elsewhere. It has been assumed that world prices, notably of cotton and groundnuts will not be affected by the increase in production resulting from the projects over and above the prices adopted. (Report No. II Rahad Project).

130. Table 23 shows Income and Expenditure from Roseires Stage I development at an assumed rate so that the water will be fully utilised by 1975 with the long term average level of production achieved by 1980. This assumes an average rate of construction for new lands and for successful cropping to be implemented (excluding Khartoum green belt and a small extension to Guneid) of 141,000 feddans per year. The capital investment shown includes both local and foreign currency but excludes duties.

131. The net contribution to the national income is approximately £S 57 million, less £S 9 million of imported materials, agricultural plant and machinery (including capital renewals) i.e. £S 48 million net. To achieve this £S 95 million will have to be invested over 9 years averaging £S 10.6 million annually on the development rate assumed. Of this about 55% will be required in foreign exchange, about £S 5.8 million annually. The demands for capital at certain peak periods can be seen to be much greater. Servicing of loans to finance these investments depends very much on the terms of the loan.

With the whole of the capital borrowed and carrying 6% interest with repayments in equal instalments over 25 years from 1970/71 or from date of investment in subsequent years, a servicing commitment of £S 7.9 million annually seems likely, excluding repayment of the dam loan. Table 24 shows the assumed repayment programme up to 1980 based on alternative types of loan and interest rates.

132. Table 25 shows Income and Expenditure from Roseires Stage I development at a higher rate than in Table 23. Successful cropping would be implemented at an average rate of 182,000 feddans per year with Stage I fully utilised by 1973 and the long term level of production reached by 1978.

Roseires Stage II.

133. A projection of income accruing from Stage II has not been attempted as many factors (e.g. the effect of large increases in output on world prices, the uncertainty of timing etc.) are too uncertain.

69-73	Interest	452	14.0	3.2	13.8
70-73	Interest and Dividend	720	23.0	3.5	20.5
71-72	-	722	23.0	4.1	22.9
72-73	Dividends	502	16.2	5.0	15.7
73-74	Dividends and other profits	1,122	36.0	5.6	35.7
74-75	Bank Interest	1,072	34.3	6.0	-
75-76			35.0	6.5	
76-77			35.0	7.4	
77-78			35.0	8.0	
78-79			35.0	8.3	
79-80			37.0	8.7	
					34.5

TABLE 23

PROJECTION OF INCOME AND EXPENDITURE FROM
ROSEIRES STAGE I DEVELOPMENT

Alternative I. 1,272,000 feddans of land made available over a 9 year period (average rate of 141,000 feddans per year)

Year	New Land	Available Area (Thousand Feddans)	Gross National Income (£S Million)	Imports (£S Million)	Capital Investment (£S Million)
65-66	-	-	3.6	1.3	3.2
66-67	Gezira etc.	70	7.2	2.0	7.6
67-68	Gezira etc. and Pump Schemes.	172	9.1	2.5	14.2
68-69	-	172	10.2	2.7	13.2
69-70	Rahad	462	14.8	3.2	13.2
70-71	Rahad and Guneid	722	23.8	3.8	8.4
71-72	-	722	27.0	4.4	12.6
72-73	Hawata	922	35.4	5.0	15.7
73-74	Hawata and other Right	1,122	40.5	5.6	6.7
74-75	Bank Scheme	1,272	46.1	6.2	-
75-76			48.5	6.8	
76-77			50.9	7.4	
77-78			53.0	8.0	
78-79			55.2	8.4	
79-80			57.3	8.7	
					94.8

TABLE 24

ROSEIRES STAGE I DEVELOPMENT

REPAYMENT PROGRAMME (£S MILLION)

Year	Gross National Income	Imports	CONDITIONS OF LOAN				
			(a) Whole of cap. borrowed at 6%	(b) Whole of cap. borrowed at 5½%	(c) Foreign cap. + 50% local borrowed at 6%	(d) Foreign cap. + 50% local borrowed at 5½%	(e) Foreign cap. + 50% local borrowed at 4½%
70-71	23.8	3.8	4.5	4.3	3.5	3.4	3.0
71-72	27.0	4.4	5.2	4.9	4.1	3.8	3.4
72-73	35.4	5.0	6.2	5.8	4.8	4.5	4.1
73-74	40.5	5.6	7.4	7.0	5.8	5.5	4.9
74-75	46.1	6.2	7.9	7.5	6.2	5.9	5.2
75-76	48.5	6.8	7.9	7.5	6.2	5.9	5.2
76-77	50.9	7.4	7.9	7.5	6.2	5.9	5.2
77-78	53.0	8.0	7.9	7.5	6.2	5.9	5.2
78-79	55.2	8.4	7.9	7.5	6.2	5.9	5.2
79-80	57.3	8.7	7.9	7.5	6.2	5.9	5.2

TABLE 25

PROJECTION OF INCOME AND EXPENDITURE FROM
ROSEIRES STAGE I DEVELOPMENT

Alternative II. 1,272,000 feddans of land made available over a 7 year period (average rate of 182,000 feddans per year)

Year	New Land	Available Area (Thousand Feddans)	Gross National Income (£S Million)	Imports (£S Million)	Capital Investment (£S Million)
65-66	-	-	3.6	1.3	3.2
66-67	Gezira etc.	70	7.2	2.0	7.6
67-68	Gezira etc. and Pump Schemes	172	9.1	2.5	14.2
68-69	-	172	10.2	2.7	16.8
69-70	Rahad	462	14.8	3.2	17.1
70-71	Rahad and Guneid	722	23.8	3.8	18.8
71-72	Hawata	1,022	34.2	4.5	17.1
72-73	Right Bank Scheme	1,272	45.0	5.2	
73-74			48.5	5.9	
74-75			50.9	6.6	
75-76			53.0	7.3	
76-77			55.2	8.0	
77-78			57.3	8.7	
					94.8

APPENDIX TO

MEMORANDUM ON UTILISATION OF WATER FROM ROSEIRES RESERVOIR

AGRICULTURAL RESEARCH

History.

A.1. The development of agricultural research in the Sudan in the twentieth century is described in a number of publications and a summary is available in the I.B.R.D. Report of the Technical Mission on Sudan Irrigation (Report T.D. 204, 1959). Provision for a widening of the scope of agricultural research under the Ten Year Plan of Economic and Social Development 1961-62 to 1971-72 has resulted in the establishment of additional research stations at Hudeiba, in Northern Province and at Abu Na'ama in the Blue Nile Province; also of two sub-research stations at Sennar and Maatug in the Managil Scheme - in the same province and a third at Khashm el Girba in Kassala Province, in connection with the Khashm el Girba Agricultural Project. In addition, new pilot project experimentation has been carried out in Kassala Province in connection with more mechanisation and better yields in the mechanised crop production schemes, the establishment of castor as a commercial crop in the Gash Flood Irrigation Project; and the possibilities of the production of kenaf in the Khashm el Girba Project; in Blue Nile Province in connection with the Guneid sugar project, and in Bahr el Ghazal Province in connection with the establishment of both rice and kenaf as commercial crops in the Aweil and Tonj areas.

Present findings.

A.2. In the Gezira, the most important development occurred at the end of 1963 with the establishment of the Working Party of the Agricultural Research Division, Wad Medani. The terms of reference are to study the merits of alternative cropping and stocking systems for existing and future

areas of production. The intensification of the Gezira Scheme was to be the immediate task as Roseires water would be available in the 1966-67 cropping season.

A.3. The Interim Report of the Working Party, of May 1965, states that a review of research results and market prospects indicates that the number of crops for which there is sufficient evidence to justify their serious consideration in the Gezira is relatively limited. Extra long staple (Egyptian) cotton, medium staple (American) cotton, dura, groundnuts and wheat are the main, commercially tested, cash crops with safflower as a possibility which has not yet been fully investigated. The fodder crops justifying consideration are lubia, phillipesara, Sudan grass and cowpea. Livestock alternatives are not considered in detail in the interim report because of lack of data.

A.4. Economic analysis shows clearly that with regard to its contribution to the national product, cotton is still the outstanding crop in the Gezira. Net revenue per irrigable feddan, the dominant factor in the choice of crops, is at least twice as high for cotton as for nearly all the alternative crops or crop sequences. The demand for the extra long staple cotton now grown is, however, highly elastic. Medium staple cotton for which there is a larger market offers an alternative, and even now appears to be somewhat more rewarding than extra long staple cotton.

Cropping patterns for the Gezira Scheme.

A.5. Limitations on having more than the existing 25% of the Gezira area under cotton are:-

The inflexibility of the present 8 course rotational pattern which could only be modified by a change in tenancy size,

The limited availability of pickers,
The general desire to reduce dependence on one crop.

In the case of medium staple cotton, labour shortages could be partly overcome by the introduction of mechanical picking of the crop, so that an increased cotton area in the Gezira is more feasible with medium staple cotton as the main cash crop.

A.6. After cotton, groundnuts is the crop likely to produce the highest net revenue per irrigable feddan and could be grown in place of dura. At this stage, however, the tenants are unlikely to agree to this change and this attitude, together with the need to grow some lubia, is likely to limit the area under groundnuts. An acceptable alternative to groundnuts is a combination of dura with wheat, the wheat using water released when the dura is harvested. This crop combination gives a net revenue per irrigable feddan that is not very much below that of groundnuts. Whilst the tenants insist on growing dura, therefore, wheat should be included in the rotation in order to obtain full season utilisation of the irrigation capacity. Wheat is justified in these circumstances even at yields of less than 0.5 tons per feddan, except in the Southern Gezira where dura yields tend to be particularly low and where wheat is a less certain crop. It is possible that safflower may provide a more profitable alternative to wheat when its production and marketing possibilities have been fully explored.

A.7. With the retention of the present dead season, the optimum cropping plan could be based on the rotation now adopted by the Sudan Gezira Board as follows:-

<u>Year</u>	<u>Crop</u>
1st	Cotton
2nd	Wheat
3rd	Fallow
4th	Cotton
5th	Groundnuts
6th	Dura
7th	Phillipesara or lubia (not irrigated)
8th	Fallow.

A.8. Consideration has been given to the elimination of the dead season with the objective of obtaining full season utilisation of the irrigation capacity. This would involve earlier sowing of groundnuts with the possibility of freeing water for a wheat crop after the groundnuts had been harvested. Another possibility is the replacement of unirrigated, July sown, phillipesara by an April sown, irrigated, phillipesara crop which would provide better hay and/or grazing and have greater beneficial effects on succeeding crops. Present results indicate that increased groundnut yields produce only a marginal return per unit of extra water required for early sowing. In the case of phillipesara it is considered that, until it can be shown that livestock returns will be very markedly improved by the better fodder supplies, the beneficial fertility effects of the April sown crop may be offset by the greater pest hazards to the cotton crop resulting from the loss of the dead season. The Working Party concludes, therefore, that the adoption of full season irrigation will depend eventually on the alternative uses available for Roseires water.

A.9. The Working Party considers that, at this time, it is unlikely that an overall improvement in fodder supplies would be economically justifiable taking into account the expected gain in livestock production in comparison with the real costs and opportunity costs in lost cash crop

production involved in such an improvement. There may, however, be scope for the encouragement of livestock production on specialist lines.

A.10. Vegetable gardens in most instances return a lower net revenue per irrigable feddan than do either groundnuts or dura and wheat in combination. A general extension of their area is, therefore, not justified on economic grounds. Evidence from Sudeira block in the Managil Scheme, however, indicates that in a favourable location returns much above the average are possible. The Working Party considers that in such areas the tenants should be given special opportunities to develop their garden areas.

Research and Experimental Activities.

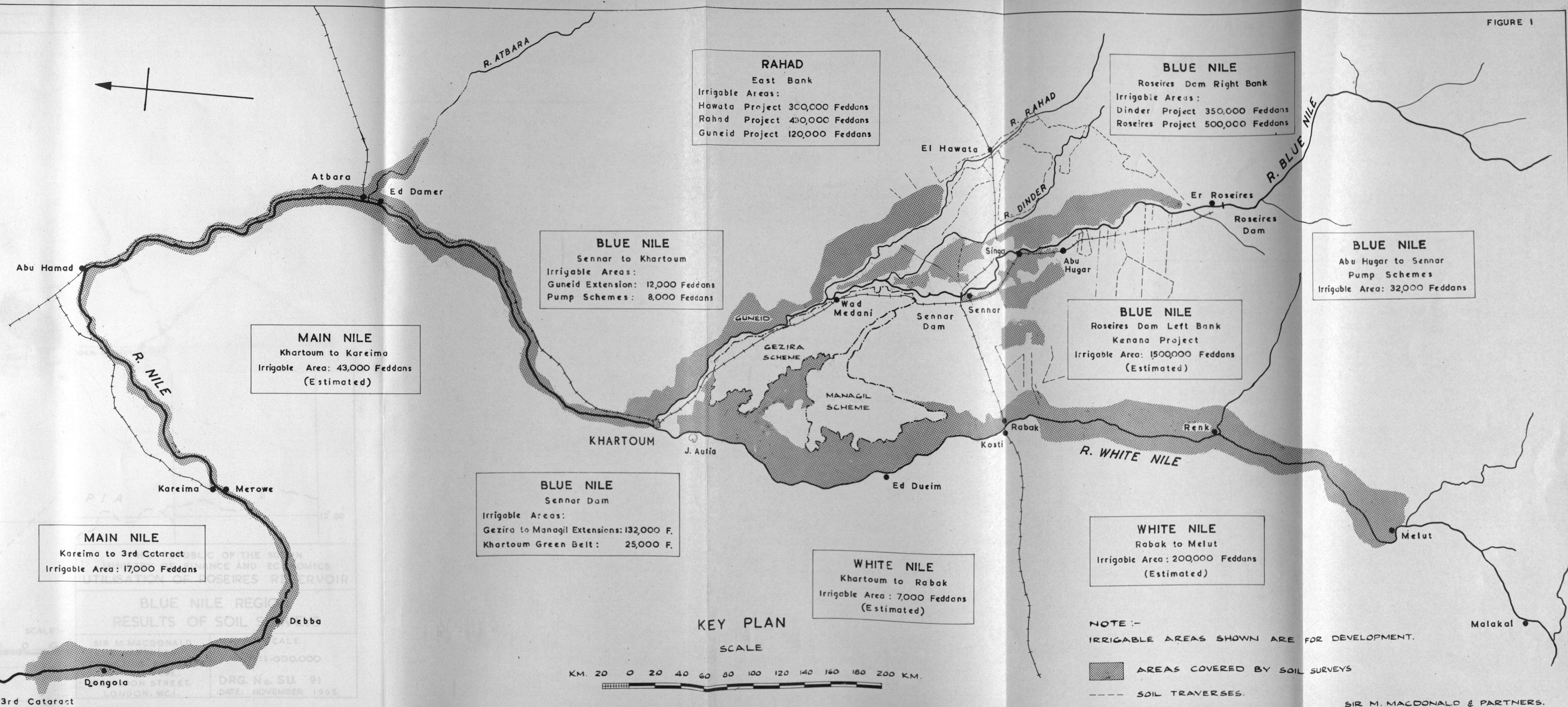
A.11. Considerable research into rotations and the intersections of crops has been undertaken at the Gezira Research Station over a period of many years, the results of which have been incorporated into the proposed rotation for the intensification of cropping. The sequence of cropping in a rotation is of considerable significance, for example the highest cotton yields were achieved when the fallow was preceded by lubia, a leguminous crop, rather than by two consecutive fallows; on the other hand dura preceding a fallow invariably reduced cotton yields. Unfortunately data on the effects of fertiliser in relation to cropping sequences is lacking and trials to determine the effects will not be concluded until 1966.

A.12. Groundnut trials and observations are being undertaken in the mechanisation of groundnut cultivation and subsequent decortication, the results of which are promising.

A.13. Mechanical picking trials on medium staple cotton varieties have been carried out and it is evident that while mechanical harvesting is possible, the economics of this system are not sufficiently attractive to justify a change from hand picking at the present time.

A.14. Agronomic trials over a range of crops have been carried out at the Gezira Research Station, the most important of which include:-

- (i) Safflower. Spacing and variety trials in which yields of 80 kg. per feddan have been achieved.
- (ii) Wheat. The testing of heat tolerant varieties and early sowing (there is a limit to early sowing due to conflicting water requirements for summer crops), with the aim of increasing the relatively low average yield under commercial conditions. Improved mechanical methods of sowing and harvesting have given encouraging results.
- (iii) Dura. Variety and fertiliser trials have given significant results.
- (iv) Soya Bean. Although variety trials have been discontinued on the ground that yields were below economic levels, there would appear to be a potential for this crop and further variety trials are contemplated.
- (v) A number of fodder crop trials have been undertaken with a view to meeting animal husbandry requirements under various conditions.



RAHAD
 East Bank
 Irrigable Areas:
 Hawata Project 300,000 Feddans
 Rahad Project 430,000 Feddans
 Guneid Project 120,000 Feddans

BLUE NILE
 Roseires Dam Right Bank
 Irrigable Areas:
 Dinder Project 350,000 Feddans
 Roseires Project 500,000 Feddans

BLUE NILE
 Sennar to Khartoum
 Irrigable Areas:
 Guneid Extension: 12,000 Feddans
 Pump Schemes: 8,000 Feddans

BLUE NILE
 Abu Hugar to Sennar
 Pump Schemes
 Irrigable Area: 32,000 Feddans

MAIN NILE
 Khartoum to Kareima
 Irrigable Area: 43,000 Feddans
 (Estimated)

BLUE NILE
 Roseires Dam Left Bank
 Kenana Project
 Irrigable Area: 150,000 Feddans
 (Estimated)

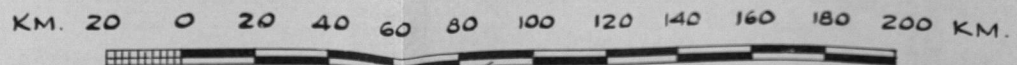
BLUE NILE
 Sennar Dam
 Irrigable Areas:
 Gezira to Managil Extensions: 132,000 F.
 Khartoum Green Belt: 25,000 F.

WHITE NILE
 Khartoum to Rabak
 Irrigable Area: 7,000 Feddans
 (Estimated)

MAIN NILE
 Kareima to 3rd Cataract
 Irrigable Area: 17,000 Feddans

WHITE NILE
 Rabak to Melut
 Irrigable Area: 200,000 Feddans
 (Estimated)

KEY PLAN
 SCALE



NOTE :-
 IRRIGABLE AREAS SHOWN ARE FOR DEVELOPMENT.

■ AREAS COVERED BY SOIL SURVEYS
 --- SOIL TRAVERSES.

TABLE 12
ROSEIRES STAGE I
AND SENNAR
BIENNIAL YEAR

BLUE NILE REGULATION
ROSEIRES STAGE I - FULL USE OF AVAILABLE STORAGE

TOTAL IRRIGABLE AREA 3,512,000 FEDDANS

All amounts in millions of cubic metres in stated period

Period	ROSEIRES - STAGE I							SENNAR							SENNAR-KHARTOUM	
	Natural Flow Median Year at Deim	Irrig. Reqts.	Evap. loss	Change in Contents	Contents at end of period	Level at end of period metres	Release down-stream	Inflow (2% loss) from Roseires	Irrig. Reqts.	Evap. loss	Change in Contents	Contents at end of period	Level at end of period metres	Release down-stream	Irrig. Reqts.	Min. Flow Down-stream Guneid
July 1-10	1045	82	3	-	638	467.0	960	941	186	4	-	330	417.2	751	25	50
11-20	1900	68	3	-			1829	1792	186	4	-			1602	22	50
21-31	3652	26	3	-			3623	3551	189	5	-			3357	21	55
Aug. 1-10	4600	12	2	-			4586	4494	247	3	-			4244	17	50
11-20	5240	12	2	-			5226	5121	241	3	-			4877	16	50
21-31	5999	13	2	-			5984	5862	269	3	-			5590	17	55
Sept. 1-10	4980	38	2	-			4940	4841	372	3	-			4466	20	50
11-20	4270	77	2	-			4191	4107	373	3	-			3731	21	50
21-30	3839	77	2	-	638	467.0	3760	3685	373	3	-	330	417.2	3309	21	50
Oct. 1-10	2876	115	5	+ 926	1574	473.7	1820	1784	355	6	+ 234	564	419.2	1189	22	50
11-20	2220	145	7	+ 716	2290	477.2	1352	1325	366	8	+ 179	743	420.45	772	22	50
21-31	1650	145	9	+ 440	2730	478.95	1056	1035	361	9	+ 110	853	421.2	555	26	55
Nov. 1-10	1110	131	15	+ 240	2970	479.8	724	710	312	12	+ 60	913	421.6	326	20	50
11-20	822	137	16	+ 54	3024	480.0	615	603	313	12	+ 17	930	421.7	261	19	50
21-30	734	137	16	-	3024	480.0	581	569	307	12	-	930	421.7	250	18	50
Dec. 1-10	553	133	19	-	3024	480.0	401	393	281	11	-	930	421.7	101	17	50
11-20	452	129	19	- 49	2975	479.8	353	346	281	11	- 12	918	421.6	66	16	50
21-31	394	138	20	- 118	2857	479.4	354	347	295	12	- 30	888	421.4	70	15	55
Jan. 1-10	299	121	18	- 160	2697	478.8	320	314	277	12	- 40	848	421.15	65	15	50
11-20	251	118	17	- 190	2507	478.1	306	300	271	12	- 47	801	420.85	64	14	50
21-31	233	77	18	- 192	2315	477.3	330	323	289	13	- 48	753	420.5	69	14	55
Feb. 1-10	183	32	17	- 146	2169	476.6	280	274	232	14	- 36	717	420.25	64	14	50
11-20	164	27	17	- 157	2012	475.95	277	271	232	14	- 39	678	420.0	64	14	50
21-28	114	23	13	- 133	1879	475.3	211	207	179	11	- 34	644	419.75	51	11	40
Mar. 1-10	123	27	17	- 77	1802	474.9	156	153	36	15	- 35	609	419.5	137	12	50
11-20	106	34	16	- 108	1694	474.35	164	161	36	15	- 35	574	419.25	145	13	50
21-31	111	61	17	- 139	1555	473.6	172	169	42	16	- 35	539	419.0	146	15	55
Apr. 1-10	92	56	14	- 157	1398	472.7	179	175	73	14	- 35	504	418.7	123	10	50
11-20	81	54	13	- 172	1226	471.6	186	182	73	13	- 35	469	418.4	121	9	50
21-31	89	65	12	- 181	1045	470.4	193	189	72	12	- 35	434	418.15	140	9	50
May 1-10	112	116	11	- 205	840	468.8	190	186	72	10	- 35	399	417.85	139	9	50
11-20	165	99	8	- 139	701	467.6	197	192	72	10	- 35	364	417.5	146	10	50
21-31	243	87	8	- 63	638	467.0	211	207	74	10	- 34	330	417.2	157	11	55
June 1-10	318	74	6	-	638	467.0	238	233	73	8	-	330	417.2	152	11	50
11-20	510	112	5	-	638	467.0	393	385	73	7	-	330	417.2	305	10	50
21-30	695	112	5	-	638	467.0	578	566	72	7	-	330	417.2	487	9	50
Totals	50,225	2910	379				46,936	45,994	7555	337				38102	565	

CHAPTER VI - UTILISATION OF ROSEIRES WATER ON COMPLETION
OF STAGE II.

Heightening of dam.

90. The present plans for irrigation development on the Blue Nile with the rotations now proposed could be met by raising the top storage level of the Stage I dam by 9.1 metres instead of the 10 metres proposed. Since such a limitation would restrict freedom to vary rotations if further intensification were found to be possible, or if new crops were found to be economically desirable, or if new irrigation areas were found on the Blue Nile, we have analysed the conditions which will apply if the full storage of Roseires Stage II were utilised on the rotations now envisaged.

Areas.

91. For this purpose we have added a residual area of 515,000 feddans, watered as proposed for the Kenana area, to the known areas which are to be irrigated directly from the Roseires reservoir. This addition, and the water requirements from the Blue Nile of all areas are shown on Table 13. In addition, 772 million cubic metres of water are supplied from the River Rahad as before. As indicated in Chapter III, Paragraph 40, these conditions would require a water allocation greater than the share at present available to the Sudan when the High Aswan Dam is in operation, unless further capital works to increase the natural discharge of the Nile system are implemented.

Reservoir operation.

92. Assuming that the Sudan must rely on its own resources for regulation of the river for irrigation purposes for many years to come, Table 13 indicates the irrigation requirements for 6.127 million feddans of land which the full resources of Roseires Stage II and Sennar can support, again with full watering in four years out of five.

93. The provisional method of operation is set out in Table 14 for the 80% year. This indicates that the reservoir can be fully filled in such a year, although filling must start earlier and at a faster rate than is required for Stage I. The period of shortage also starts earlier, the entire pattern of operation from November 1st to June 20th being determined by irrigation demands and the requirements of a minimum flow of 5 million cubic metres per day in the river below Guneid.

94. Of the total flow at Deim (40.11 milliiards in the 80% year) 19.40 milliiards are used for irrigation, 1.02 milliiards are lost by evaporation from both reservoirs and 19.12 milliiards are passed onwards below Guneid. The difference of 0.57 milliiards represents natural transmission losses in the reach. Evaporation losses from Roseires increase by 0.33 milliiards when the reservoir is raised by 10 metres from Stage I levels to Stage II.

95. For years in which the flow is less than that of the 80% year, it would be necessary to apply restrictions which became more severe as the deficiency increased and, in some exceptional years, it might not be possible to fill the reservoirs completely. Detailed study of some individual years is necessary before the full implications of extreme conditions can be assessed, with particular reference to the method of filling the reservoirs and the best manner for restricting irrigation demands when it should prove necessary.

96. The provisional method of operating in a median year is set out in Table 15 where the surplus storage available in such a year has been utilised for the improvement of energy output from March to June. In such a year 28.98 milliiards are passed onwards below Guneid out of a total of 50.25 milliiards passing at Deim. Evaporation losses for the two reservoirs are 1.08 milliiards.

Power.

97. With these provisional methods of operation, the power and energy outputs with seven sets installed are shown in Fig. 8 for a median and an 80% year. The general pattern is similar to that of Stage I, but there are a number of differences of significance.
98. Earlier filling of the reservoirs means that the period of restriction of power output caused by the annual flood is reduced by a month. Shortage of energy due to insufficient water passing the dam to develop continuously the full potential output of 7 sets increases with the increase of upstream abstractions but, in the critical period from March to June, the energy available is increased from 29 MW. to 34 MW. at Roseires in an 80% year, and from 48 MW. to 70 MW. in a median year. The period when full peak power is available, even though there is a deficiency of water, increases due to the wider range of levels in the reservoir.
99. Conditions at Sennar change slightly, the period of deficiency of peak power reducing since the reservoir is filled earlier and the period of shortage of energy increases because of increased abstractions upstream.
100. For comparison with Stage I, the energy output to Roseires Power Station with 7 sets installed increases by 139 million units to 1,100 million in a median year and by 99 million units to 1,005 million units in an 80% year.
101. These figures are subject to refinement when the operation of Roseires Stage II can be studied more closely with more certain knowledge of future intentions regarding the location of residual areas allowed at present in the calculations, but generally it can be said that raising Roseires from Stage I to Stage II will produce a potential increase in energy output of about 10%.

BLUE NILE REGULATION

TABLE 13

FORECAST OF WATER REQUIREMENTS FOR FULL USE OF ROSEIRES STAGE II
TOTAL IRRIGABLE AREA 6,127,000 FEDDANS

	Gross Irrigable Area Feddans (1,000)	Water Demand - million m ³												
		July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
<u>Taking water from Downstream Sennar</u>														
Guneid (Sugar)	44	37	27	35	36	25	22	21	20	24	28	30	30	335
Pumps (Existing)	62	28	20	24	31	29	23	19	16	13	-	-	-	203
Pumps (Extensions)	8	3	3	3	3	3	3	3	3	3	-	-	-	27
Total	114	68	50	62	70	57	48	43	39	40	28	30	30	565
<u>Taking water from Roseires - Sennar</u>														
Existing Gezira (Intensified) inc. Abdel Magid	982	198	295	477	462	416	393	393	276	16	117	117	117	3277
Existing Managil	838	177	300	438	383	297	279	279	233	9	71	71	71	2608
Gezira Extensions	97	19	29	47	45	41	39	39	27	3	12	12	12	325
Managil Extensions	35	7	13	18	16	12	12	12	10	3	3	3	3	112
Green belt (Forest and fodder)	25	15	15	15	15	15	15	15	14	15	15	15	15	179
Pumps (Existing)	289	131	94	111	145	136	107	89	75	61	-	-	-	949
Pumps (Extensions)	32	14	11	12	16	15	12	10	8	7	-	-	-	105
Total	2298	561	757	1118	1082	932	857	837	643	114	218	218	218	7555
<u>Taking water from Upstream Roseires</u>														
Rahad - Hawata - Guneid	850	133	*	157	313	309	308	257	73	74	90	237	244	2195
Roseires (Right Bank)	500	84	75	71	183	193	183	118	21	99	172	128	106	1433
Dinder	350	59	53	49	126	136	128	83	14	70	120	89	76	1003
Kenana	1,500	297	329	671	748	582	544	406	105	187	277	407	395	4948
Residual Area	515	102	113	230	257	200	187	139	36	64	96	140	135	1699
Total	3,715	675	570	1178	1627	1420	1350	1003	249	494	755	1001	956	11278
GRAND TOTAL	6,127													** 19398

* Rahad-Hawata-Guneid is supplemented from River Rahad in July-November inclusive.

** Excluding the residual area the total water demand is approximately 17.7 milliards.

TABLE 14

ROSEIRES STAGE II
AND SENNAR
80% YEAR

BLUE NILE REGULATION

ROSEIRES STAGE II - FULL USE OF AVAILABLE STORAGE

TOTAL IRRIGABLE AREA 6,127,000 FEDDANS

All amounts in millions of cubic metres in stated period

Period	ROSEIRES - STAGE II							SENNAR							SENNAR-KHARTOUM		
	Natural Flow 80% Year at Deim.	Irrig. Reqs.	Evap. loss	Change in Contents	Contents at end of period	Level at end of period metres	Release down- stream	Inflow (2% loss) from Roseires	Irrig. Reqs.	Evap. loss	Change in Contents	Contents at end of period	Level at end of period metres	Release down- stream	Irrig. Reqs.	Min. Flow Down- stream Guneid	
July 1-10	811	265	3	-	638	467.0	543	532	186	4	-	330	417.2	342	25	50	}
11-20	1410	219	3	-			1188	1164	186	4	-			974	22	50	
21-31	2760	191	3	-			2566	2515	189	5	-			2321	21	55	
Aug. 1-10	3983	171	2	-			3810	3734	247	3	-			3484	17	50	} Surplus water
11-20	4380	181	2	-			4197	4113	241	3	-			3869	16	50	
21-31	4950	218	2	-	638	467.0	4730	4635	269	3	-			4363	17	55	
Sept. 1-10	3933	304	5	+ 2360	2998	479.9	1264	1239	372	3	-			864	20	50*	} Roseires filling starts
11-20	3440	405	9	+ 1930	4928	485.1	1096	1074	373	3	-			698	21	50	
21-30	3176	469	12	+ 1680	6608	488.35	1015	995	373	4	-	330	417.2	618	21	50	
Oct. 1-10	2260	544	20	+ 600	7208	489.4	1096	1074	355	7	+ 365	695	420.1	347	22	50*	} Sennar filling starts
11-20	1570	550	21	+ 315	7523	489.9	684	670	366	8	+ 193	888	421.4	103	22	50	
21-31	1144	533	23	+ 65	7588	490.0	523	513	361	9	+ 42	930	421.7	101	26	55*	
Nov. 1-10	891	471	35	- 17	7571	490.0	402	394	312	12	-	930	421.7	70	20	50	} withdrawals approximately 90% Roseires & Sennar
11-20	693	478	35	- 202	7369	489.65	382	374	313	12	- 20	910	421.6	69	19	50	
21-30	540	471	33	- 323	7046	489.1	359	352	307	12	- 35	875	421.35	68	18	50	
Dec. 1-10	442	452	37	- 378	6668	488.5	331	324	281	11	- 35	840	421.1	67	17	50	}
11-20	363	433	36	- 436	6232	487.7	330	323	281	11	- 35	805	420.85	66	16	50	
21-31	320	465	37	- 521	5711	486.7	339	332	295	12	- 45	760	420.55	70	15	55	
Jan. 1-10	257	403	34	- 495	5216	485.7	315	309	277	12	- 45	715	420.25	65	15	50	}
11-20	213	376	32	- 503	4713	484.6	308	302	271	12	- 45	670	419.95	64	14	50	
21-31	199	224	32	- 399	4314	483.7	342	335	289	12	- 35	635	419.7	69	14	55	
Feb. 1-10	157	97	30	- 260	4054	483.05	290	284	232	13	- 25	610	419.5	64	14	50	}
11-20	131	83	29	- 271	3783	482.3	290	284	232	13	- 25	585	419.3	64	14	50	
21-28	91	69	22	- 225	3558	481.7	225	220	179	10	- 20	565	419.2	51	11	40	
Mar. 1-10	105	83	28	- 110	3448	481.35	104	102	36	14	- 10	555	419.1	62	12	50	}
11-20	86	127	27	- 168	3280	480.85	100	98	36	14	- 15	540	419.0	63	13	50	
21-31	89	284	27	- 320	2960	479.8	98	96	42	14	- 30	510	418.8	70	15	55	
Apr. 1-10	73	258	22	- 325	2635	478.6	118	116	73	13	- 30	480	418.5	60	10	50	}
11-20	71	246	20	- 317	2318	477.3	122	120	73	13	- 25	455	418.3	59	9	50	
21-30	70	251	18	- 319	1999	475.9	120	118	72	12	- 25	430	418.1	59	9	50	
May. 1-10	69	384	14	- 447	1552	473.6	118	116	72	10	- 25	405	417.9	59	9	50	}
11-20	99	327	12	- 359	1193	471.4	119	117	72	10	- 25	380	417.7	60	10	50	
21-31	167	290	11	- 262	931	469.5	128	125	74	10	- 25	355	417.45	66	11	55	
June 1-10	245	254	6	- 145	786	468.35	130	127	73	8	- 15	340	417.3	61	11	50	} Surplus water
11-20	369	352	6	- 148	638	467.0	159	156	73	7	- 10	330	417.2	86	10	50	
21-30	551	350	5	-	638	467.0	196	192	72	7	-	-	417.2	113	9	50	
Totals	40108	11278	693				28137	27574	7555	330				19689	565		