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LAND AND WATER USE SURVEY IN KORDOFAN PROVINCE

THE SUDAN

FINAL REPORT

UNITED NATIONS DEVELOPMENT PROGRAM
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome 1967

INDEX

TO

FINAL REPORT

INDEX OF FIGURES

INDEX OF PLATES

INDEX OF TABLES

CHAPTER 1

INTRODUCTORY

LOCATION

1. The location of the Kordofan Land and Water Use Survey of the United Nations Special Fund is shown in Fig. 1. It occupies a section of the great belt of savannah country which stretches right across Africa from ocean to ocean.

2. The area covered by the photo-survey is 66,000 square kilometres. The rainfall varies from 250 mm. or less in the north of the Project Area to 600 mm. or more in the south. The town of El Obeid, population 65,000, is at the middle of the Project Area, with a rainfall of about 400 mm., roughly the average within the area. See Fig. 2.

ORIGINS OF THE PROJECT

3. A steep rise in population started earlier in the century, as soon as rail and motor transport opened up the country and brought in the health and educational services. According to the 1956 census, about 70% of the population in the Project Area at that time consisted of farmers and farm labourers. Fig. 3 shows a projection of population increase for the Sudan up to 1996, based on the 1956 census.

4. The result was that parts of the area were progressively over-cultivated and over-grazed, especially where the availability of water, or proximity to markets and communications, caused a concentration.

5. But although these symptoms could be seen and recognised, policies and plans for dealing with the dangers and for developing the potentialities required knowledge which was not available and could only be gained by systematic surveys and investigations.

6. In the autumn of 1961 an agreement for the Kordofan Land and Water Use Survey was signed between the United Nations Special Fund, the Food and Agriculture Organisation (as Executing Agency) and the Government of the Republic of the Sudan. The Government nominated the Department of Land Use and Rural Water Development as the Co-operating Agency, and the Department appointed the Co-Manager for the Project. Following Special Fund procedures the Agreement embodied a Plan of Operation specifying the scope of the Survey, together with a budget of man-power, equipment and finance, to be contributed from the sides of the United Nations and the Sudan Government. The Plan of Operation is reproduced in full, in Appendix 1.

7. In December, 1961, the Food and Agriculture Organisation signed a contract with Doxiadis Associates, who were thereby made responsible for providing the Project Manager, Deputy Project Manager, experts and headquarters services at their main office in Athens and their affiliated office in London, Doxiadis Ionides Associates, Ltd. Co-operation with Hunting Technical Services, Ltd., of the United Kingdom was also provided for.

8. The main organisational elements are illustrated in the chart in Fig. 4.

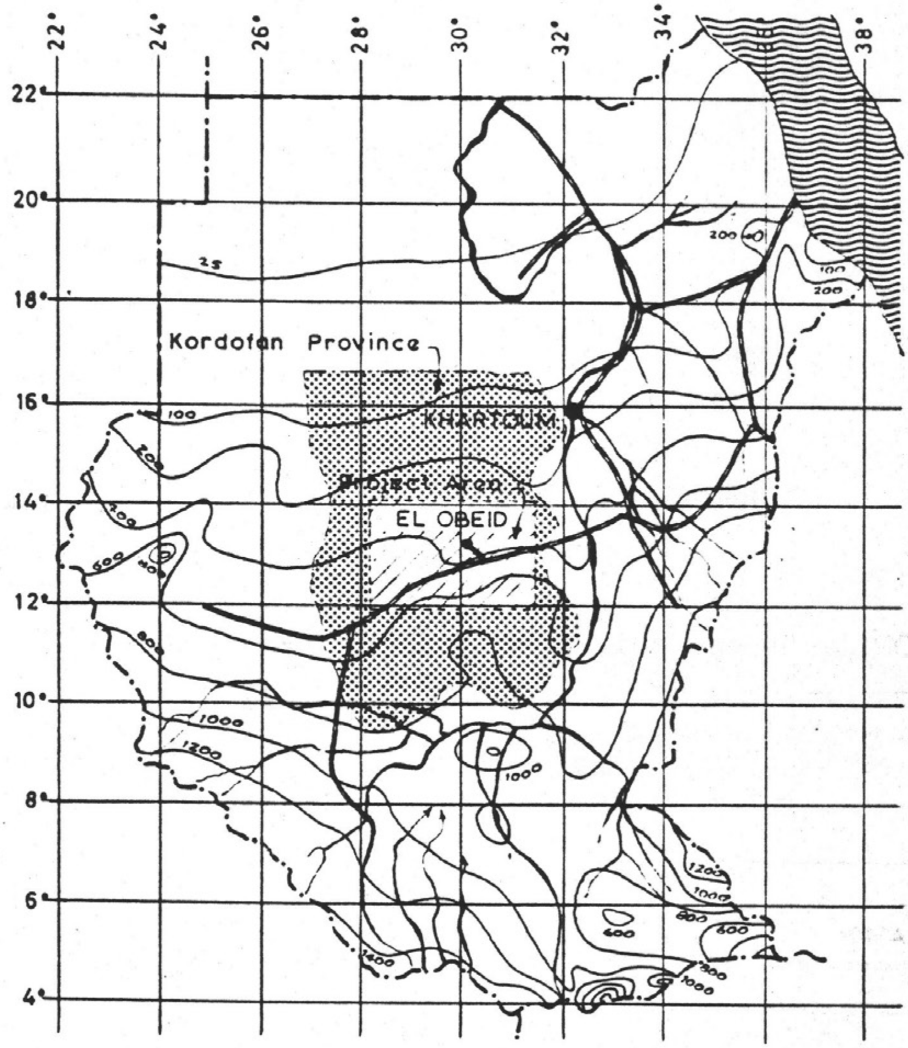
ORGANISATION AND PLANNING OF OPERATIONS

9. Although the work of the survey came to a clear functional focus in the Department of Land Use and Rural Water Development, other Departments were vitally interested. In alphabetical order these are as follows: Agriculture, Animal Resources, Forests, Geology, and Surveys. These Departments were brought into consultation when preparations for operational field work were started by the Project Manager, Co-Manager and Deputy Project Manager in January, 1962.

10. A general Work Plan was drafted in January/February, 1962. It was circulated to all the interested Departments, and discussed by them at an Inter-Departmental meeting in February 1962. Thereafter

THE PROJECT AREA WITHIN THE SUDAN

Fig 2



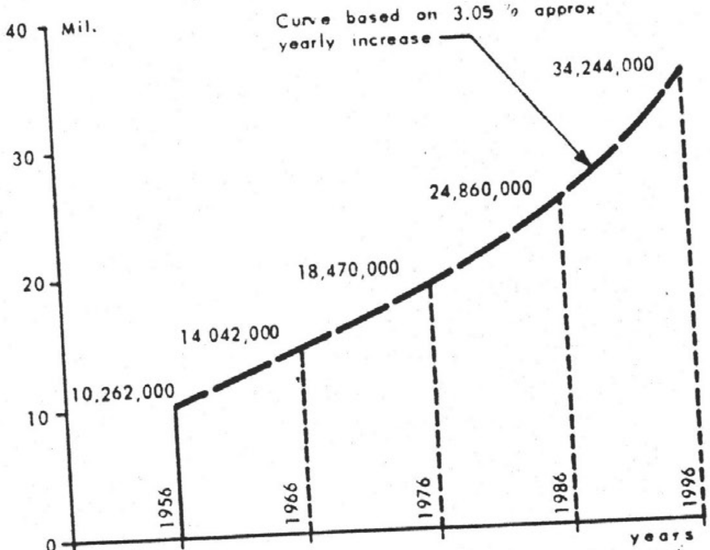
—100— Isohyet in mm. (1921 - 1950)
From Topo N°912-54 of Survey Dept.

0 100 300 500 Km.

The Project Area is in the middle of the Sudan, west of the Nile, and in the middle of Kordofan Province. From south to north it runs from Lat 12° N. to 14° N. Rainfall varies from 600 m. in the south of the Project Area to under 300mm in the north.

Fig. 3

POPULATION GROWTH IN THE SUDAN

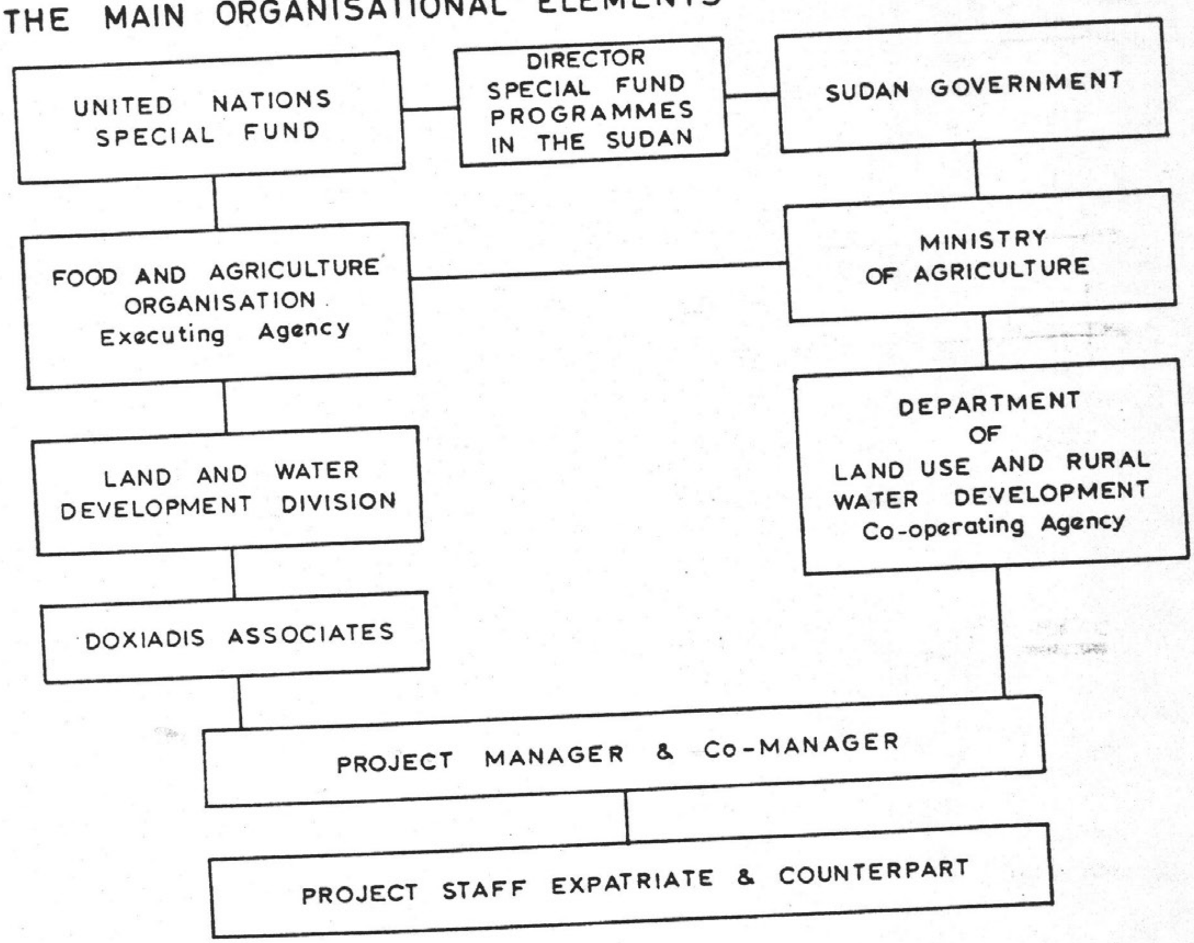


(From Prof Van den Boomen's " The population of the Sudan".)

The population in the Sudan is increasing rapidly This is an estimated projection based on the 1956 census.

Fig. 4

THE MAIN ORGANISATIONAL ELEMENTS



the General Work Plan was submitted, as laid down, to the Supervising Officer in FAO in Rome. The same procedure was followed at each annual stage of forward planning. The Project Reports were issued to all concerned. The Project Office in El Obeid was opened, as planned, at the beginning of April, 1962, and field operations were started at once.

11. Inter-departmental planning conferences were held in December, 1962, 1963 and 1964. At each of them the detailed draft Work Plan for the suceeding year was discussed, the draft having been previously circulated.

12. In May, 1964, midway through the Project, a four-day Inter-departmental Conference was held in El Obeid. (See Plates 1 and 2)

13. The final inter-departmental conference was held in Khartoum on March 7th, 1966. This was to discuss the chief findings of the Project and to consider the Work Plan for 1966, i. e. the first year of the follow-up after the completion of the Project itself.

14. Field operations were completed before the end of 1965 and the remaining months were occupied in completing reports, winding up and handing over.

PERSONNEL

15. In Appendix II there is a complete list of all the professional and administrative personnel who served on the staff as Experts, Counterparts or individual Consultants. Dates of service or visit are also given, and the profession of the person concerned.

16. At all stages of the Project and in all sections of the programme the work was organised so that the Special Fund personnel and their Sudanese counterparts worked together as a team. Of necessity, this team constituted an administrative and technical unit, and of necessity (i. e. through the terms of the Plan of Operation) the Project Manager's direct responsibility was to FAO Headquarters in Rome.

17. From the beginning, however, account was taken of the fact that when the Project was completed the follow-up would be taken over by the Department of Land Use, through the nominated Co-Manager.

18. The switch was in two stages. At the end of January, 1966, the Project Manager the Deputy Project Manager and the Agronomist moved to Europe so as to be in day-to-day contact with Doxiadis Associates Headquarters Drawing Office and all its facilities for rapid working, while the final reporting work was done. The Co-Manager assumed charge in El Obeid Project Office, acting on the Project Manager's behalf.

19. The final handing-over was at the end of April, 1966, when the Co-Manager, Seyid Abbas Abdul Magid, took charge of the Project Office with responsibility to the Director of Land Use and Rural Water Development, Seyid Abdul Rahim Bayoumi.

ACKNOWLEDGEMENTS

20. The Project Manager and his colleagues are much indebted to all the official staff of the Sudan Government, whose active co-operation was so important to the success of the Project. The closest day-to-day links were through the Department of Land Use and Rural Water Development. Special thanks are due to the staff of the Department and in particular to the Director, Seyid Abdul Rahim Bayoumi, and the Co-Manager of the Project, Seyid Abbas Abdul Magid.

CHAPTER 2

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

SUMMARY OF CONCLUSIONS

INTRODUCTION

21. Rising population has led to pressures on the land and on the drinking water supplies. At the same time there is much land which is "empty", where the soil and the rainfall are suitable for agriculture, but where there is no water to drink in the long dry season. The map in Fig. 5 shows these "empty" areas, in relation to the "inhabited" areas. All the cultivation and all the villages are within the envelope of the inhabited areas shown shaded; there is no cultivation and no grazing in the "empty" areas.

22. The result is that pressures on the land resources are uneven. At one extreme there are places where the land is overcultivated or overgrazed. At the other extreme there are places which are empty. This uneven distribution of the load means low productivity, at both ends of the scale; at one end because of exhaustive usage of the soil, and at the other end because of no use at all.

23. The fundamental objective for development is to spread the load over the land resources as a whole, and also to raise productivity in all places and in all aspects of land use. This means opening up the empty lands and making full use of them according to their capabilities, and at the same time up-grading all the existing land uses.

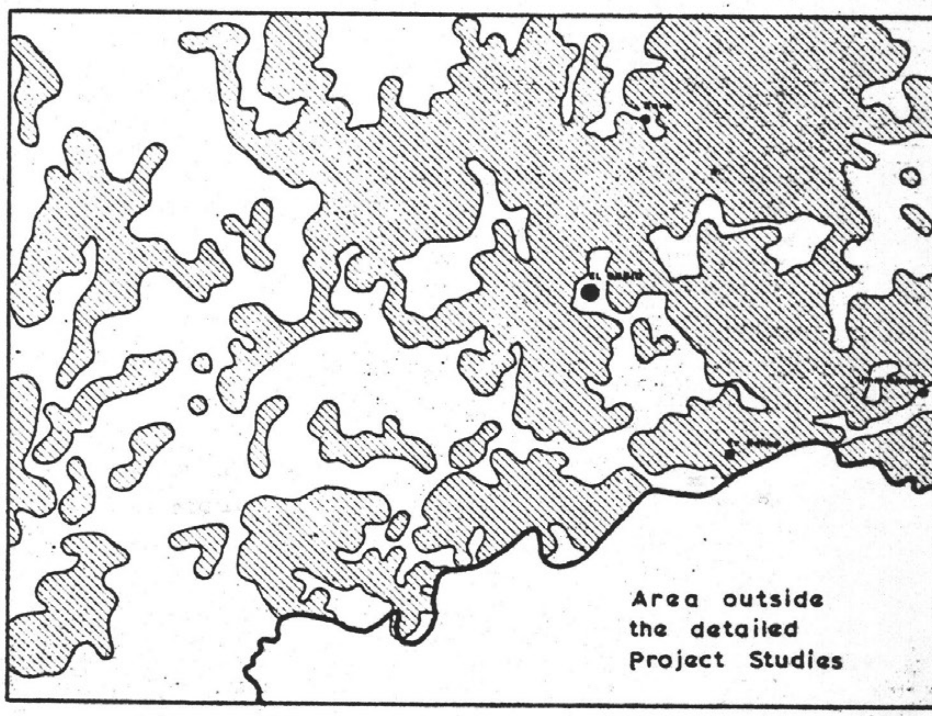
24. The first part of this chapter summarises the diagnosis of present conditions and the conclusions reached about policies and plans. The second part - Summary of Recommendations - is a classified list of items for action, with abstracts of estimates.

DRINKING WATER SUPPLY IS THE DECISIVE FACTOR

25. The drinking water problem stands as a barrier in the way of this objective on two counts. First, there are the stretches of empty land where there is no reasonable hope of providing water at acceptable cost by any of the customary methods, i. e. dug wells, or boreholes, or hafirs

THE INHABITED AREAS

Fig. 5



The lines which enclose the « Inhabited Areas » are drawn so that all the cultivated land and all the villages are inside; and conversely, the remaining areas contain no cultivation and no villages.

<u>Gross Area</u>
under Project Studies .... 55,600 Km²

<u>Inhabited Area</u>
(hatched) .... 32,450 "

<u>Empty Areas</u>
i.e. outside inhabited area
and ungrazed (virtually) .... 16,000 "

<u>Rainy Season Grazing Areas</u>
(nomadic cattle from the south) .... 7,150 "

(large excavated reservoirs filled seasonally from transient streams) or small dams, or by pipeline from major sources. Most of the empty areas, as shown in Fig. 5 suffer from this problem.

26. Second, a big proportion of the people rely, in the dry season, on water transported from sources which are five, ten, fifteen or more kilometres distant. Water is carried either by animal or by lorry. The cost is excessive, either in cash for lorry transport, or in effort by man and animal. So long as peasants have to carry this heavy burden there is very little hope of any really substantial agricultural improvement. A real impact on up-grading of existing peasant farming can only be made if the heavy cost of fetching and carrying water can be saved, and if that saving can be converted into productive uses. Drinking water sources are needed at each village so that the wasteful cost of transport can be avoided.

27. Thus, the drinking water problem stands in the way of opening up the empty areas and also of up-grading existing land uses.

SOLUTION TO THE DRINKING WATER PROBLEM

28. However, there is one solution which is technically possible anywhere in the empty areas, and that is to catch the rainfall and store it on the spot. Wherever drinking water is needed there is agriculture; wherever there is agriculture there is rain; wherever there is rain, it can be collected on small artificial catchment aprons (just as it can be caught on the roof of a house) and then put into storage tanks to be kept till it is needed in the dry season.

29. It was a prime objective of the Project to find a practical solution on these lines at acceptable cost. The result was the "catchment tank", for which type-designs have been developed for units varying from forty or fifty thousand gallons down to a "family" unit of one or two thousand gallons. These type-designs were developed to suit the particular circumstances of the Project Area and are not necessarily suitable for other areas.

COMPREHENSIVE LAND USE PLANNING IS NOW POSSIBLE

30. With this solution made available, comprehensive planning of the land use can now proceed without necessarily having to wait for the question of water availability in any particular place to be answered.

When the land use planners have decided where they want to provide water, on the basis of best land use, it then becomes a matter for the engineers to decide on the best method of supply. Naturally, when the planners are making their choice they will take into account all the information already available about the various potential sources of water. The essential point is, however, that if considerations of best land use point to the choice of an area for development where the hydrology is unknown or uncertain, the planners need not wait for hydrological investigations to be made before they commit themselves to planning decisions, because they know that catchment tanks can always provide whatever water they need, if none of the other methods are practicable or preferable.

LAND USE ZONES FOR PLANNING

31. Fig. 6 shows a grid of "Land Use Zones" which serves as a frame of reference for planning purposes. The Zones are distinguished by their different geomorphic characteristics.

32. Zones A_1 to A_6 are thick sand sheets and dunes deposited by the wind in a past geological age. The <u>acacia senegal</u>, which produces the valuable gum arable cash crop, thrives naturally in these zones. The soil is very permeable and there is virtually no run-off and no surface drainage streams, because the rainwater soaks straight in. The total area of these Zones is 28 700 sq. kilometres out of which 20, 300 are inhabited and 8, 400 are empty (on the definitions given above).

33. Zone B is also sandy, permeable and with no surface drainage streams but for some reason which has not yet been diagnosed, the <u>acacia senegal</u> does not grow naturally. The total area of Zone B is 8, 250 sq. km. out of which 2, 450 are inhabited and 5, 800 are empty.

34. The soil in Zones A and B is sandy, light and easy to cultivate with the hand-powered tools which the local farmers use. Zone C_1 and C_2 soil is quite different. Predominantly the soil is clayey, red non-cracking. This is too hard for cultivation by hand-power. Within the envelope of Zone C_1 and C_2 cultivation is confined to pockets of sandy soil superimposed on the underlying clayey layer. This clayey soil is more fertile than the sandy soils, however. It carries good pasture and Zone C comprises the main grazing-grounds for the big semi-nomadic and nomadic herds of livestock, chiefly cattle.

35. Since the Zone C soil is relatively hard and impervious, surface run-off is generated in the rainy season, giving rise to two major surface drainage systems. One of these drainage basins is Zone C, draining eastwards and the other is Zone C_2, draining south-westwards.

36. The actual uses and the potentialities of the sandy soils of Zones A and B, are quite different from these of Zone C. Locally, the sandy soils are known as "goz" and the hard, clayey soils as "gardud".

DEVELOPMENT IN THE GOZ COUNTRY

Basic Policy

37. Development policy for the goz country is concerned with two main streams of action; opening up and settling the empty lands, and up-grading standards in the existing farming settlements.

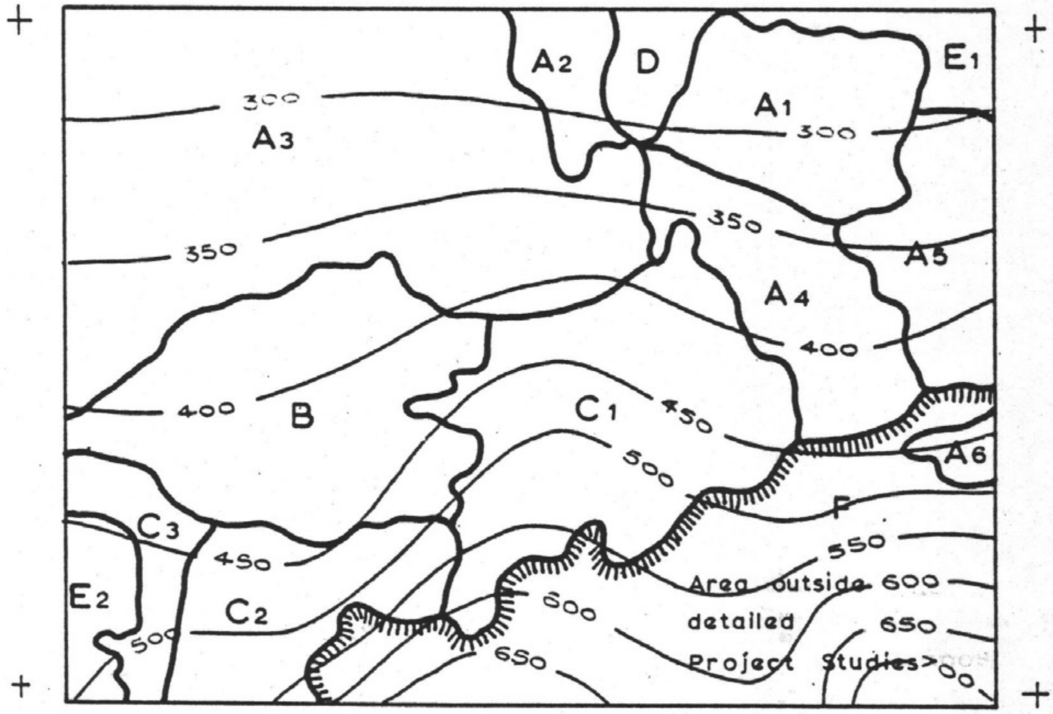
38. It is proposed that the settlement of the empty lands should be done by establishing new peasant farming communities which will be, essentially, an evolutionary improvement of the existing settlements. That is to say, the improvements proposed can be absorbed, progressively, without any sudden or radical changes in the socio-economic system. The pattern for establishing the new settlements in the empty lands also provides a model or target for up-grading standards in the existing settlements.

39. So far as concerns the technical use of the land, basic policy is to promote, maintain and continuously improve the mixed system of land use i. e. field crops; gum and forestry; pastures and livestock; horticulture under micro-irrigation with soil-moisture conservation techniques. These four uses are mutually reinforcing, socio-economically and from the point of view of soil fertility and moisture in the two strata of soil i. e. the shallow stratum for the field crops and annual pastures, and the deep sub-stratum for the trees.

40. Animal husbandry in the sandy goz areas should be limited to the numbers and types of animal which fit most fruitfully into the individual mixed farming system described above. The animals should be supported entirely on grazing within the farm lands and the communal village grazing lands, throughout the year, without seasonal migration elsewhere in search of either grazing or water. That is, numbers should be determined by the carrying capacity of the pastures which are within day-to-day reach of the village base.

LAND USE ZONES

Fig. 6



<u>Zone A</u>: The main gum-belt. "Goz" soils are deep sandy, deposited by wind, and stabilised by vegetation. Cultivation plus gum culture.

<u>Zones A1 and A2 and A6</u>: Plentiful village wells. Dense cultivation, mainly cash - cropping.

<u>Zone B</u>: Sandy, but different from Zone A1, being formed in situ over Nubian Sand stone. Cultivation mainly in serpentine depressions which are remains of old river system. Gum acacia does not grow in the sandy soil of Zone B.

<u>Zone C</u>: Hard, red, non-cracking clay: "clayey pediplain", locally "Gardud". Pockets of sandy soil are cultivated by peasants. The gardud is too hard. Good grazing and good rain - pools of water in the rainy season hence the cattle nomads from the south gather in Zone C.

<u>Zone D</u>: The "Kheiran" Unstable dunes. Pockets of cultivation in inter- dune hallows and sometimes wells.

The soil in Zones A and B is so sandy that the rainfall soaks straight in and so there is no run- off. In Zone C the soil is hard and relatively impermeable, except for sandy inter - fluvial pockets. So run - off is generated when it rains. C1 is part of the East - ward - flowing drainage basin dominated by Khor Abu Habl . C2 is part of the Wadi Ghala basin, flowing south eastwards.

—500— Isohyets

Model Villages and Farms

41. In order to provide a pattern for creating new settlements in the empty areas, and also to provide a target for up-grading, models for new villages and farms have been worked out.

42. The model consists of a group of nine villages of 100 family farm units each, totalling 900 families, which is a big enough community to support central establishments for administrative, community and social services.

43. The individual farm has a gross area of 80 acres, planned according to the policy given above, with a leasehold tenure. Since the need arises from pressure on the land there will be no shortage of applicants for farm holdings.

44. The work involved in creating these new settlements comprises water supply for drinking by man and beast, and for small scale hand-watering of the household vegetable plot (micro-irrigation); fencing round the perimeter of each village's territory; planting of gum acacia to establish the pattern and the rotation; partial sowing of a pasture mixture; planting of shade trees; access tracks.

Costs and Farm Income in Model Village Settlements

45. The total estimated cost is L. S. 250,000, which is L. S. 3.1 per acre of farm-land. Costs of water supply are based on catchment tanks because there is no means of knowing whether dug wells, boreholes or other methods will succeed or be preferable until the actual sites for each of the villages has been located on the ground, followed by the usual hydrological investigations. No provision has been made for housing because the peasants customarily build their own huts and their interests will be far better served if the limited funds for development are channelled into productive investment.

46. A fully-developed farm of 80 acres gross, benefitting from the results of the Project, should bring a total income to the farmer which is estimated at L. S. 259, of which L. S. 192 is in cash and L. S. 67 is the equivalent value of his own consumption. This is about double the present average income.

The Introduction of Power

47. The peasant farming system as proposed is capable of absorbing a wide range of scientifically-based improvements while still retaining the essentials of the present socio-economic pattern, and while still remaining a hand-powered system, i.e. without using either animal power or machine power. A stage will come, however, when further advance will need extra power and it seems probable that when this stage comes, the people will be ready for light machines.

48. But when machine power is introduced into the goz country it should be used to intensify and fortify the mixed farming system of the model. Power should on no account be used, in the sandy goz country to open up large tracts of land under the mechanical plough. The mixed system based on a "land rotation" with field crops, gum acacia and livestock must be developed and perpetuated if the full productive potentialities of these soils are to be achieved.

Location for First Group of New Village Settlements

49. A location is proposed for the first group of settlements in the empty area north of Umm Ruaba and south of Umm Damm, where they would relieve pressure in the densely cultivated areas which are near. A succeeding location could be in the empty area near Jebel Abu Sinun. The first "new village settlement project" will yield new knowledge and experience, and as execution proceeds, the preparation of a comprehensive long-term schedule for the empty areas as a whole will emerge.

Up-Grading the Existing Farming Settlements in the Goz Country

50. The model for new settlements provides a target for up-grading existing farming standards. If all the technical knowledge now available could be absorbed and applied by all the farmers there would be a notable improvement. The communication by teaching is a major problem and the success of up-grading depends more on this than on anything else.

A Field Demonstrators' Training School

51. It is proposed to establish a training school for field demonstrators, with a capacity of 25 pupils, situated at the central village of the first group of nine new village settlements. The estimated capital cost is L.S. 120,000. In the meantime, until the school is running, pilot-type extension and demonstration should be done so far as man power permits.

Village School Gardens, Film and Radio

52. It is proposed that gardens should be established in the village schools with practical elementary teaching, and that the use of film and radio for propagating the Project results should be explored.

Catchment Tanks for the Water Crisis Area

53. The worst water supply situation is in the "water crisis area" in Land Use Zone A_3, where an estimated 335 villages rely on water supplies transported by lorry during the dry season. They buy the water at an average price of 4 piastres per four-gallon tin (£10 or U.S. $28 per thousand gallons).

54. A five-year programme is proposed for constructing catchment tanks at each village. Assuming that the villagers provide their labour free, the total cost of materials and supervision is estimated at L.S. 350,000. It is estimated that the water which these tanks would yield would cost L.S. 250,000 p.a. if purchased for cash at current prices from the tank lorries.

55. This will call for training of overseers, which can be done at the existing Experimental Yard in El Obeid.

Land Tenure in General

56. The absence of a cadastral survey and a land registry is not an immediate barrier to improvement but the time will come when they will be needed. The subject was outside the Project's terms of reference, but it is permissible to recommend that an expert should be commissioned to make a study and report.

DEVELOPMENT IN THE GARDUD COUNTRY

General

57. The gardud country comprises Land Use Zone C (Fig. 6) with the exception of pockets of sandy soil which are cultivated. Apart from these cultivated pockets there are 7,150 square kilometres of the gardud soil area which is at present the grazing-ground for the semi-nomadic and nomadic cattle herds.

58. Over-grazing has reduced the gardud soil carrying capacity and has affected the soils, giving rise to small but universal patches of bare hard-pan on which nothing grows. But trials at Kaba have shown that the damage is not irreversible. When rested, recovery begins, though slowly.

59. To get the best out of these gardud soils, initial rehabilitation by heavy machinery is needed and this points to development policies based upon the creation of big units, whether of ranches or farms, operated with properly capitalised installations and equipment, and under modern scientific management.

Model For Pilot Ranch

60. The model consists of a ranch of 9,000 acres, provided with a perimeter fence, and quartered by internal fences. The land is cleared, ploughed and sown with a pasture mixture. Water supply is provided by pipe. Necessary buildings and installations are provided, and access tracks. The estimated total cost is L.S. 50,000. Initially, three ranches are proposed: one near El Obeid, one near Rahad, and one near Nahud, at a total estimated cost of L.S. 150,000.

61. The purpose of the pilots is partly to conduct indispensable full-scale trials on the establishment and use of pastures after deep-ploughing, and also to test the response of the tribesmen and the merchants. The essential function of these ranches is that they should provide good pasture, where animals can be fattened en route for the market. By this they can provide a connecting link between the indigenous customs of the cattle nomad, and the requirements of the commercial markets.

Dairy and Meat Production and Research Institute

62. An Institute is proposed, to resolve the problems concerning land preparation, pasture establishment, and grazing, fodder conservation and supplementary feeding, slaughter and marketing of meat and treatment of dairy products.

63. The best site is near Rahad, where five major soil types are within easy reach and where water from the lake is plentiful.

64. Estimation of costs involves studies outside the Project terms of reference. A small team is proposed to study details.

Main Barrier Fence

65. If the Pilot ranches succeed, a comprehensive plan for progressive conversion of the gardud lands in Zone C to ranches can be launched. At that stage a main barrier fence across the southern boundary of Zone C is suggested, with gateways, under control, and provision for veterinary services and counts. The estimated cost is L.S. 150,000.

Pilot Farms for Mechanised Agriculture

66. There are possibilities of economically successful mechanised farming in the gardud country and it is proposed to open up a block of farms, near El Obeid, which could be put on offer when they are developed, for lease or sale to substantial farmers.

67. Each farm would be 1,000 acres, fenced, provided with water supply and access tracks, and the soil would be rehabilitated by heavy machinery. Government would retain one farm for experimental purposes.

68. The estimated capital cost is L.S. 42,000 for the six farms.

RAHAD TURDA (LAKE) DEVELOPMENT PROJECT

69. This project is dealt with in a section of its own because it relates to parts of the goz country and parts of the gardud.

70. The proposal is to improve the storage capacity of this natural lake and to improve the existing feeder from the Khor Abu Habl by which flood waters are diverted from the Khor and put into storage in the Lake.

71. Under the proposed first stage, there would be a gravity-fed conduit running eastwards down the valley of the Khor Abu Habl, as far as Tendelti, feeding a broad belt of territory with drinking water and some irrigation water for local village supplies of fresh vegetables and fruits.

72. The estimated cost of this first stage is L.S. 1,750,000.

73. In addition it is proposed to study the possibility of a pumping main running north-westwards, to connect with the El Obeid water supply system and also to test the possibilities of enlarging the supply by suppressing evaporation with a mono-molecular film. The estimated cost of these investigations is L.S. 35,000.

RESEARCH

Subjects for Research

74. Detailed recommendations on subjects and programmes for research are given in Volume IV, V, VI and VII. (water; field crops; pastures and livestock; forests)

Establishments for Research

75. The experimental work proposed for water supplies can be done at the existing Experimental Yard at El Obeid. Field hydrometric work can be based at the same establishment.

76. Research on field crops can continue at the two Experiment Sites at Kaba and Umm Heglig, and a further similar site is proposed, near Sa'ata, to assess the sandy pediplain soils.

77. The proposed Mechanised Farm Pilot Project will provide for full-scale experimentation. Micro-irrigation can be done at the El Obeid Experiment Yard where there is piped water supply.

78. The proposed Dairy and Meat Production and Research Institute will provide the main base for research relating to pastures, livestock and processing and marketing of animal products. The three proposed pilot ranches are by nature experimental and can in addition accommodate specific small-scale experimental work. The existing pasture observation exclosures should be continued, on a limited basis.

79. Forestry research establishments are not dealt with here because this is the province of the Forestry Research and Education Project.

80. It is suggested that the location of the Dairy and Meat Production and Research Institute should become the nucleus and base for all research on all aspects of land use relating to the five types of soil which are within easy reach of that site, i.e. goz (sand sheets and dunes) sandy pediplain, gardud (clayey pediplain) dark cracking clay and alluvium.

FURTHER APPLICATIONS OF THE METHODOLOGIES AND TECHNIQUES OF THE PROJECT

Applications Inside the Project Area

81. The specific recommendations given in this Report are only a start towards the opening up of all the suitable empty areas and the up-grading of all aspects of land and water usage. The maps and reports give a fully documented basis for progressive development throughout the Project Area.

Applications Outside the Project Area

82. The results can be applied within the whole belt of territory which is geomorphically and climatically similar. Detailed specifications for making a start on this work are in the Work Plan for 1966, Volume X.

SUMMARY OF RECOMMENDATIONS

INTRODUCTION

83. In this Summary the specific recommendations are collected into groups which are related to the processes of implementation, i. e. :

Capital Investment Projects.
Pilot Investment Projects.
Training and Extension.
Research.
Application of the Project's results to other areas.

CAPITAL INVESTMENT PROJECTS

New Village Settlements in the Sandy Goz Country

84. Make a start with one group of nine villages in the "empty" area between Umm Ruaba and Umm Damm 100 family farms each, with fencing, water supply (for people and 3 cattle-equivalents per family and for household vegetable micro-irrigation), preparation of land and planting of gum acacia; and with public buildings at the central village to serve them all. (See Chapters 11 and 13, and Volumes V, VI and VII. Reports No. DOX-SUD-A 45, 47 and 54).

Estimated cost : L. S. 250,000
(equivalent to L. S. 3.1 per acre)

Catchment Tanks for Water Crisis Area

85. Launch a five-year plan to build catchment tanks at the 335 villages in the gum acacia belt where supplies at present rely on transport by lorry at excessive cost. (For details see under Volume IV, Report No. DOX-SUD-A57. Also see summary in Chapter 13 below)

Estimated cost, assuming that Government provides the materials and supervision, while the villagers provide the labour, for their own village tanks : L. S. 350,000
(The present expenditure by the villagers, spent in buying water by the drum or the tin for cash, is L. S. 250,000 per annum)

Rahad Turda (Lake) Development Project

86. Proceed with detailed surveys, designs and specifications for the first stage of development, to provide and distribute 17 million cubic metres of water per annum for drinking in the villages and for some irrigation. (For complete study see Volume VIII, especially Report No. DOX-SUD-A 52. Also summary in Chapter 6 and 13)

Estimated cost : L. S. 1,750,000

87. Proceed with surveys and investigations to assess the practicability of delivering water up the land-slopes from Rahad Lake to join the El Obeid water works and to supply water for development along the belt commanded by the pipeline.

Estimated cost : L. S. 20,000

88. Proceed with experimental investigation to establish the quantities of water which could be saved from evaporation from Rahad Lake, by means of monomolecular film.

Estimated cost : L. S. 15,000

PILOT INVESTMENT PROJECTS

Pilot Finishing Ranches

89. Establish three ranches in the gardud country, one near El Obeid, one near Rahad, one between Nahud and El Obeid, 9,000 acres each; provide fencing, clear and plough, sow with pasture mixture, piped water

supply, buildings and access tracks. (See estimates in Chapters 12 and 13 and discussion in Volume VI, Report No. DOX-SUD-A47)

Estimated cost, three ranches : L.S. 150,000

Pilot Block of Mechanised Farms

90. Establish six farms each of 1000 acres in the gardud country near El Obeid; soil rehabilitated by heavy machine, fencing round each farm, piped water supply. One farm to be retained by Government for experimental purposes. (See estimates in Chapters 12 and 13 and discussion in Volumes V and VI, Reports Nos. DOX-SUD-A47 and 54)

Estimated cost : L.S. 42,000

Barrier Fence for Cattle Control

91. Hold this item until Pilot Ranches have proved the potentialities and until surveys and investigations in the region to the south of the present Project Area have enabled a full policy for the Baggara Cattle Tribes to be formulated. (See estimates in Chapters 12 and 13 and discussion in Volume VI, Report No. DOX-SUD-A47)

Estimated cost : L.S. 150,000

PROJECTS FOR TRAINING AND EXTENSION

Field Demonstrators' Training School

92. Establish a Training School for Field Demonstrators, covering all aspects of farming by peasants under improved conditions. Capacity, 25 pupils. Location, at the central village of the first group of nine new village settlements. Residential provision for staff and pupils. (See further details in Chapters 11 and 13)

Estimated cost : L.S. 120,000

Dairy and Meat Production and Research Institute

93. Provide a small expert team to study the proposal in detail. (See Chapters 12 and 13 and discussion in Volume VI, Report No. DOX-SUD-A47)

Estimate : 9 expert man-months in aggregate.

Interim Training School for Catchment Tank Techniques

94. Until the Field Demonstrators' Training School is operating, use the Experiment Yard at El Obeid as a base for training in the new catchment tank techniques, with particular reference to the overseers needed for the Catchment Tank Programme for the Water Crisis Area. (See Chapters 11 and 13)

Estimated cost of additional accommodation and facilities, say :	L.S. 5,000

Interim Agricultural Extension Work in Priority Areas

95. Until the Field Demonstrators' Training School is operating, use available staff for pilot-type extension work in the field, starting in the heavily over-cultivated area near Umm Ruaba. (See Chapters 11 and 13)

School Gardens

96. Introduce a programme for school gardens, with a simplified teaching curriculum related to the peasant mixed-farm system; start this with a spear-head in the Umm Ruaba area and expand progressively to other areas. (See Chapters 11 and 13)

Film and Radio

97. Make a full expert review of the use of film and radio, with special reference to the policies and plans for up-grading peasant agriculture. (See Chapters 11 and 13)

RESEARCH

98. Follow the lists of subjects for research as referred to in Chapter 13, dealing with water supplies; field crops; pasture and livestock; forestry; and household horticulture in the peasant villages aided by micro-irrigation and the soil-moisture trap.

99. The establishments needed for the purpose are: the existing agricultural experiment sites at Kaba and Umm Heglig; the existing Water Experiment Yard at El Obeid; the existing pasture observation exclosures; the proposed new Dairy and Meat Production and Research Institute; the proposed new agricultural experiment site near Sa'ata; the proposed new Pilot Ranches; and the proposed new pilot mechanised farm.

FURTHER APPLICATIONS OF THE METHODOLOGIES AND TECHNIQUES OF THE PROJECT

100. Pursue the applications inside the Project Area and in the region of similar geomorphology and climate outside the Project Area, as described in the present Report and in the Work Plan for 1966 (Volume X).

LAND TENURE

101. Appoint an Expert to study the whole question of land tenure with special reference to the potentialities and problems of up grading peasant farming practices. Period required, say 6 months.

CHAPTER 3

BRIEF ACCOUNT OF THE SURVEYS AND INVESTIGATIONS

INTRODUCTION

102. "Surveys" means collecting information in the field about soils, vegetation, climate, water, crops, livestock, present system of farming, animal husbandry, gum culture etc.; and casting all this information into the form of maps, charts, statistics. "Investigations" means carrying out field trials in experiment sites to investigate the use of fertilisers varieties, soil moisture, soil management and other items; experiments in the experiment yard on methods of controlling seepage and evaporation from water storage tanks; investigations into specified problems relating to forestry or pastures or livestock or soils which call for answers.

103. The present Chapter gives a brief descriptive account of the way the surveys and investigations were divided and organised so as to cover the various fields of technical study. Each technical subdivision is related to the series of Volumes, numbered Volume II to Volume XI, as shown in the Index to Volumes; the present report being Volume I, i. e. the General Report.

104. Each of the series of Volumes is supported by one or more technical annexes in the form of reports containing semi-processed data. It was decided at the outset, (as explained in the General Work Plan which was submitted and approved in February 1962) that the semi-processed data, with interim analysis and discussion when appropriate, would be issued as and when it matured, and would be circulated so that all concerned would have the new material at hand, for their information and for review and analysis, throughout the course of the Project.

105. The "Index to Volumes" and their Technical Annexes, which appears in the present report after the title-page, gives a complete list of all these reports. They were issued at various times, and were circulated as follows: to FAO and the U.N. Special Fund, to the Department of Land Use and Rural Water Development, and to the Project Office in El Obeid. Together they constitute a substantial bulk of specialised data, source-material from which the present General Report, complete in itself, is the final distillation. The semi-processed data contained in the series of Volumes and technical annexes are adequate for analytical treatment on a far wider and deeper scale than has actually been done under the Project.

106. The explanation is that the work of the Project was necessarily general to provide a sufficient foundation for formulating comprehensive land use policies and plans for action. Technical analyses were carried as far as was necessary for this practical purpose, and were not carried any further because there were no resources to spare for any investigations beyond the actual needs, however rewarding they might be as contributions to scientific knowledge for its own sake - which is a very proper pursuit in its own place and time, but was not a goal of this project.

107. At the same time, it was recognized that students with a legitimate interest in research and analysis for the sake of the sciences would find the data invaluable, and it was therefore decided to make it generally accessible by including it in the reports, which come under cover of the series of Volumes.

108. This special note applies rather particularly to the Hydronomic reports because this work, by its nature, yields masses of statistical data which are capable of analytical treatment in a great variety of ways and are capable of yielding analytical contributions to the several hydronomic sciences which go very far beyond the limited requirements of the Project.

LAUNCHING THE OPERATIONS

109. The Project Office was opened in El Obeid at the beginning of April, 1962. A General Work Plan and a Work Plan for 1962 had been prepared and agreed at an inter-departmental meeting in Khartoum in February, 1962.

110. Although orders had been placed by FAO for transport, instruments, equipment and stores in good time, i.e. autumn 1961, there were delays in transit. In the event the Director of Department of Land Use and Rural Water Development, Seyid Abdul Rahim Bayoumi, kindly arranged to lend certain essential items such as transport and camp equipment, so that the field work could begin promptly in April. The importance of this date was that the rainy season begins normally in June. If a real start could be made in April, hydrometric and other work could be started which would otherwise be put back by a season. Thanks to the help given by the Department of Land Use and Rural Water Development the agreed programme started on time.

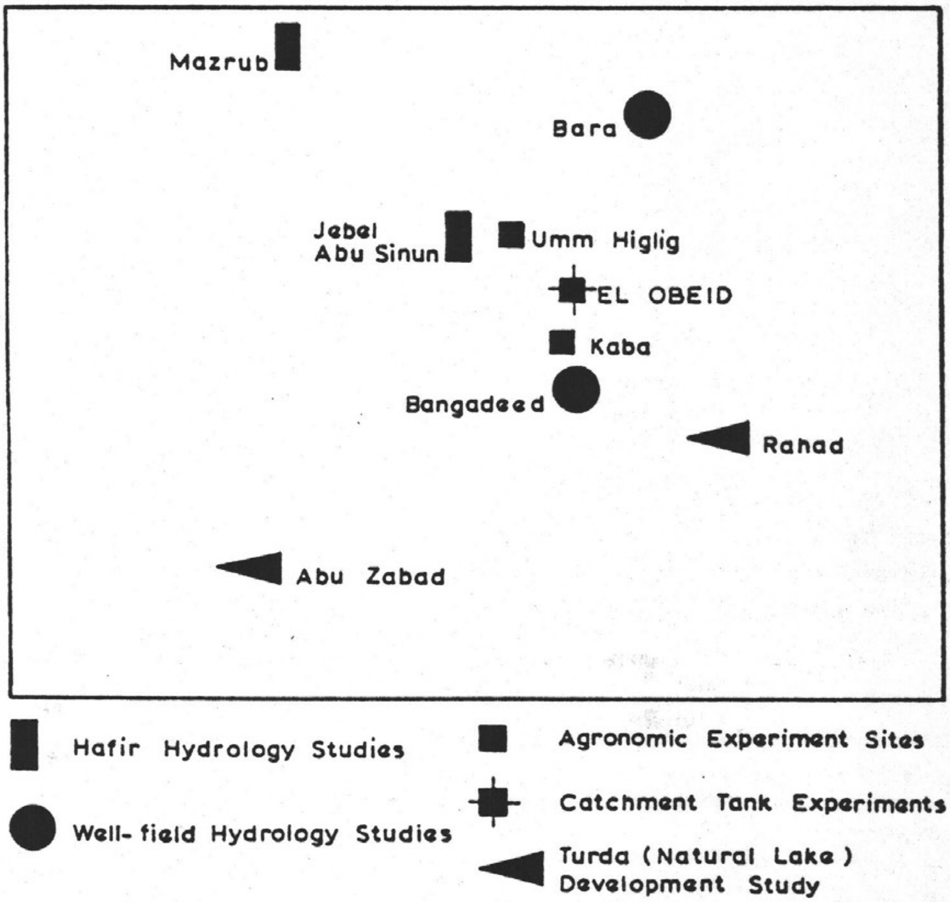
111. It had been hoped that the Basic Survey and mapping (sub-contracted to Hunting Technical Services, Ltd.) would yield working editions of the technical maps well before the 1963 rainy season. There were delays over the photo-mosaics, despite the efforts of the Sudan Surveys Department to deliver them on time and to the necessary standard of quality, and working editions of the maps were not available until autumn 1963. The result was that the planning of the agronomic experiment sites and the pasture enclosure plots, and certain other items, had to proceed in 1963, before the rains, without the help of the maps, except for very preliminary versions.

112. Nevertheless, two sites for agronomic trials in the 1963 season were chosen, and sites for pasture observation enclosures, because it was essential to get the agricultural field trials and the pasture observations started. From the beginning it had been decided to start this field experimental work in 1963 and not in 1962, so that it could be planned in the light of the data from the survey of soils and vegetation rather than in ignorance. This meant that there would be only three seasons for trials and observations. This did not by any means preclude the possibility of valid conclusions but it did limit the scope.

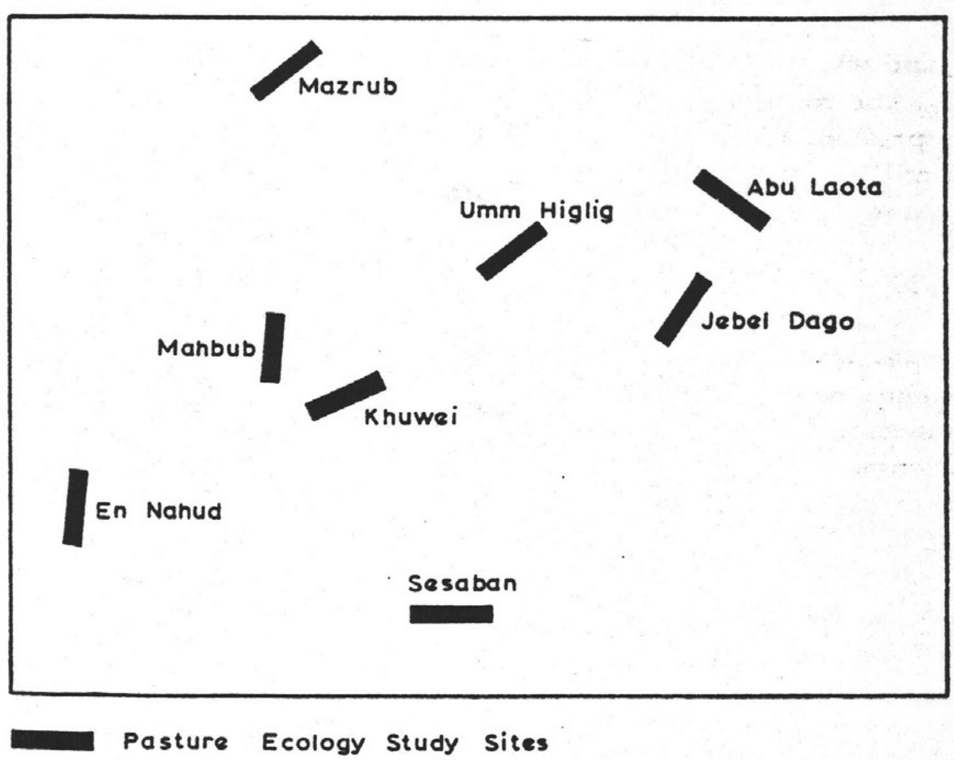
113. The delay over the photo-mosaics affected the work and hindered it, but did not cripple it, nor did it impose the necessity of any radical re-planning. Indeed, as time went on, the course of the work followed more closely the agreed work-plans.

114. Figs. 7 and 8 show the geographical locations of the sites established for investigations of various kinds and for certain survey operations.

AGRICULTURAL AND HYDROLOGICAL STUDY SITES Fig. 7



PASTURE STUDY SITES Fig. 8



BACKGROUND STUDIES

115. Records of past history and past work were collected, including maps, climatic records, agricultural and hydronomic records. At the outset of the Project, socio-economic data were gathered from villages, on the basis of a Questionnaire.

BASIC SURVEY AND MAPPING

116. Photo-mosaics based on air survey done by the Sudan Survey were provided, to scales of 1:40,000 or 1:50,000. The team provided by Hunting Technical Services made the field traverses, did the photo-interpretation, and produced the final maps, ready for reproduction in colour by Sudan Surveys Department. Soil analyses were partly done in the Project Laboratory in El Obeid and partly by Sudan Agricultural Services Ltd. in Khartoum.

117. These maps were to a scale of 1:250,000, requiring four sheets to cover the Project Area. Five sets of Technical maps were made, each set comprising the four sheets, as follows:

- a. Topography
- b. Geology
- c. Soils and geomorphology
- d. Vegetation
- e. Present Land Use

Black and white versions were made to a scale of 1:500,000 and 1:1,000,000. Finally, the maps at a scale of 1:2,500,000 (which are the main illustrations in this present Report), were specifically designed, each one being edited and simplified to fit the context of the Report. Volume II covers the Basic Survey and Mapping.

CLIMATE

118. It was decided that the meteorological observation-stations established by the Project would be limited to those which were required in connection with specific investigations - at the Experiment Sites; at the places chosen for study of the behaviour of hafirs and well fields; at Rahad. For the rest, the records were drawn from the Sudan Meteorological Service.

119. Rainfall required a specially full treatment. A set of charts was issued with "iso"lines for annual rainfall, dates of first and last "effective"

rains of the season, length of rainy season in days, length (in days) of the interval between the first and second effective rains of the season. In each case, the charts covered the mean value, the five-year "high" probability, and the five-year "low" probability. Evaporation data were collected and an "iso-vap" chart was made.

120. Volume IV includes a compact summary of the climatic data.

AGRICULTURE

Present Land Use

121. Observations on "Present Land Use" were regarded as being an essential preparation for considering improvements and developments, because it is not possible to satisfactorily suggest how farmers might do things better unless the methods they are using now are well understood. The "Present Land Use" Map shows the areas under cultivation in two categories, i.e. "light" and "dense".

122. In addition, observational and statistical data were collected, through questionnaires, by members of the team travelling on a series of traverses over the Project Area. Information collected related to the local systems of agriculture, crops raised, rotations, cultivation, weeding, timing etc. Volume III covers Present Land Use.

Field Crop Trials

123. The resources of the Project were enough to provide for two small experiment sites where field trials could be made to get experimental data on the capabilities of the soils. The site at Kaba was chosen to represent the hard, red "gardud" soil. The Umm Heglig site was on the sandy "goz" soil, with natural gum acacia. As will be seen later, these two are reasonably representative of the two predominant soil zones in the Project Area.

124. Each of the two experiment sites was chosen on land which had lain fallow for a long period of years. There were several reasons for choosing well-rested land, instead of choosing exhausted land. The main reason is that this is the only way of knowing, with sufficient certainty (by the age of the trees) what the previous history has been.

125. The programme of trials covered basic fertility and fertilizers, varieties, crop sequence, population densities, new crops, sowing dates, soil moisture and soil management.

126. As soon as each year's harvest was over the results were calculated and a full report was issued. Thus, by the end of the Project, reports issued covered three seasons, 1963-1965.

127. Volume V contains a comprehensive account of the results, with detailed recommendations.

PASTURES AND LIVESTOCK

128. The man-months provided specifically for this subject were enough to provide for an expert for only a quarter of the total period of the Project. The policy adopted was to use the earlier phases of the Project in collecting, under expert advice, data which would be useful for the subject, and then have the Pasture Expert in the closing phase of the Project, when his presence would be essential for discussing the results in the context of general land use planning.

129. Some field trials of introduced fodder species were included in the 1964 Field Trials. The Pasture Expert tested some further introductions in 1965.

130. The nomadic tribes have a very special importance and they pose very special problems. In order to provide data, special studies of these tribes were made, focussed particularly on their migration and their usage of the grazing grounds, and the economics of their husbandry.

131. Volume VI is a comprehensive coverage of both the surveys and the investigations relating to Pastures and Livestock, with detailed recommendations.

FORESTRY

132. The scope to be covered by this Project was specifically limited, in the Plan of Operation, so that it placed the main emphasis on a survey of the gum acacia and its place in the cultivation cycle, and omitted all research into methods of improving the production of gum. Other forest products were covered more lightly.

133. As with Pastures, the man-months provided were not enough to enable an Expert Forester to be continuously attached, and the same solution was adopted - i.e. to bring the Expert into the field during the closing phases of the Project.

134. Questionnaires were used to collect data on the many aspects of gum culture and forestry. The studies included a review of past work, and the history of the gum trade.

135. A revised map showing the distribution of the gum acacia was made, with three categories of density.

136. Volume VII covers all the surveys and investigations relating to gum acacia and other forestry, with detailed recommendations.

WATER

137. The water-supply surveys were designed to reveal a picture of supplies as they are at the time, and the investigations were to find out how far the problems of shortage could be solved.

138. Specific hydrometric work was carried out, relating to the actual surface waters and groundwaters, with periodic observations of water level and other data.

139. In addition, six particular localities were put under closer hydrometric observation. These were: The natural lakes (turda) at Rahad and Abu Zabad, the hafirs at Jebel Abu Sinun and Mazroub, and the two well-fields at Bara and Bangadeed. The objectives were to investigate development potentialities, to diagnose problems, and to get basic hydronomic data.

"Catchment Tanks"

140. Experiments were conducted, in a special experimental yard in El Obeid, to find methods of controlling losses by seepage and evaporation from hafirs, and to develop techniques for constructing storage tanks of a size suitable for individual villages and for individual families, which can be filled up during the rainy season by catching the run-off from an adjacent artificial catchment apron. This led to the construction of a series of full-scale proto-type village and family-size "catchment tanks" in the experiment yard in El Obeid in 1964, followed in 1965 by others, built in two villages near to El Obeid.

Micro-irrigation

141. The possibility arose of using small rainwater tanks to provide supplementary irrigation for the household vegetable plot which many (or most) villagers have next to their houses. From this there emerged the further possibility in certain circumstances of providing similar small-scale irrigation for fruit trees throughout the dry season. Investigations on this "micro-irrigation" were carried as far as the period of the project allowed.

142. Volume IV covers all the surveys, investigation and assessments relating to water for drinking and for irrigation, with recommendations.

Rahad Turda (Lake) Development Project

143. Particular attention was given to the Rahad Turda (Lake) because of its size and the important potentialities of developing it to improve water supplies. The feasibility study has been given a section of its own, in Volume VIII.

SOIL EROSION

144. Almost every technical aspect of the Project yields some kind of information relating to soil erosion. The phenomena of soil erosion need to be looked for in the geomorphology, the soils, the vegetation, the hydrology and the climatology. Consequently every one of the professional disciplines has something to contribute; the agronomist, the forester, the pasture expert, the ecologist, the soil surveyor and scientist, the geologist, the hydrologist, the meteorologist, the engineer and the geographer.

145. All these varying channels of observation and interpretation converge in the end, so far as Government is concerned, to a key question: "How much effort ought we to spend in man-power and money in coping with soil erosion, bearing in mind (as Governments must) that whatever we spend on soil erosion must be budgetted for by deducting it from something else?" The observations and studies on soil erosion were all geared to this question.

ANALYTICAL MAPS

146. In order to study the mapped elements and the correlation of every technical aspect of the Project Area, and to examine cross-correlations between them, a version of the technical maps was made to a scale of 1:1,000,000.

147. Volume IX contains a substantial selection of these analytical maps.

WORK PLAN FOR 1966

148. The last operational action under the U.N.D.P. Survey as such was to draw up a Work Plan for 1966, the first year of the follow-up after the Expert team had left. This was based upon the conclusions and recommendations resulting from the Survey. It is in Volume X.

ADMINISTRATIVE REPORT

149. Each of the Quarterly Progress Reports submitted by Doxiadis Associates to FAO included essential administrative and organisational data with statistics.

150. Volume XI is a general administrative report, with records covering the whole of the period of the Project.

CHAPTER 4

THE GEOGRAPHY OF THE LAND AND WATER RESOURCES

INTRODUCTORY SKETCH

151. This short account is focussed upon the resources which are significant for Land Use Planning and are specially relevant to the Project. The sequence and balance of the presentation are, therefore, different from those which would be appropriate in a geographical sketch for general geographer's purposes.

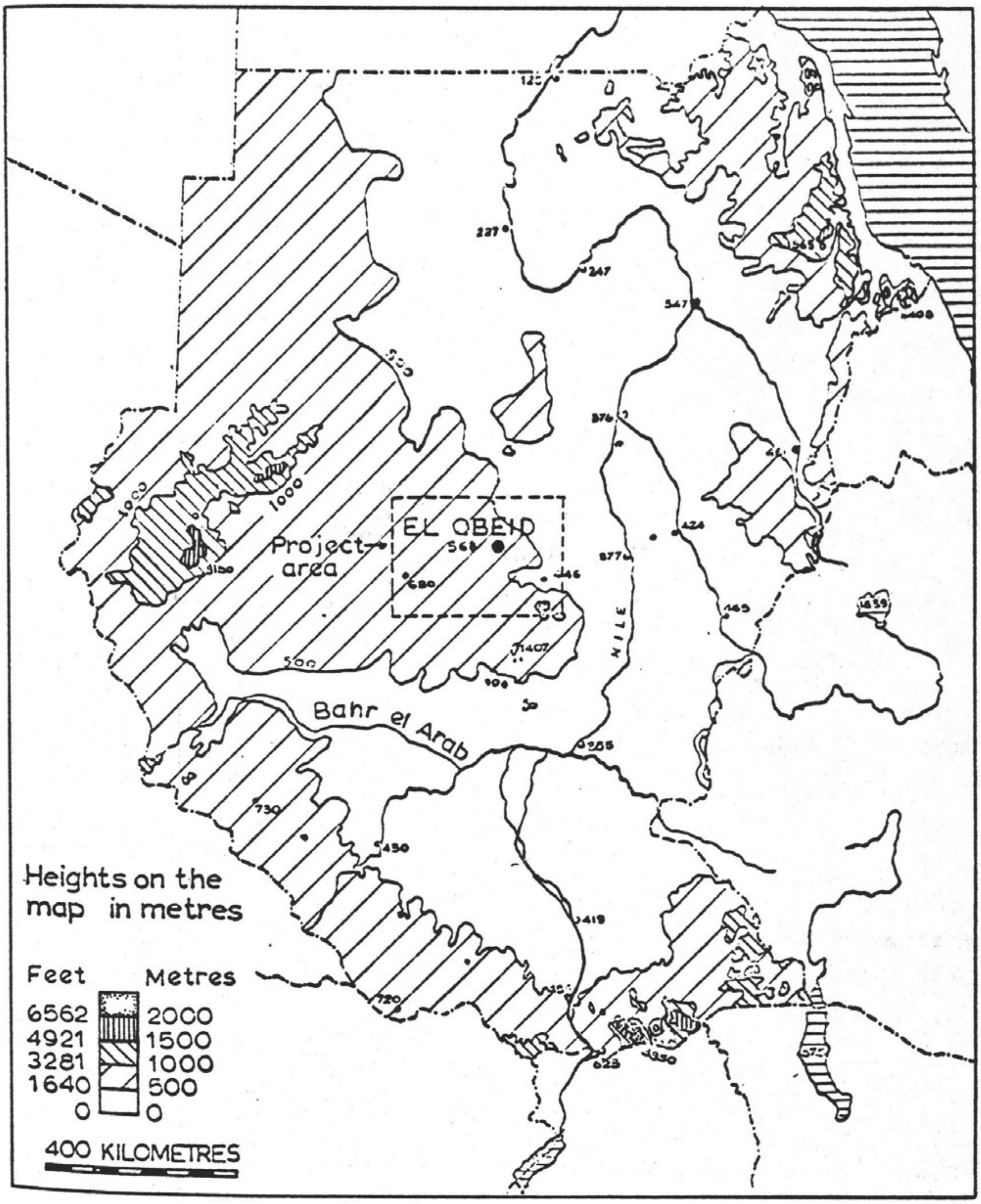
152. Topographically the Project Area lies in the Nile basin, as shown in Fig. 9. It is a wide open plain with occasional inselbergs standing up from it. In the northern half of the area the sandy soil is so permeable that there is virtually no run-off, though the rainfall supports agriculture. In the southern part, run-off collects into transient surface drainage systems. But none of the water gets as far as the Nile before soaking in, although the average total of rainfall on the Project Area alone is something like 30,000,000,000 cubic metres per annum, about a third of the annual flow of the Nile. For the most part, land slopes are very gentle, often almost imperceptible as far as the eye can reach. The Nile drainage system is shown in Fig. 10, with the frame of the Project Area.

153. Plate 3 is a picture of a sweep of the country, with acacia senegal, the thorny tree which yields gum arabic. The Arabic name is "Hashab". In conversation in English it is often called "gum acacia"; a conveniently descriptive term.

154. Kordofan is the world's main producing area for gum arabic, picked from the gum acacia which grows naturally in this region. Gum is an important source of cash to the farmers and of foreign exchange to the country. Sesame and groundnuts also go into the markets for cash, as well as vegetables and fruits, which are grown (in very few places) with small-scale irrigation for local consumption.

CONTOURS

Fig. 9

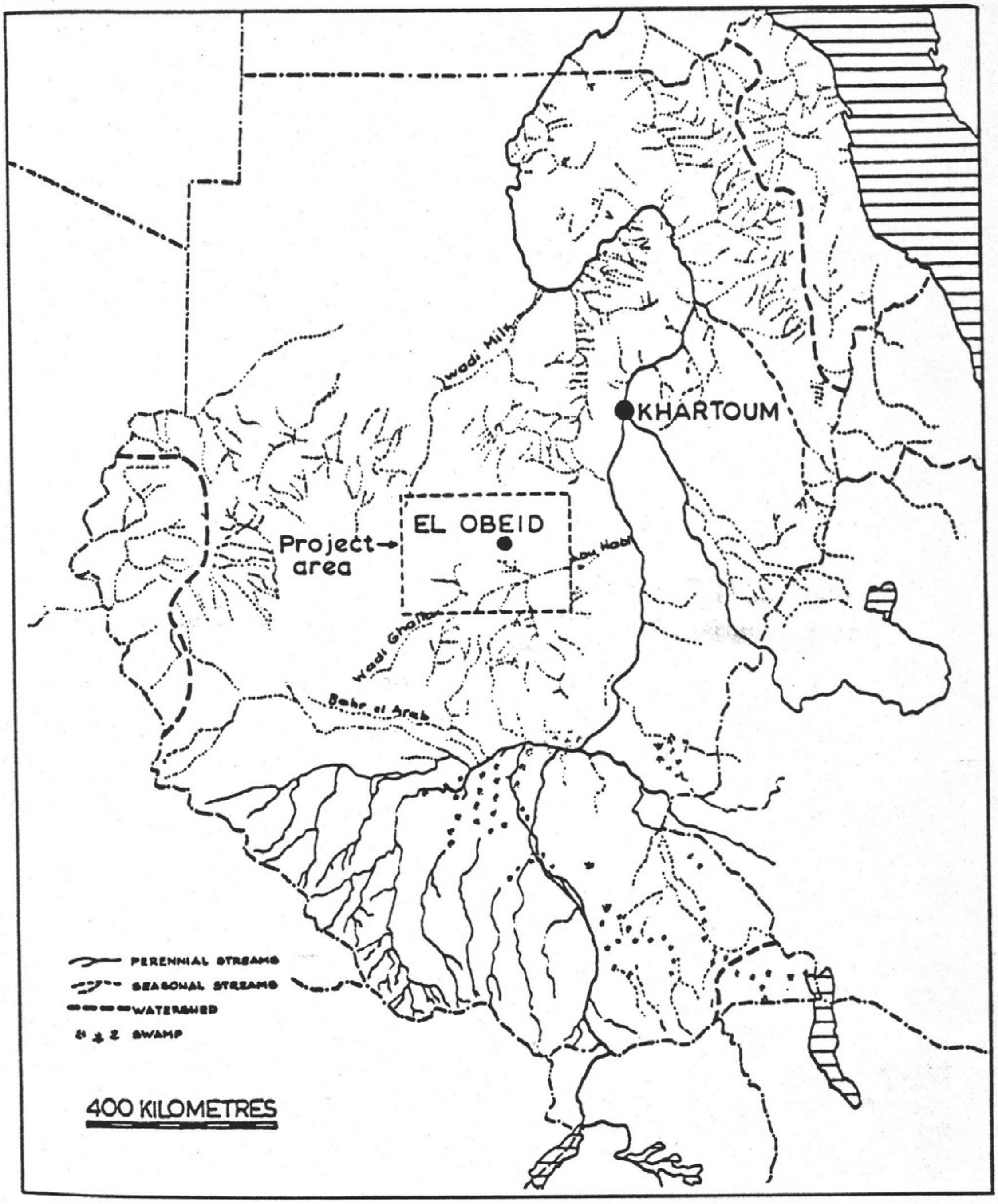


This sketch-map from Barbour's Geography, shows the setting of the Project Area in the Nile Basin, with the predominant contours which illustrate the general shape of the land.

155. Most of the country folk are peasant farmers, living in fixed villages, but there is an annual influx of nomadic cattle owning tribes who move up from the south when the fresh grasses spring up, watered by the rains in May and June. When the rains tail off in September and the land begins to bake dry, the nomads move south again down towards the Bahr al Ghazal, tributary of the Nile. Plate 4 shows a typical village with its skilfully-made round thatched huts. In Plate 5 some of the nomadic cattle are shown grazing.

156. In most parts of the belt which the Project Area characterises, the rainwater soaks in quickly and the soil does not churn into sticky mud. There are comparatively few flies and pests. Roads and tracks are passable, even in the rainy season. It is good and healthy country for cattle in the short season when the grass is green; and for the peasant farmers the sandy soil is easy to till. They clear the bush with axes, strip the weeds with a hose and plant the seed in holes made with a pointed stick. Ploughs are not used except in some of the very small patches of irrigation. Plate 6 shows a standing crop with the peasant farmer.

157 Animal power is used only for transport and the main job is to carry water in skins from the water-points to the villages. There are no perennial streams and no springs. During the dry months from October till the next rains start in May or June all the drinking water is drawn from dug wells, boreholes or from various forms of surface storage. Most of the water carrying is done by donkeys. A scene at a well-yard, with donkeys carrying skins of water, is shown in Plate 7.



(From Barbour's Geography)

The drainage-lines and the main water-sheds of Nile Basin within the Sudan. Note how the Khor Abu Habl system swings eastwards towards the Nile, but peters out in the sands before it gets there, while the Wadi Ghala system runs south-westwards towards the Bahr el Arab. In the north and northwest parts of the Project Area there are no surface drainages because the permeable sandy soil generates no run-off.

CLIMATE

158. A descriptive account of the climate is given in the accompanying diagrams and tables.

Rainfall: Annual Charts

159. The mean annual isohyets are shown in Figs. 11 to 13 which are adapted from the full series in DOX SUD-A34. The five-year high and low probabilities are shown, and the mean.

160. Fig. 14 shows the mean length of the rainy season in days varying from 70 days in the north west corner of the project area, to 120 days in the south east and south. The number of days is reckoned between the first storm of 10 mm. or over in a day, to the last similar storm of the season.

161. The initial "iso-drought" shown in Fig. 15 is particularly interesting. After the first 10 mm/day rain-storm has fallen the soil is usually moist enough for sowing. There may be a substantial time-lag, in days, before the next useful rainfall, which is called the "initial" drought. Fig. 15 shows the "initial iso-drought" lines. The specially interesting point is that the average "initial drought" period is not much greater in the north than in the south of the Project Area. This means that although the annual average total of rainfall is twice as much in the south of the Project Area as it is in the north, a crop sown after the first 10 mm. storm has to wait about the same average period of days before the next 10 mm/day rainfall arrives.

162. The estimated mean annual open water evaporation is shown on Fig. 16 based on evaporation pan data at the main meteorological stations. These are provisional estimates because the available data relate to very few places.

Rainfall: Seasonal Variations

163. Seasonal variations for the mean year are shown in Fig. 17 for a number of stations in and around the Project Area. The rainiest months are July and August.

Rainfall: Minima

164. Table 1 shows the lowest annual rainfall ever recorded for a number of stations in and around the Project Area, and also the second lowest on the record.

Wind Directions

165. The seasonal variations of wind directions are shown in Fig. 18. The essential feature is that during the dry season from October to June the predominant wind comes from the north, while the rain-bearing winds come from the south.

Wind Forces

166. Wind forces are shown in Tables 2 and 3. Two particular points are to be noted. The first is that the biggest wind-speeds occur during the rainy season, when the vegetation cover is at its strongest and the soil tends to be bound by moisture. The second is that in comparison with a number of other places in the world, the wind speeds are low. They are lower in the southern parts of the Sudan than in the northern parts. These features are important when considering wind-erosion.

Climatic Normals at El Obeid

167. Temperatures, relative humidity and rainfall are shown in Fig. 19 for El Obeid. These give a general impression of the month-by-month variation during the year.

Fig. 11

Isohyet _ 5 Year high probability

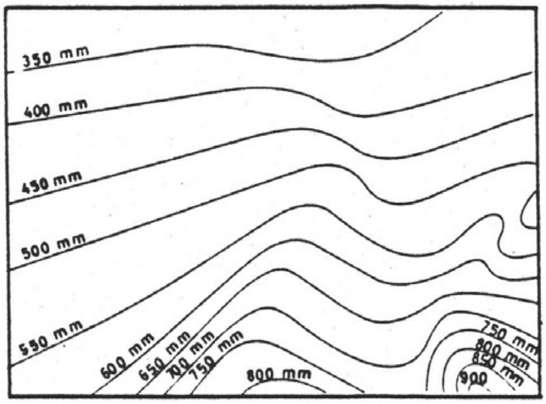


Fig. 14

Mean length of Rainy Season

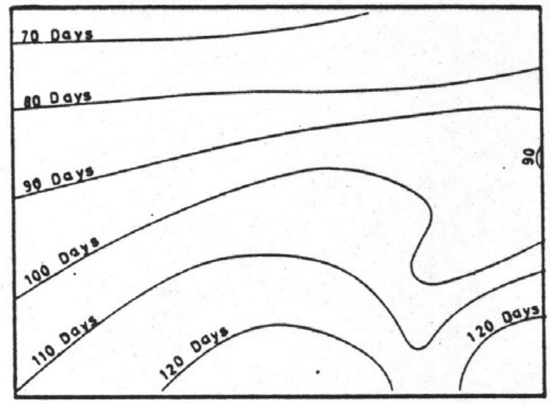


Fig. 12

Isohyet _ Mean

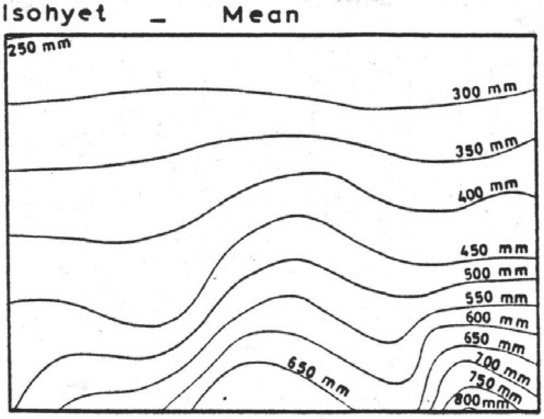


Fig. 15

Mean Initial Drought

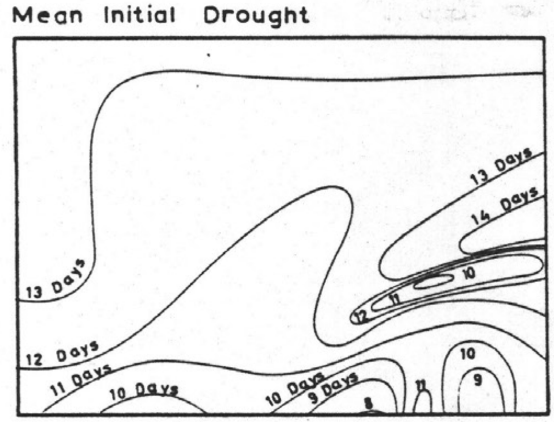


Fig. 13

Isohyet _ 5 Year low probability

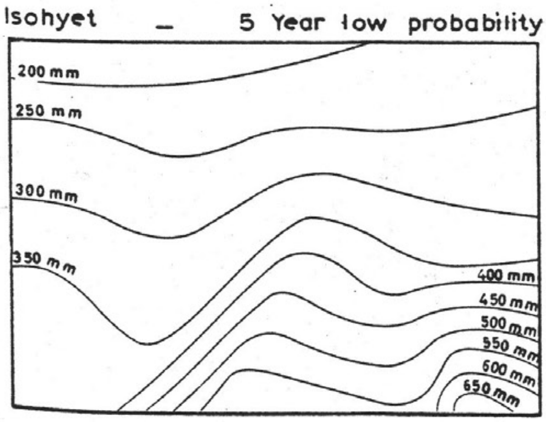


Fig. 16

Mean Annual Evaporation

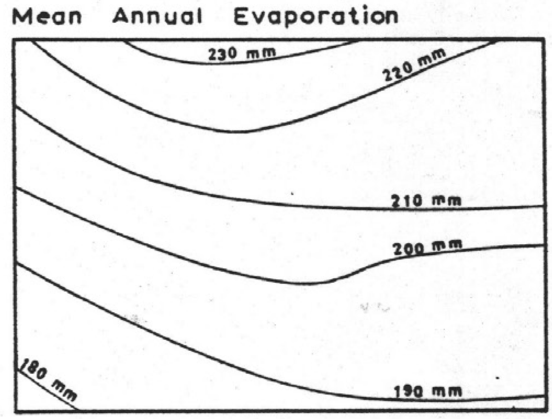
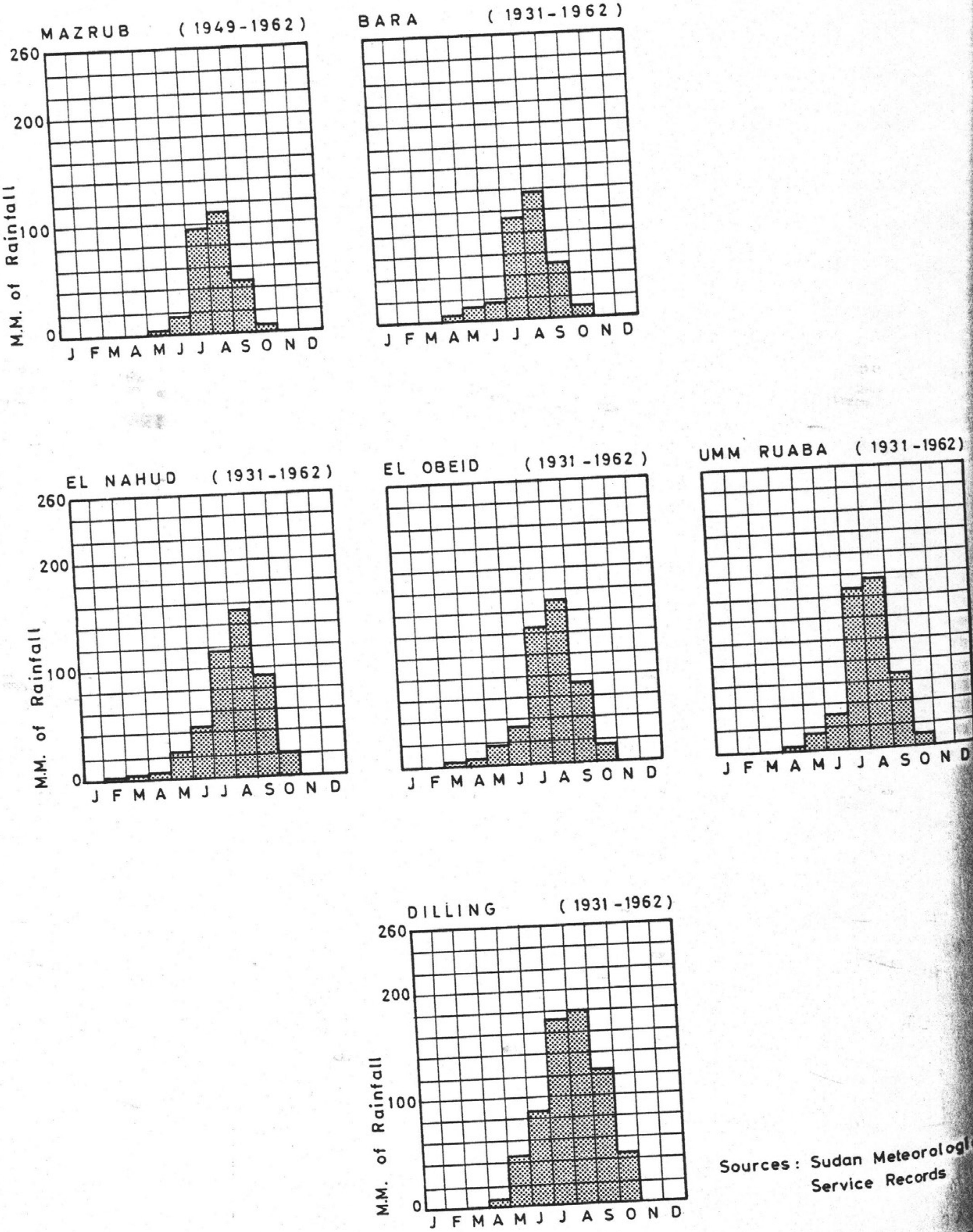


Fig. 17

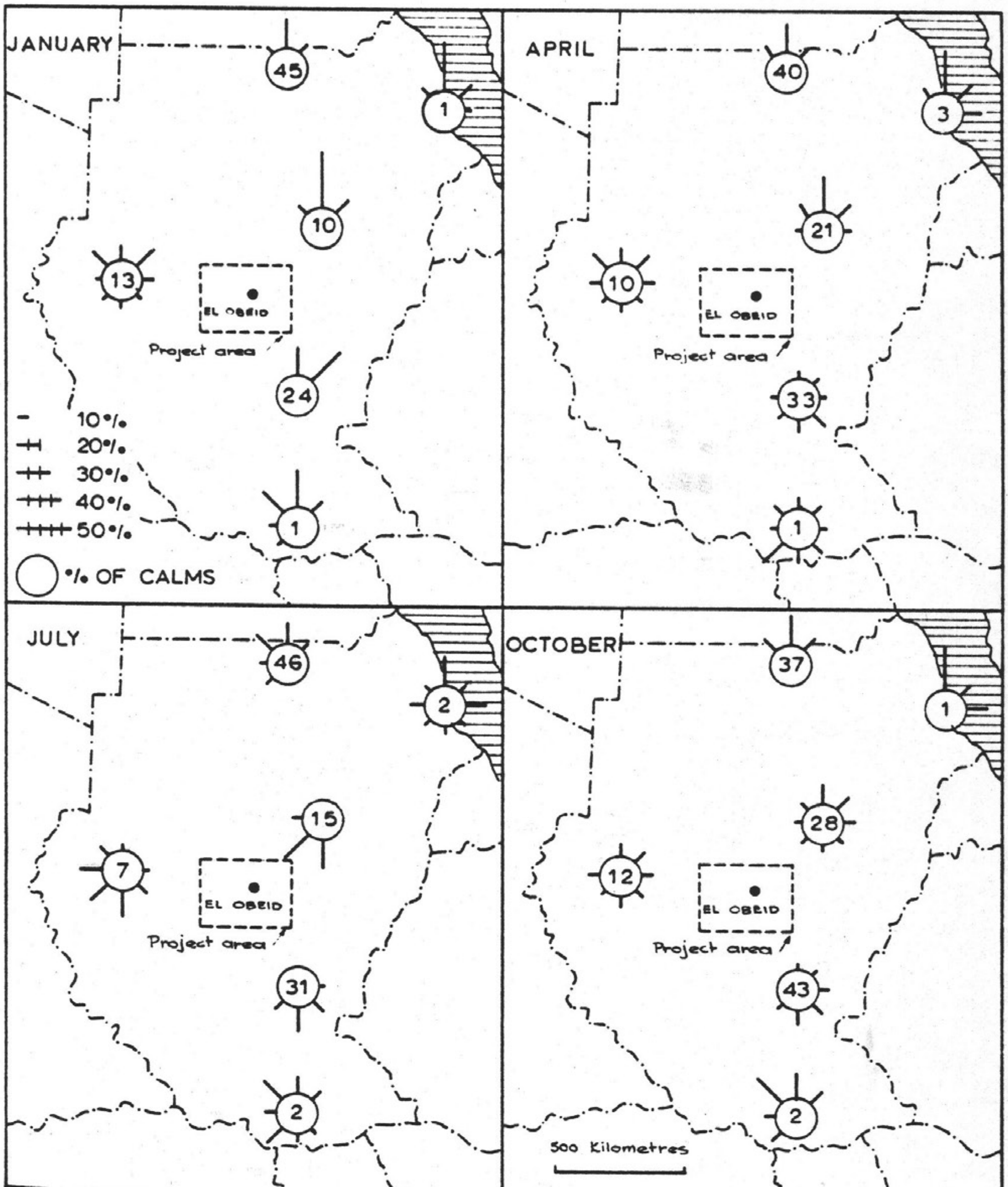
RAINFALL CHARACTERISTICS



Sources: Sudan Meteorological Service Records

Fig. 18

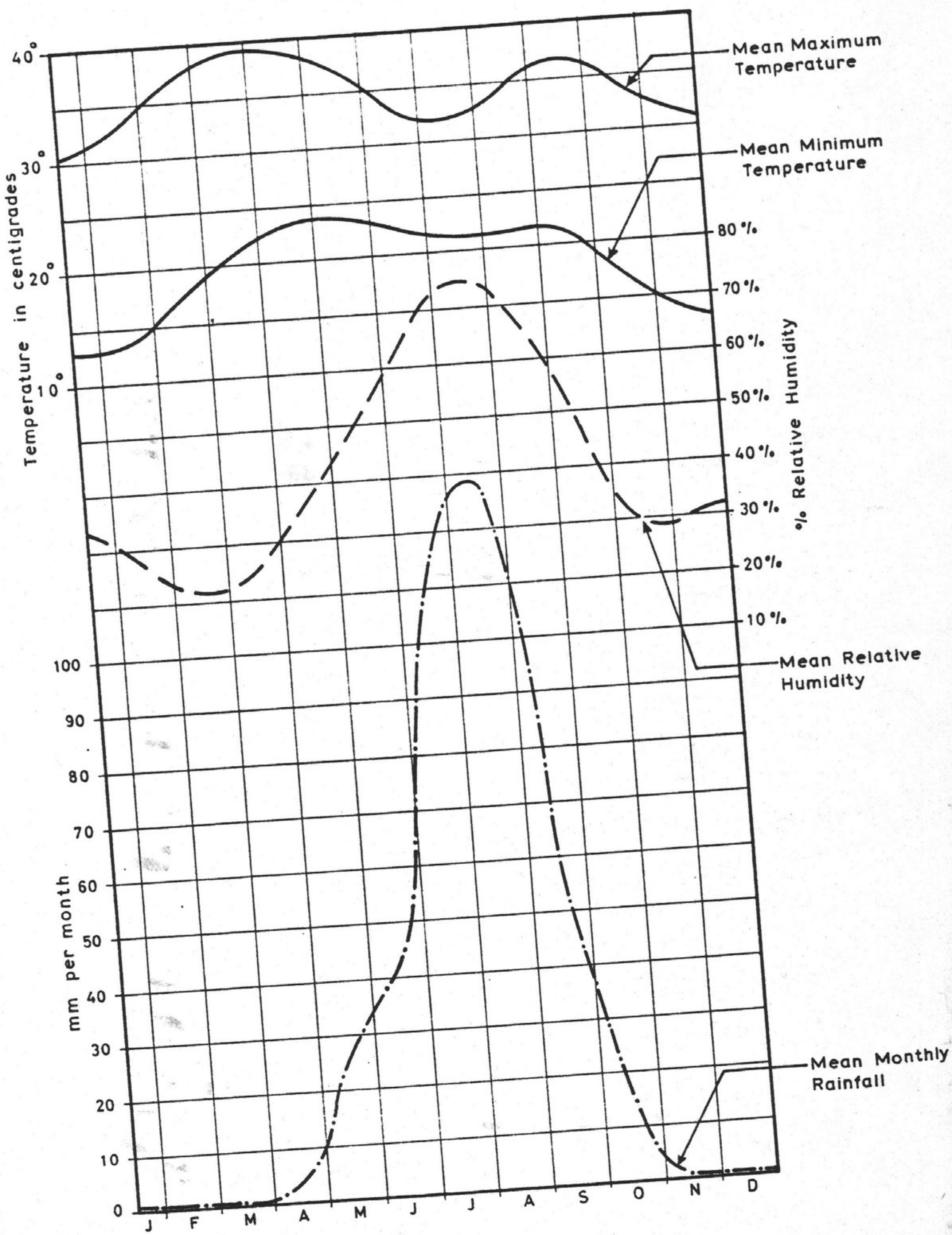
WIND DIRECTIONS AND FORCES



The wind direction diagrams are shown for a number of places in the Sudan, from Barbours Geography, for January, April, July and October.

Fig. 19

CLIMATIC NORMALS AT EL OBEID



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DOXIADIS ASSOCIATES — CONSULTANTS ON DEVELOPMENT AND EKI

TABLE 1

RAINFALL MINIMA

Lowest, and second lowest, on record

Place	Period		Lowest		Second Lowest	
	A. D.	No. of Years	mm.	Year	mm.	Year
Abbassiyah	1938-62	24	488	1960	492	1961
Abu Habl	1946-62	16	210	1960	351	1953
Abu Zabad	1946-62	16	271	1949	296	1961
Bara	1931-62	31	168	1955	206	1951
Dilling	1931-62	31	396	1960	479	1955
El Obeid	1931-62	31	256	1949	274	1941
Nahud	1931-62	31	251	1941	306	1948
Rahad	1931-62	31	300	1942	310	1931
Rashad	1931-62	31	594	1960	611	1940
Sherkeila	1946-62	16	293	1954	307	1941
	COMBINATION:	258	168		206	

TABLE 2

WIND SPEEDS IN M. P. H. AT EL OBEID

	Ann. Average	Maximum	Maximum Gust
January	9.1	23	32
February	9.5	25	35
March	10.1	29	47
April	7.1	26	40
May	7.0	24	61
June	8.8	30	69
July	10.4	27	74
August	7.9	28	67
September	5.5	25	58
October	6.5	23	51
November	7.8	25	32
December	8.7	21	33

TABLE 3

AVERAGE ANNUAL MEAN WIND SPEED M. P. H.

Oklahoma City	USA	11.4
Plymouth	UK	11.2
Helwan	Egypt	10.7
Aberdeen	UK	9.7
Khartum	Sudan	9.6
El Obeid	Sudan	8.2
Baltimore	USA	7.7
Kew	UK	7.6
Phoenix	USA	5.8
El Fasher	Sudan	5.0
Wau	Sudan	3.8
Juba	Sudan	2.1

SOILS AND LANDFORMS

The Desert, The Goz and The Clay Plains

168. Fig. 20 is a sketch-map of the Sudan, and on it there are three zones: The desert in the north, a region called the "Goz" belt in the middle, and the clay plains to the south and east of the Goz.

Goz and Gardud Soils

169. The goz lands have reddish sandy soil. Much, or most of it was deposited by the wind in past geological ages. Over big stretches, the sandy profile may go very deep, ten or twenty metres down without any marked stratification.

170. These goz soils are extremely pervious. The rain soaks in quickly. There is virtually no run-off, so there are no surface drainages or streams. Goz country, by the understanding of the word, is land which is sandy enough to be cultivated easily by hand. The word has a specific "land-use" significance. In its quality of ease of cultivation, goz soil stands in contrast to a second generalised type, which is locally called gardud. This soil is red and hard. Unlike the black soils of the clay plains (Fig. 20) it does not crack when it dries. It is too hard to cultivate by hand-power. On the other hand, the gardud soils are inherently more fertile than the goz.

171. Fig. 21 shows generalised, inclusive envelopes of the whole of the goz (within the Project Area) and the whole of the gardud, with distinctive hatching but with no other features, so that the mutual relationship can be seen without confusion.

172. This very simple classification of the soils in two dominant zones, goz and gardud, has a very practical significance in relation to present and future land use. The geographical pattern shown in the simplified map of Fig. 21 constitutes the main frame of reference for much of the discussion which follows and it is, therefore, useful to have it firmly fixed in mind before looking at the soil classifications in more detail.

Details of Soils and Geomorphology

173. A full description, with details of the sampling analyses, is given in Volume II (Report on Mapping) illustrated by the 1:250,000 set of maps, showing soils and geomorphology. Fig. 22 in the present Report is a version of the map to a scale of 1:1,000,000. The geology, to the same scale, is shown in Fig. 23.

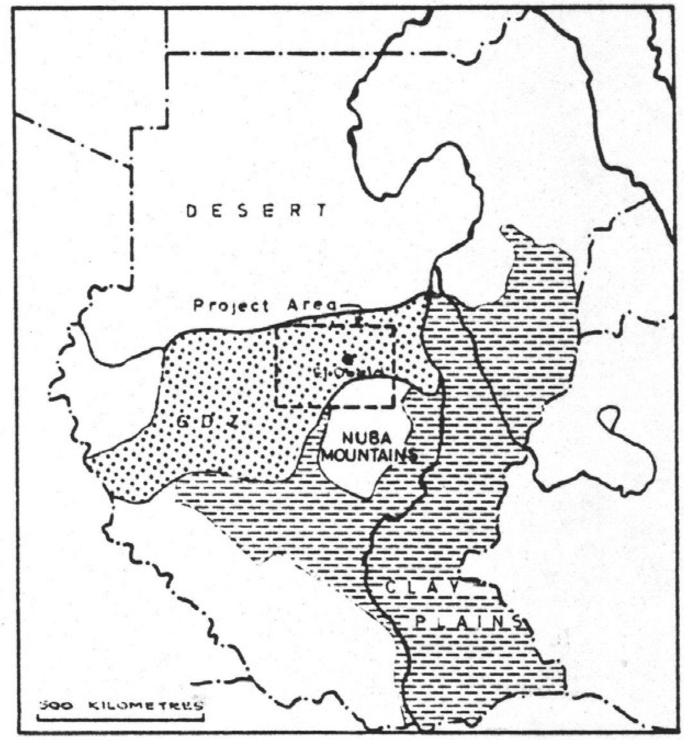
174. There is a close correlation between the various land forms and the soils. The topography is a gently undulating erosion surface, cut in past geological time across the Basement Complex and the Nubian Series of rocks. Soils developed on this surface. In more recent geological times, the northern half of this erosion surface has been covered by deposits of wind-blown sand, and sands and clays were deposited in the river valleys by the action of running water.

175. Soils formed in situ from the rocks of the Nubian sandstones ("Sandy Pedi-plain")are generally strongly acid, red or reddish brown sandy loams. The soils formed in situ from the rocks of the Basement Complex are more varied in character and their topographic position is important ("Clayey Pedi-plain", locally called gardud). On freely drained ridge crests and convex slopes, strongly acid reddish brown sandy loams have developed, which show a marked increase in clay content down the profile. The subsoil is permeable to water. On concave slopes, the soils are also reddish brown sandy loams with an increase in clay content down the profile. They have an alkaline reaction and the subsoil is much less permeable than the soils on the ridge crest positions. On the lower foot-slopes, dark grey brown alkaline soils have developed, which are only very slowly permeable to water.

176. The soils formed from the wind-blown sand are all rather similar in spite of the great variation in dune types ("Sand sheets and dunes" locally called "goz"). In general, they are neutral to slightly alkaline reddish brown sands and loamy sands, very permeable to water.

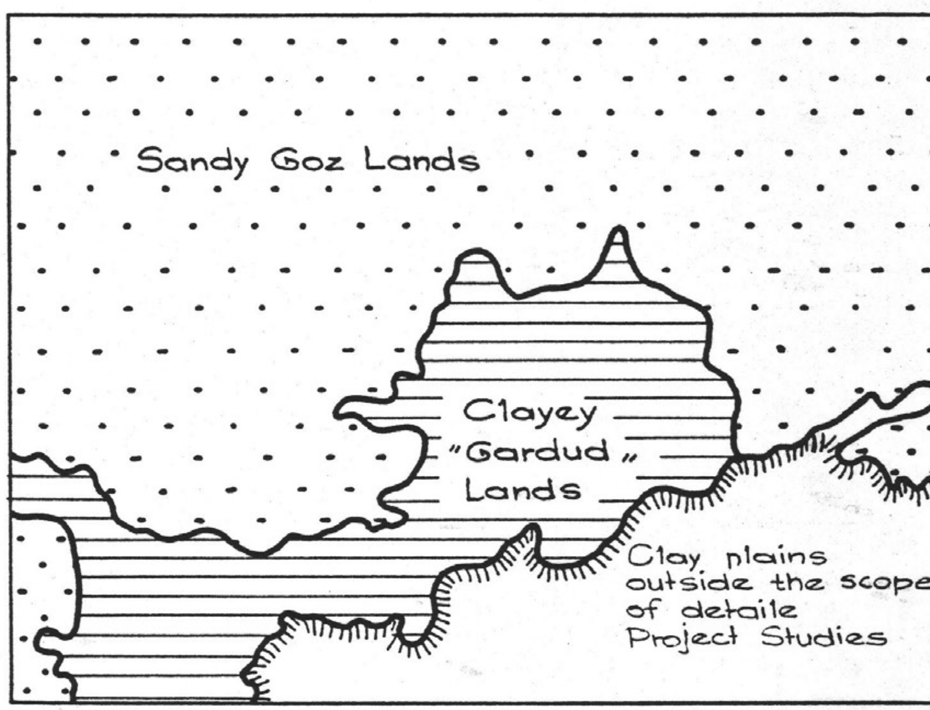
177. In certain low-lying areas on the sand sheet, and in certain inter-dune hollows, geologically-recent lacustrine deposits are found. These lacustrine deposits are also found in the former drainage lines on the old erosion surface over Nubian sand-stones, but not on the erosion surface cut across the Basement Complex.

MAJOR SOIL ZONES IN RELATION TO PROJECT AREA Fig. 20



The Project Area is shown, in relation to the desert to the north and the clay-plains (alluvial and lacustrine) to the south and east with the Nuba mountains an "Island,, just south of the Project Area. The Project Area is a rectangle cut out of the sandy savannah belt known as the Goz

THE GOZ AND THE GARDUD Fig. 21



178. The soils, in general, are deficient in nitrogen and phosphorus. The potassium status is generally good. Organic carbon content is low in most soils. Calcium and magnesium values are low throughout the area of sandy soils and very low on some of the very acid sandy pediplain soils.

179. Many of the more claeye soils have high quantities of exchangeable and soluble sodium.

180. The soils formed on the sand sheets and sand dunes have very low field capacities and a low content of available moisture. Permeability is high. The acid sandy soils on the old erosion surface are reasonably permeable even at depth and retain a moderate quantity of water in the subsoil, which should be available for plant growth.

181. The soil combinations and the geomorphic units correspond, and the Table below lists them all, with figures showing the percentage of the Project Area which is occupied by each:

TABLE 4

Geomorphic Unit	Soil Combination	% of Total Area
Inselberg and pediment	Nuba	5.44
Sandy pediplain	Abu Zabad	19.36
Clayey pediplain	Kazgeil	10.93
Clay Plain	Magolin	10.52
Alluvial flood plain	Semeih	3.04
Sand sheet & low dune complex	Taloshi	25.79
Longitudinal dunes	El Taiyara	7.47
Transverse dunes	Umm Busha	9.86
Dune complex	Mahbub	6.23
Fluvio-lacustrine deposits	Umm Hassas	1.36

182. Tables 5 and 6 give soil profile descriptions, from the two Field crop Experiment sites at Kaba and Umm Heglig, characteristic of the gardud and the goz respectively.

TABLE 5

THE SOIL PROFILE OF KABA EXPERIMENT SITE (GARDUD TYPE)

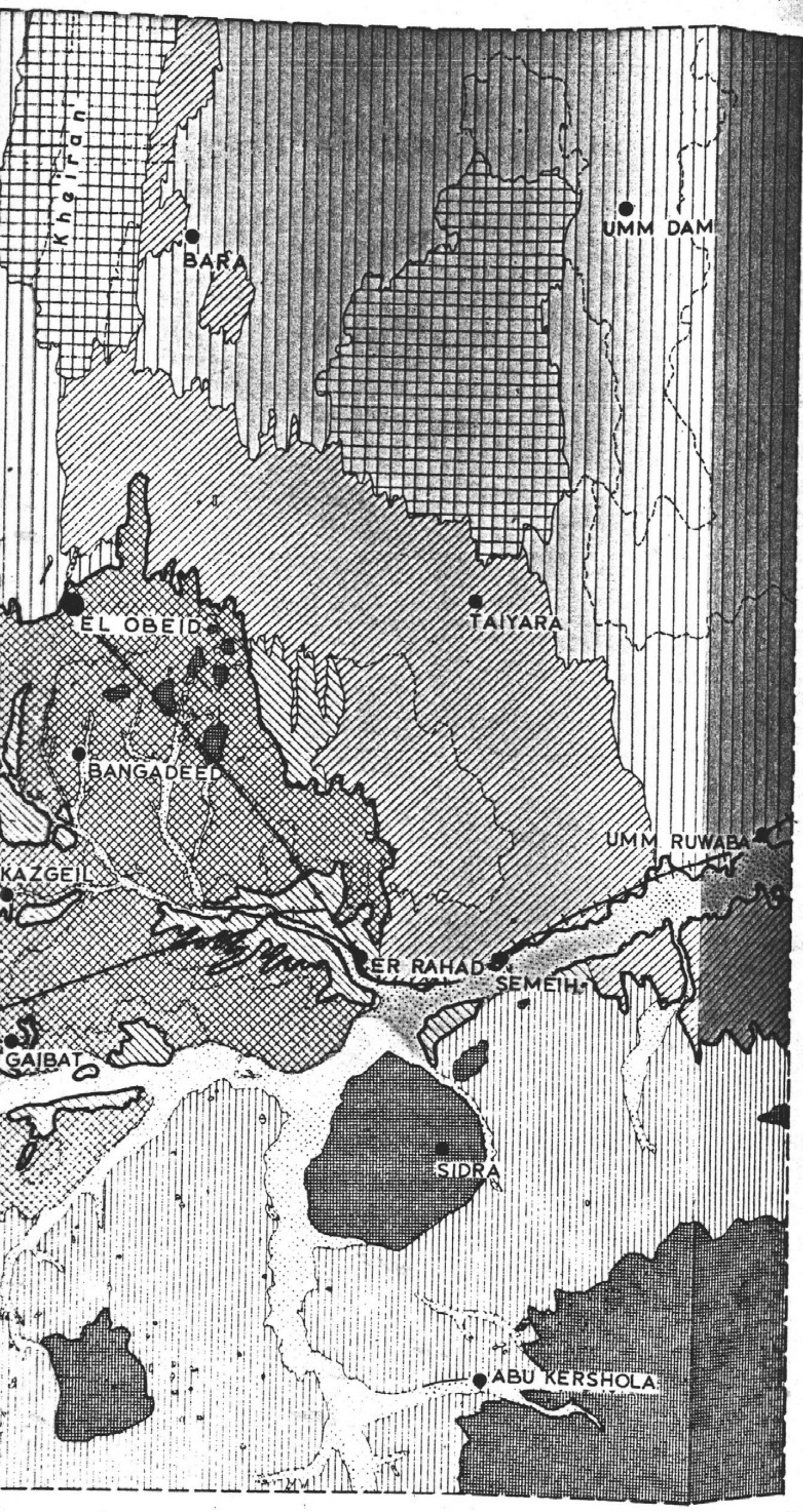
Depth	Description
0 - 20 cm	Yellowish red dry to reddish brown moist sand weak fine subangular blocky, hard dry: friable moist: non-sticky and not plastic wet, few roots: fairly clear smooth boundary.
20 - 55 cm	Yellowish red dry to reddish brown moist. Sandy loam. Undefined columnar structure: hard dry friable moist: slightly sticky and slightly plastic wet, small size of $CaCO_3$ concretions scattered through the horizon. Very few roots.
55 - 105 cm	Strong brown dry to dark brown moist sandy clay loam: structureless massive: very hard dry and slightly friable moist. Sticky and plastic wet. $CaCO_3$ concretions are medium sized and greater in number than above. Transitional.
105 cm	Yellowish brown dry to dark yellowish brown moist. Sandy clay loam. Granular, hard dry, slightly firm moist: sticky and plastic wet. Many big sizes of $CaCO_3$ concretions.

TABLE 6

THE SOIL PROFILE IN UMM HIGLIG EXPERIMENT SITE (GOZ TYPE)

Depth	Description
0 - 20 cm	Reddish yellow dry to brown moist. Sand: structureless massive, hard dry friable moist non-sticky, non-plastic wet: few to many roots: a clear smooth boundary.
20 - 50 cm	Yellowish red dry to reddish brown moist. Sand: structureless massive; hard dry, friable moist; non-sticky and non-plastic wet; very few roots and a gradual smooth boundary.
50 - 130 cm	Yellowish red dry to reddish brown moist. Sand: structureless massive: hard dry, friable moist, non-sticky, non-plastic wet.

Fig. 2



N

LEGEND

GEOMORPHIC UNIT

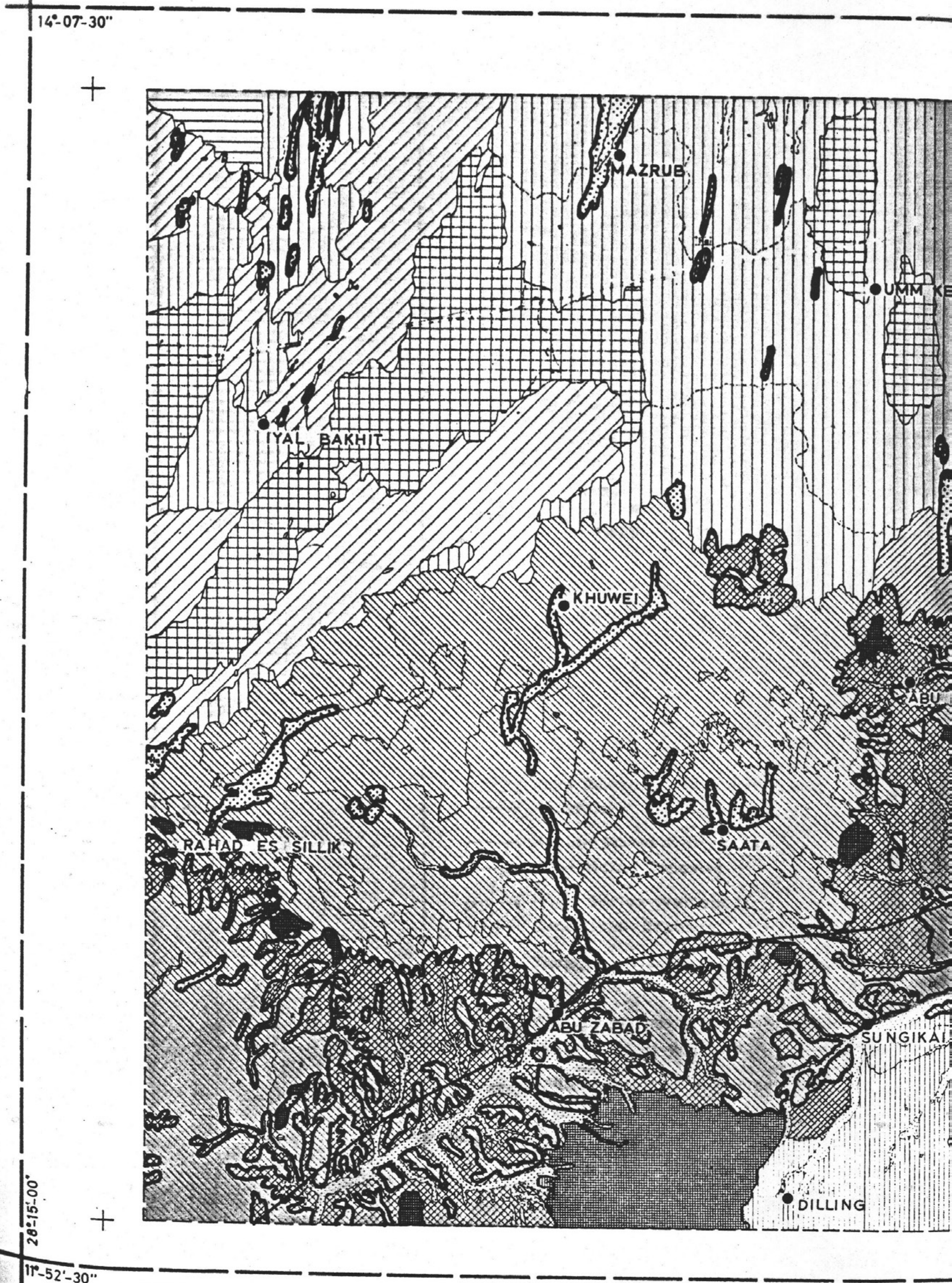
- Inselberg and Pediment
- Surface Drainage Features:
  - Alluvial flood plain
  - Fluvio-Lacustrine deposits
- Clay plain
- Clayey pediplain = Gardud Soils
- Gōz Soils:
  - Sandy pediplain
  - Sand sheet and Low Dune Complex
  - Longitudinal dunes
  - Transverse dunes
  - Dune complex

NOTE

The territory shown washed over in colour lies within the general envelope of the Sandy Goz country and incorporates also the clayey pediplain, i.e. the Gardud soils. The uncoloured S.E. triangle was excluded from detailed studies because it belongs to a different soil system.

Technical Services, London
Surveys Dept.

GEOMORPHOLOGY AND SOILS MAP



SCALE 1:1000000

0 10 20 30 Km.

Reduced in scale from the 1963 maps prepared and printed in colour at 1:250.000 (four sheets)

Fig. 2

N

LEGEND

GEOMORPHIC UNIT

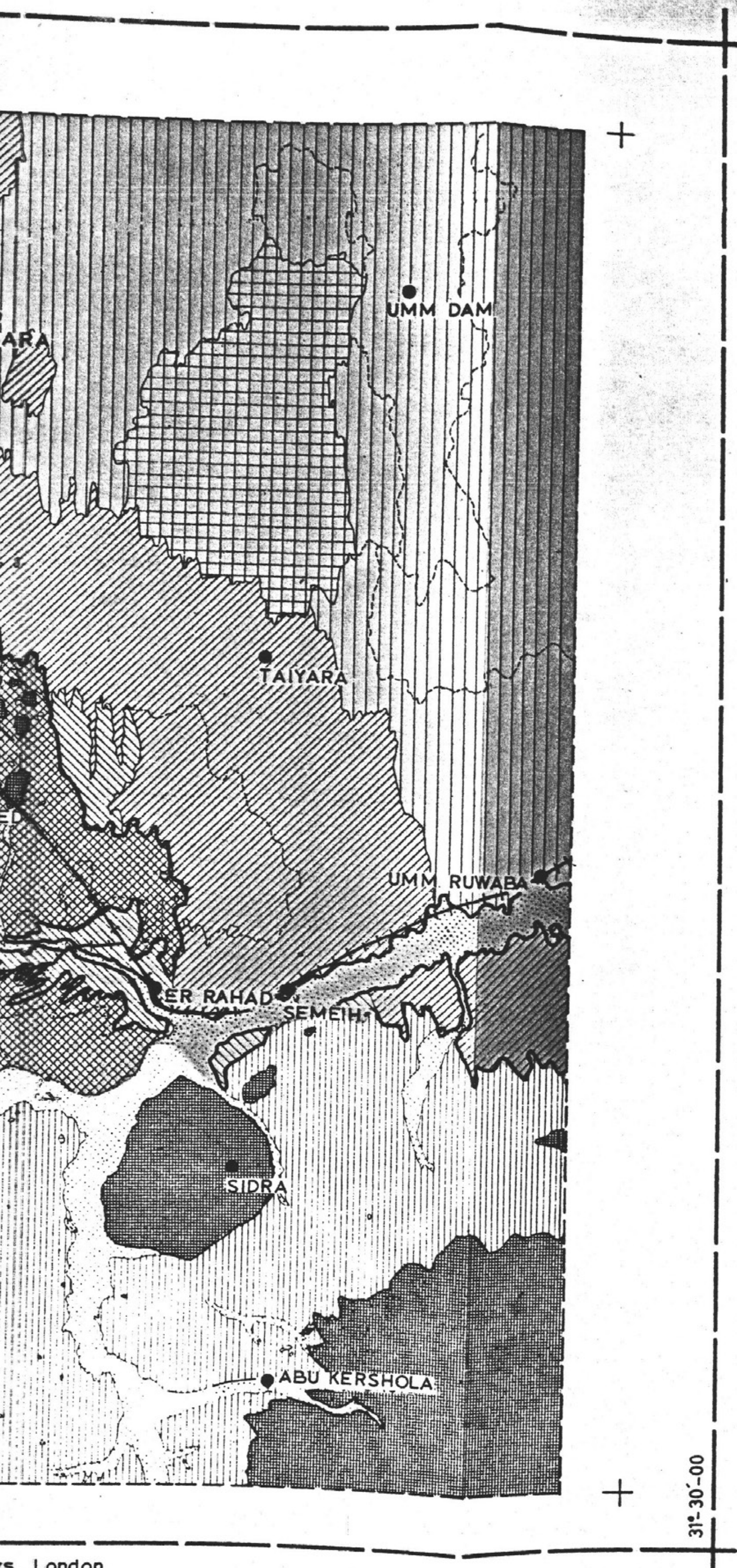
- Inselberg and Pediment
- Alluvial flood plain } Surface Drainage Features
- Fluvio-Lacustrine deposits } Surface Drainage Features
- Clay plain
- Clayey pediplain = Gardud Soils
- Sandy pediplain } Gōz Soils
- Sand sheet and Low Dune Complex } Gōz Soils
- Longitudinal dunes } Gōz Soils
- Transverse dunes } Gōz Soils
- Dune complex } Gōz Soils

NOTE

The territory shown washed over in colour lies within the general envelope of the Sandy Goz country and incorporates also the clayey pediplain, i.e. the Gardud soils. The uncoloured S.E. triangle was excluded from detailed studies because it belongs to a different soil system.

ices, London

Fig. 22



N

LEGEND

GEOMORPHIC UNIT

- Inselberg and Pediment
- Alluvial flood plain } Surface Drainage Features
- Fluvio-Lacustrine deposits } Surface Drainage Features
- Clay plain
- Clayey pediplain = Gardud Soils
- Sandy pediplain } Gōz Soils
- Sand sheet and Low Dune Complex } Gōz Soils
- Longitudinal dunes } Gōz Soils
- Transverse dunes } Gōz Soils
- Dune complex } Gōz Soils

NOTE

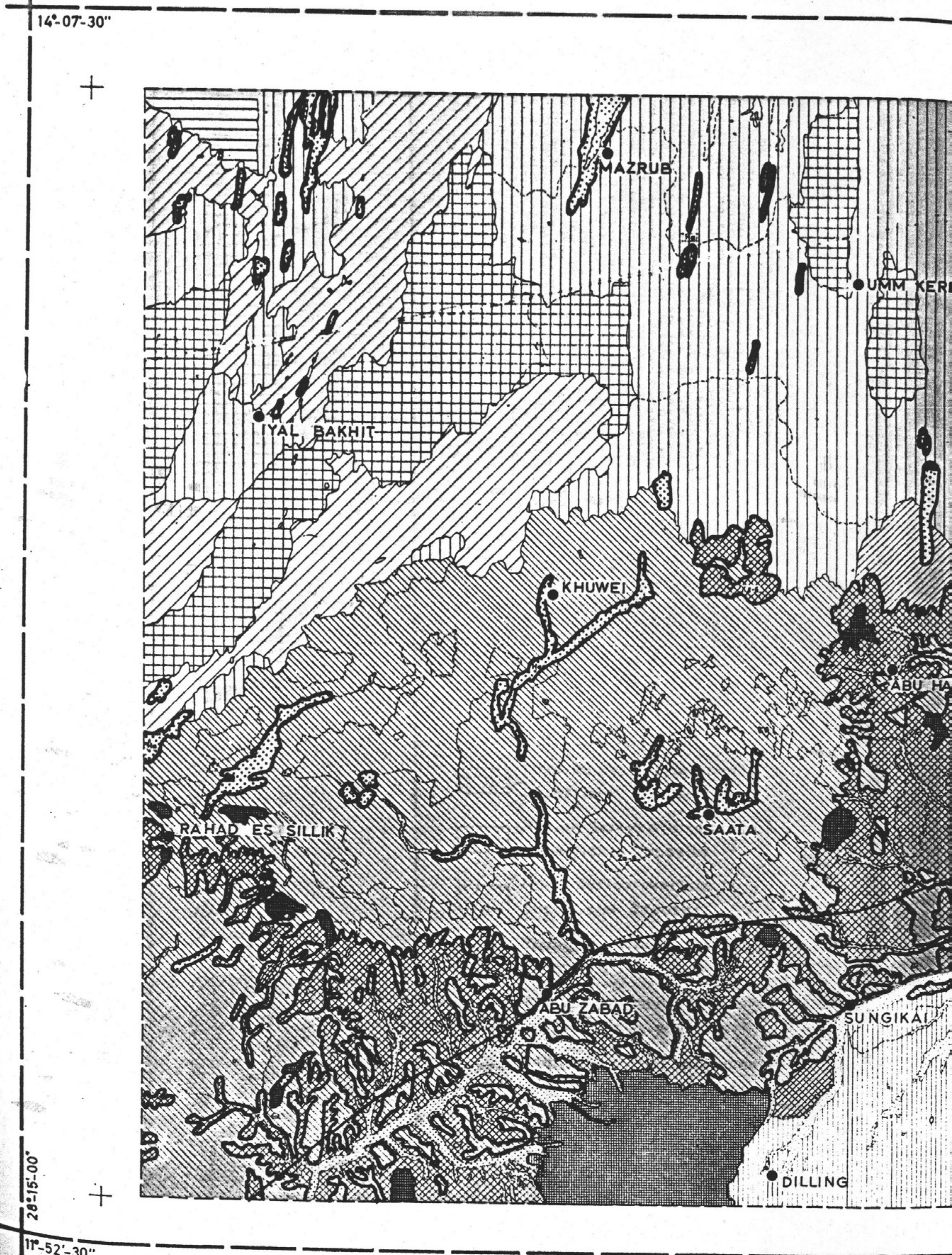
The territory shown washed over in colour lies within the general envelope of the Sandy Goz country and incorporates also the clayey pediplain, i.e. the Gardud soils. The uncoloured S.E. triangle was excluded from detailed studies because it belongs to a different soil system.

GEOMORPHOLOGY AND SOILS MAP

SCALE 1:1000000
0 10 20 30 Km.

Reduced in scale from the 1963 maps prepared by Hu
and printed in colour at 1:250.000 (four sheets) by Su

GEOMORPHOLOGY AND SOILS MAP



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0 10 20 30 Km.

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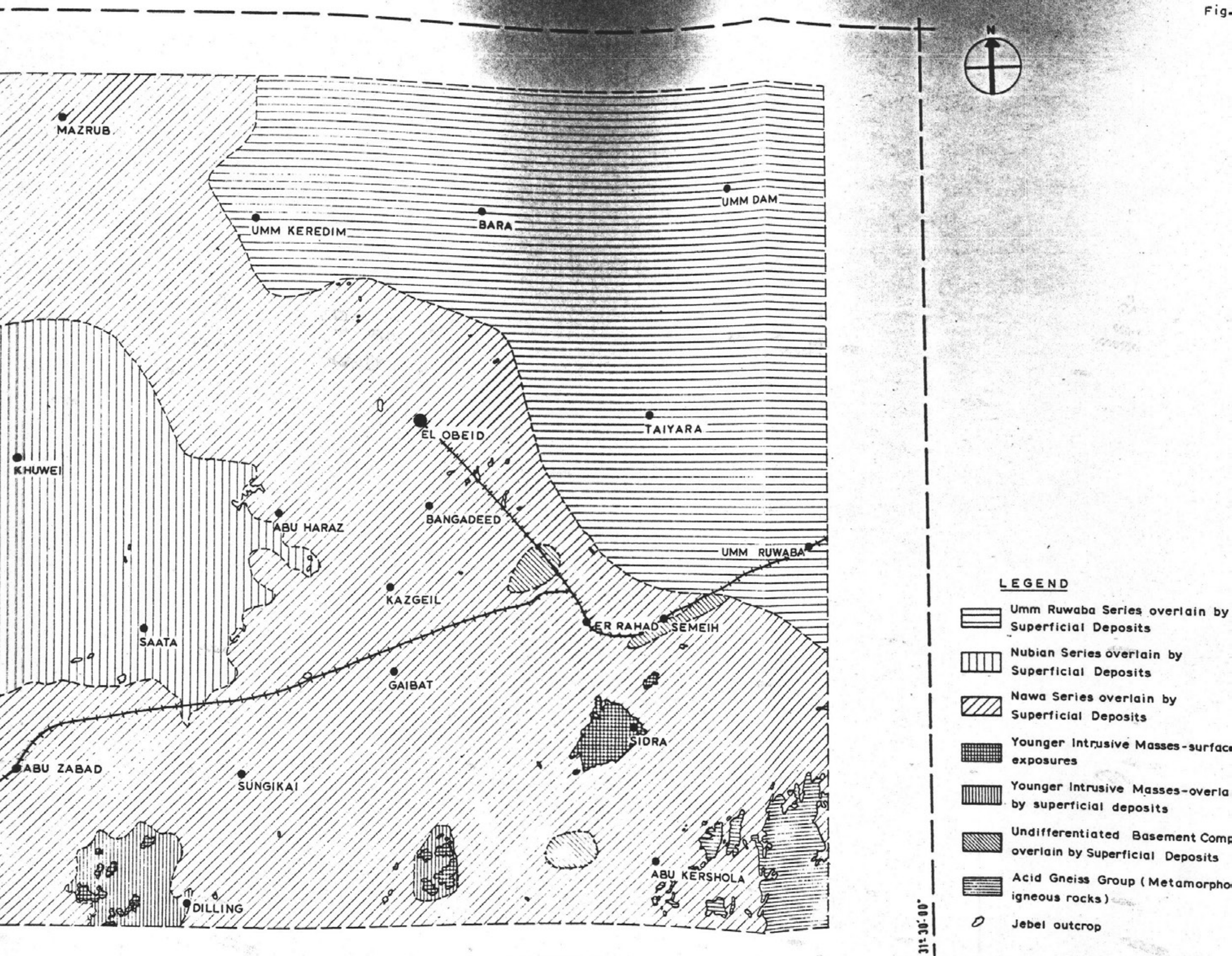
and printed in colour at 1:250.000 (four sheets) b



...ced in scale from the 1963 maps prepared by Hunting Technical Services, London
...printed in colour at 1:250.000 (four sheets) by Sudan Surveys Dept.

DOXIADIS ASSOCIATES - CONSULTANTS ON DEVELOPMENT AND EKIST...

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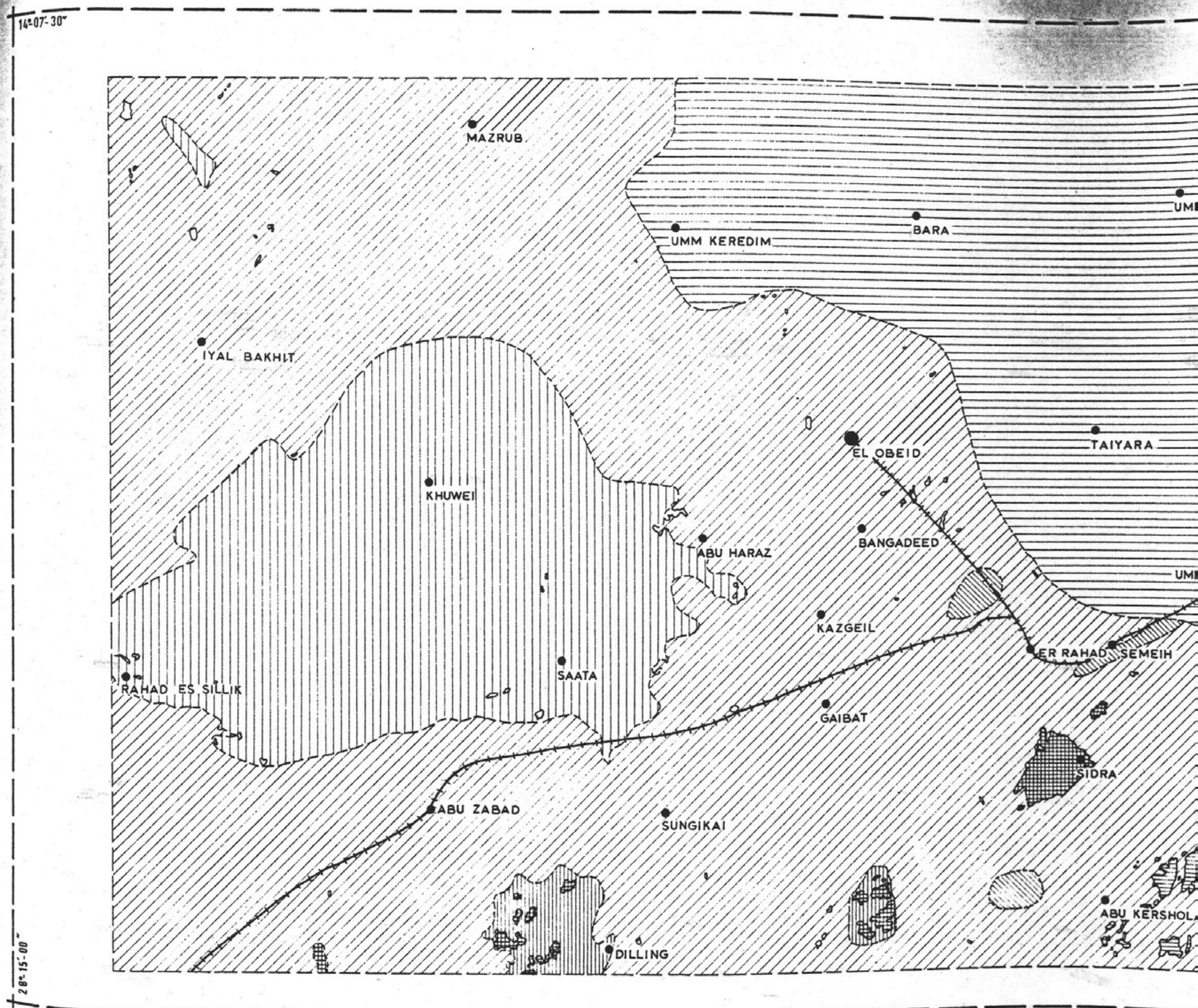
GEOLOGICAL MAP



SCALE 1:1000 000
0 10 20 30 Km

Reduced in scale from the 1963 maps prepared by Hunting Technical Services, London and printed in colour at 1:250.000 (four sheets) by Sudan Surveys Dept.

DOXIADIS A

VEGETATION

183. The vegetation (Fig. 24) is classified on a combination of the physiognomic, climatic and edaphic features. To restrict the formation to the isohyet boundaries is not a satisfactory solution, because the soil type in this region has nearly as important an influence as the rainfall.

184. The areas of the sub-formations and the percentage of the total area are:

Formation		Sub-formation	% of Total Area
Semi-desert Grassland	I	Semi-desert Grassland	4.10
Thorn Savannah	II	Acacia senegal Savannah on sand	45.96
	III	Acacia seyal - Balanites Savannah on Clay	6.72
Thorn Scrub	IV	Acacia Mellifera Thornland on hard soils	12.36
	IVR	Riparian Vegetation	5.10
Savannah Woodland	V	Combretum - Albizzia - Terminalia Savannah Woodland	22.29
	VI	Jebel and Rock Outcrop and Pediments	3.48

185. Volume II (Report on Mapping) contains full details, accompanied by the coloured maps to a scale of 1:250,000.

186. In this general discussion, attention is drawn specially to two trees: the acacia senegal or gum acacia which produces gum arabic, and the tebeldi tree (baobab) which is traditionally hollowed out, while still living healthily, and used as a tank for storing rainwater for use in the dry season.

Gum Acacia and Tebeldi

187. Plates 8 to 11 show pictures of the gum acacia, the tebeldi, and other features of the vegetation. Fig. 25 shows the gum acacia and the tebeldis in relation to the goz and gardud soils, the fluvio-lacustrine depressions, and the surface drainages.

188. The gum acacia favours the goz soils except for the big islands of sandy pediplain which overlies the Nubian sandstone, where it is conspicuously absent except for the serpentine depressions, with fluvio-lacustrine deposits.

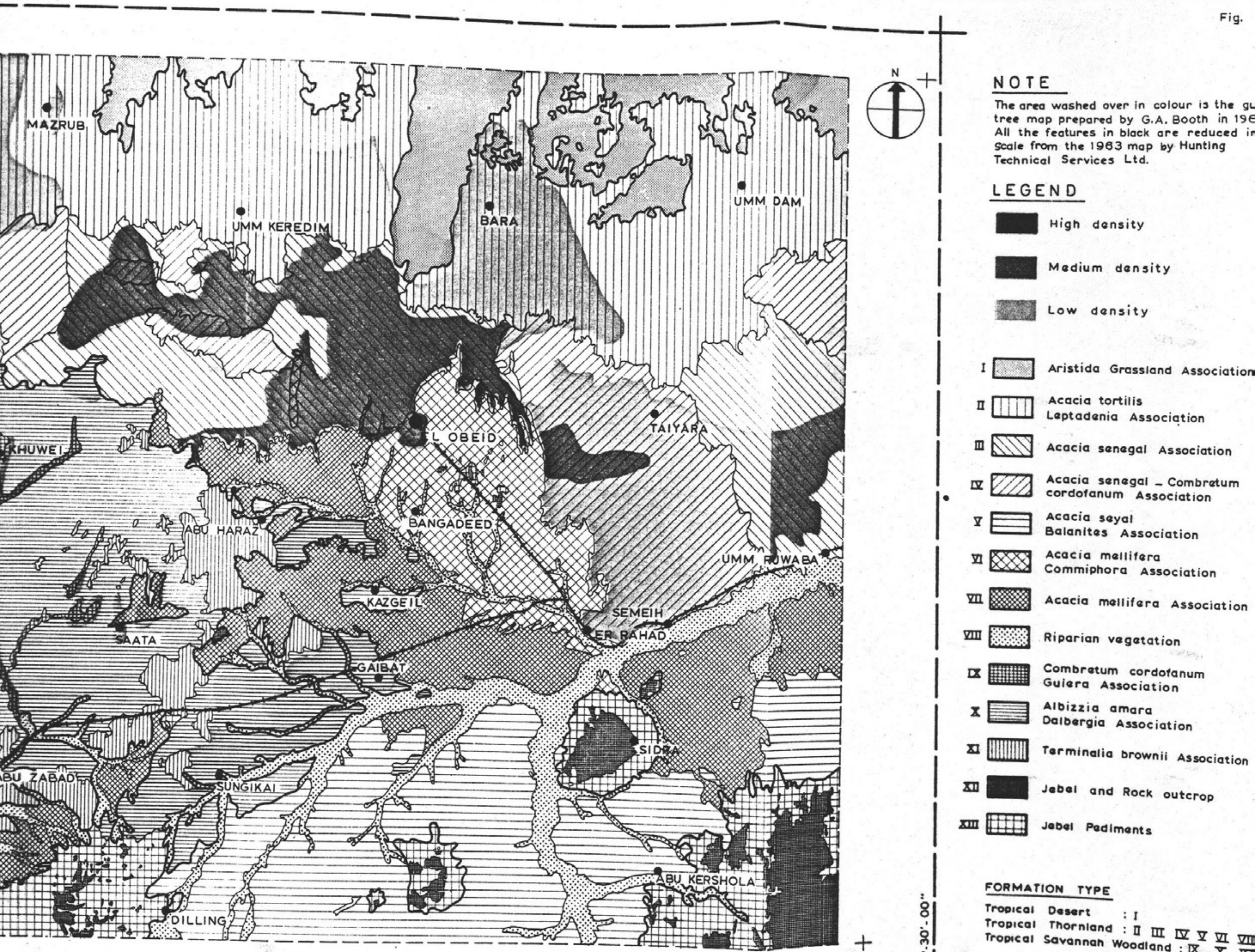
189. The tebeldi tree is particularly important in its association with these fluvio-lacustrine depressions which also lie over the Nubian sandstone. By using tebeldi trees for water supply, villages could be settled in places where there were no other available water sources.

Other Vegetation

190. The legend on the right-hand side of Fig. 24 shows the range of vegetation, with the areas coloured. The acacia senegal (Arabic "Hashab") favours the sand sheet and low dunes, the longitudinal dunes, transverse dunes, and dune complex. It does not favour the sandy pediplain or the clayey pediplain (gardud).

191. The sandy pediplain carries, predominantly, the Albizzia Amara-Dalbergia (Arabic "Arrada") Association. The gardud and the Acacia Mellifera, (Arabic "Kitr"), and in some parts Commiphora (Arabic "Gafal") go together.

Fig.



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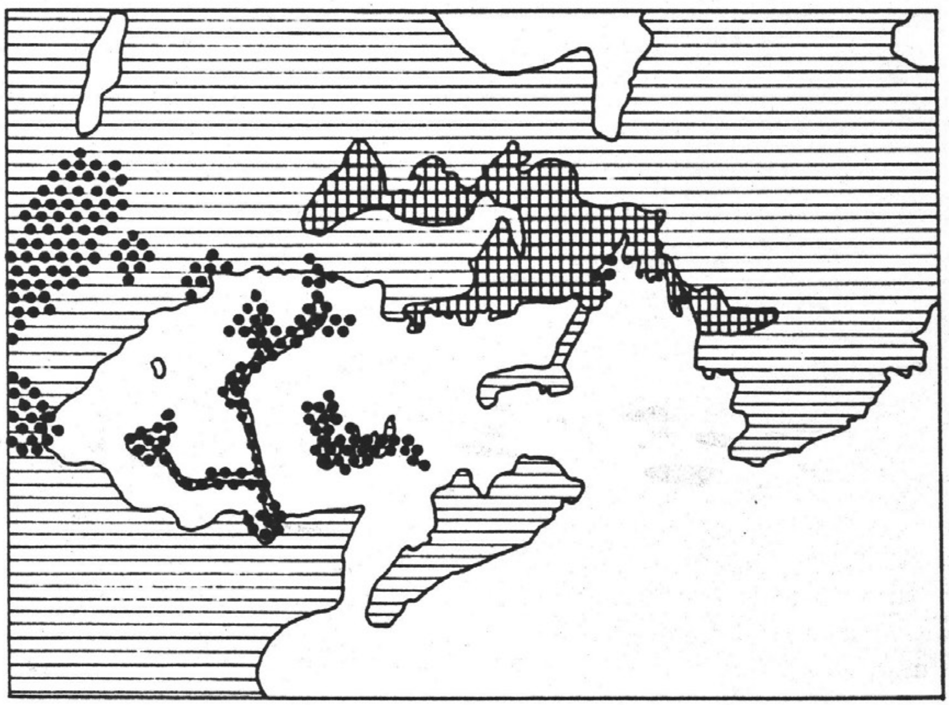
VEGETATION MAP

ACACIA SENEGAL AND TEBELTI TREE DISTRIBUTION

Fig. 25



Legend

ACACIA SENEGAL

DENSE ACACIA SENEGAL

MAJOR TEBELTI TREE AREAS

THE SURFACE DRAINAGE PATTERN

192. The gardud country is cut up by surface drainages, as shown in Fig. 26 illustrating the main basins to small scale. To the east there is the Khor Abu Habl system which comes from the south and west, swings eastwards near Rahad, runs for 150 kilometres to Tendelti, and peters out. To the west is the Wadi Ghala drainage system, which at first runs from east to west, turns south and peters out. The tributary surface drainages in the gardud country carry water intermittently, only during rains heavy enough to generate run-off.

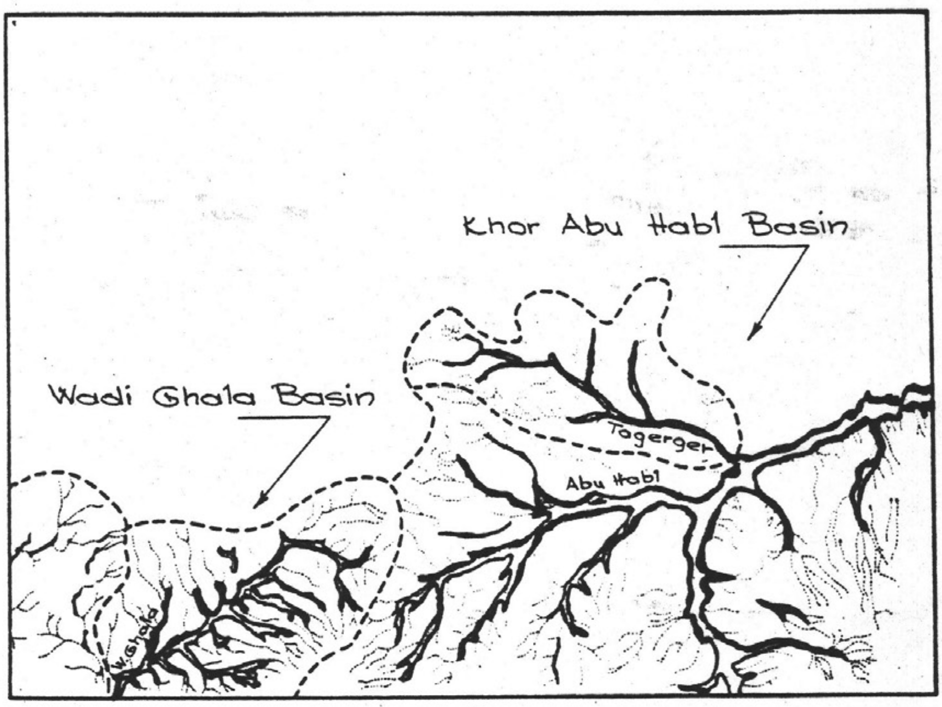
193. The main Abu Habl channel runs like a river, but with big fluctuations, for about three months in the rainy season, being fed from the Nuba Mountain complex which overlaps the southern part of the Project Area and has a comparatively high rainfall.

194. At its main meeting point near Rahad, the Khor Abu Habl has an annual average flow of 90 million cubic metres, which is equivalent to about 5 mm. depth over its basin. This is less than 1.0% of the rainfall. The waterway is about 10 m. bedwidth and 4 m. deep.

195. Only the upper part of the Wadi Ghala basin is included in the Project Area, much smaller than Abu Habl. Once the tributary drainages have joined the main axis of the Wadi the water drifts down the wide dendritic ribbon of the flood-plain, where it may lie for days or weeks, soaking in and evaporating.

SURFACE DRAINAGE BASINS

Fig. 26



Goz and Gardud Patchwork in the Drainage Basins

196. When the drainage pattern in Fig. 26 is compared with the soil pattern in Fig. 22, a relationship becomes clear. Fig. 24 helps to understand it. Fig. 27A asks us to imagine a sandwich with goz on top, gardud in the middle and rock underneath. Now imagine that in millenia of annual rains, the drainage pattern of Fig. 26 is cut down through the sandwich.

197. Characteristically it leads to cross sections like Fig. 27B. The result is a branching system filled with alluvium, and islands and tongues of sandy goz with gardud between. Another glance at Fig. 22 helps to get the picture clear - see, especially, round Abu Zabad.

198. A very short explanation of what the Project is about might well be: "The goz and gardud lands in Kordofan: - how the people are using (or not using) them now - the difficulties they are getting into - and what they can do about it".

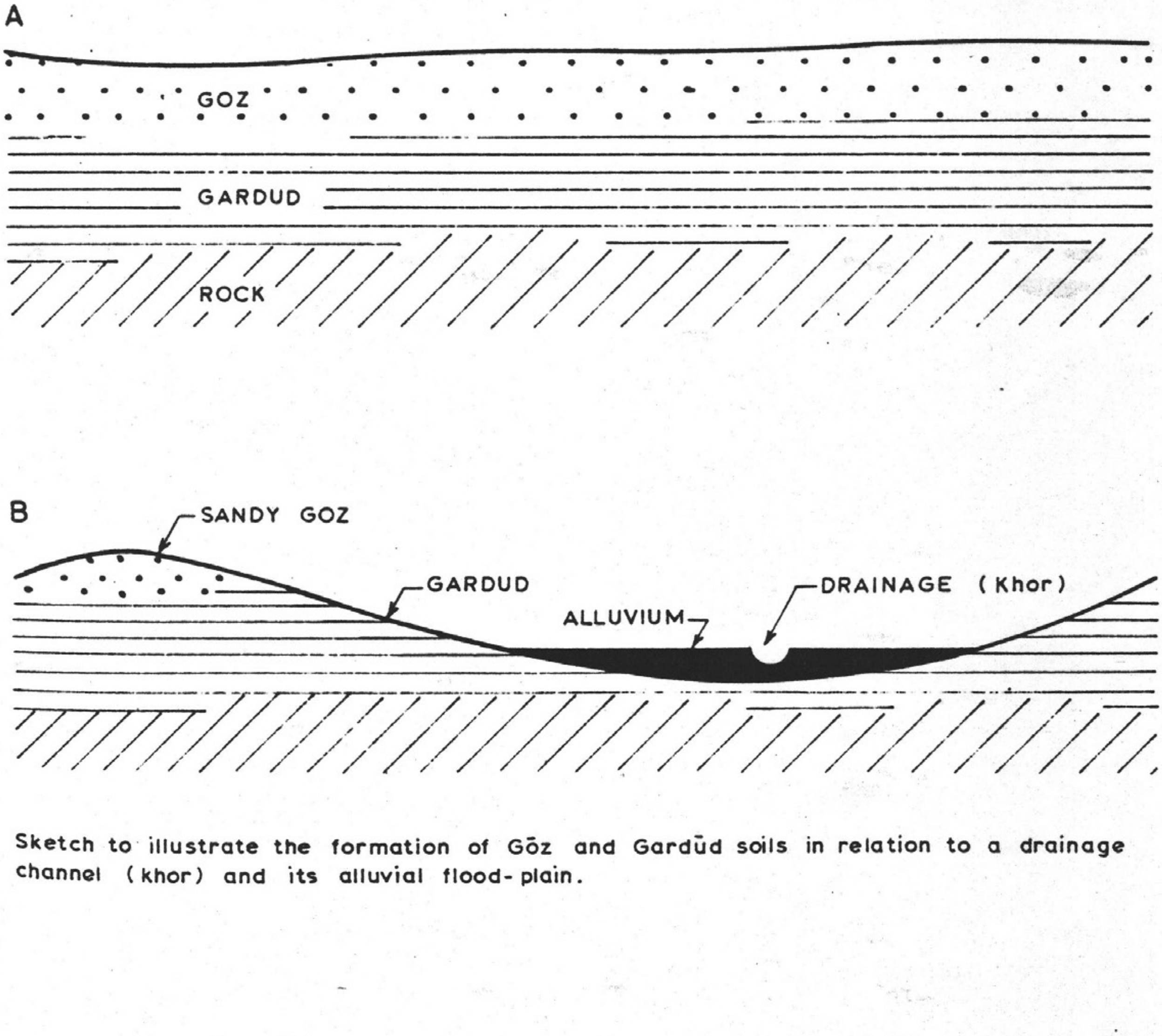
Exclusion of the S. E. Corner from the Detailed Studies

199. As Fig. 20 shows, the rectangle enclosed by the Project boundaries only takes in a part of the goz/gardud belt. It was, in fact, intended as a sample. It was hoped and assumed that the surveys and investigations of the Project would not only provide answers to the Project Area itself, but would be applicable also to the other parts of the goz belt. Although the work of the Project is necessarily confined to the Project area itself, it is always with an eye to extensions into the whole of the goz belt, as shown in Fig. 20.

200. It will be seen (Fig. 21) that the rectangular boundaries of the Project Area cut off a triangular slice of the Clay Plain, and part of the Nuba Mountain complex. By common agreement it was decided that as this is a more or less accidental inclusion of a bit of territory belonging to a system which is totally different from the goz, it would not be included in the detailed investigations. Since the air-photography covered this corner, the Basic Survey and mapping work also covered it, so that the five sets of technical maps are complete, within their rectangles. But there were no agricultural field trials, observations and surveys in this south-east triangle.

DISSECTED PATTERN OF GOZ AND GARDUD

Fig. 27



Sketch to illustrate the formation of Gōz and Gardūd soils in relation to a drainage channel (khor) and its alluvial flood-plain.

201. The two broad envelopes in Fig. 21, i. e. the goz and gardud, represent the whole of the land-area under survey, since they cover the whole of the rectangle except the south eastern triangle which is omitted from the studies for reasons given above.

The Sandy Pediplain and the Fluvio-Lacustrine Depressions

202. As has already been stated, the pattern of goz and gardud, shown simply in Fig. 21, provides a fundamental frame of geographical reference. Two subdivisions now need to be introduced, which are the "Sandy Pediplain" and the "Fluvio-lacustrine Depressions", the latter being what now remains of freshwater lakes during the last pluvial period. These further subdivisions are shown in Fig. 28.

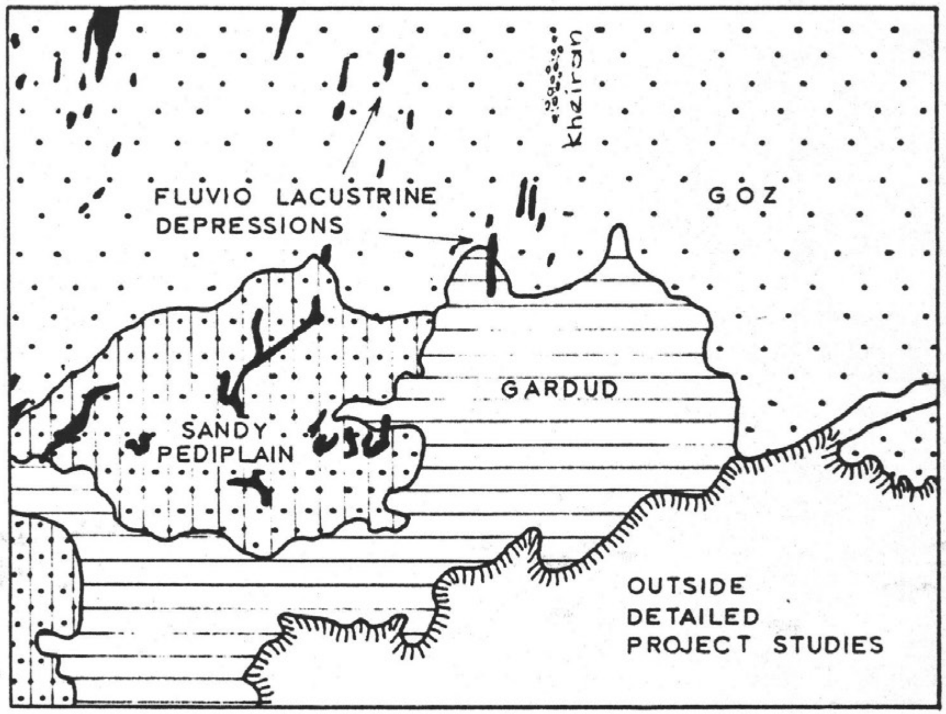
203. There are three different types of fluvio-lacustrine deposit. The small, oval type, with the axis running roughly north and south, occurs only in goz areas where the sand was, beyond doubt, deposited by the northerly winds. These depressions all lie to the south of a jebel (inselberg). The Volume II explains how the northerly wind formed, to the south of these jebels, a pair of downward "trailing dunes", with a depression between them. A diagrammatic cross-section, E/W across one of these depressions is shown in Fig. 29. In the last pluvial period these depressions were fresh-water lakes.

204. The second type of fluvio-lacustrine depression is found only in the big "island" of the Sandy Pediplain (Fig. 28). These have a special significance which will be discussed in the next sub-section.

205. The third type of fluvio-lacustrine deposit is in the depression between the dunes in the Kheiran area, north west of Bara. They are relatively small and their size is exaggerated in Fig. 28 because otherwise they would be invisible. They are important because these depressions often contain dug wells, and because they are situated in hollows between the systems of unstable dunes which is a particular feature of this Kheiran area.

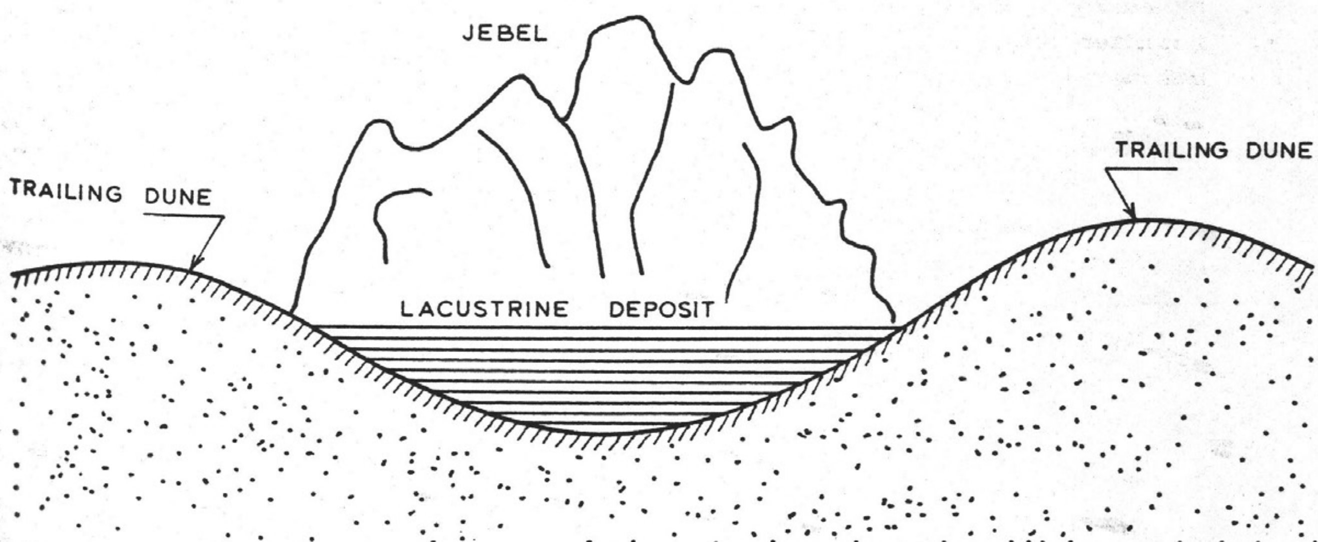
SANDY PEDIPLAIN AND FLUVIO-LACUSTRINE DEPRESSIONS

Fig. 28



CROSS-SECTION E-W TO ILLUSTRATE FORMATION OF TRAILING DUNES

Fig. 29



DIAGRAMMATIC CROSS-SECTION ACROSS A LACUSTRINE DEPRESSION, SOUTH OF A JEBEL, LOOKING NORTHWARDS.

HOW WATER HAS SHAPED THE LANDFORMS

Limits of the Area which is Subject to Water Erosion

206. Fig. 26 shows the boundaries of the Abu Habl and Wadi Ghala drainage basins. Within these boundaries the landforms are clearly subject to re-shaping by water erosion. The area lying to the north of these basins is the permeable sandy goz and sandy pediplain, where the rain water soaks in so fast that there is virtually no surface run-off.

207. The drainage basins correspond with the gardud soil types, and these are the present limits of the area where water as well as wind has shaped the landforms.

Changes in the Drainage Basins as a Dry Age Succeeded the Last Pluvial

208. It has been explained in Volume II that there was a pluvial period which came after the formation of the wind-blown sand sheets and dunes. During that pluvial period, it may be presumed, the drainage systems of the Khor Abu Habl and the Wadi Ghala must have flowed perennially, as tributaries to the Nile (see Fig. 30) and there was presumably a northward-flowing system also, from the main E-W watershed.

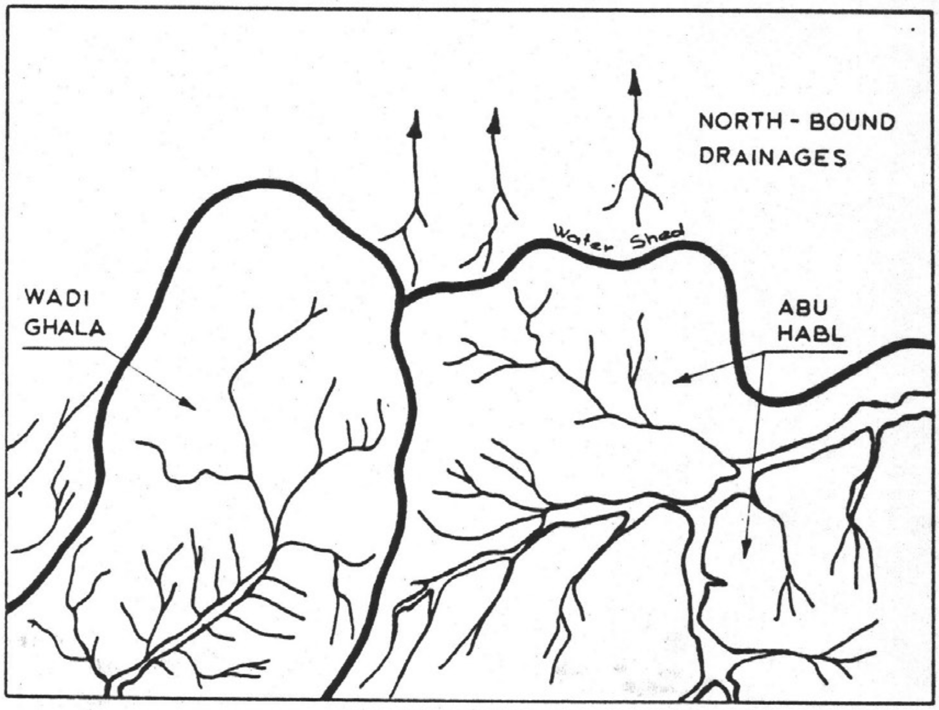
209. As the pluvial period was succeeded by a drier age, accompanied by renewed sand-blowing from the north, changes took place which have resulted in a series of hydraulically separate and smaller drainage basins as indicated in Fig. 31.

The Surface Drainage Pattern, "Then and Now"

210. Basin C, which is the basin of the Khor Tagerger lying between El Obeid and Rahad, discharges into the Rahad Turda (Lake). This is now a sump. Its downstream (eastern) end is closed by a bar, formed partly of alluvium but also, in all probability, helped by sand blowing from the north. The Khor Abu Habl basin, A, is quite separate hydrologically.

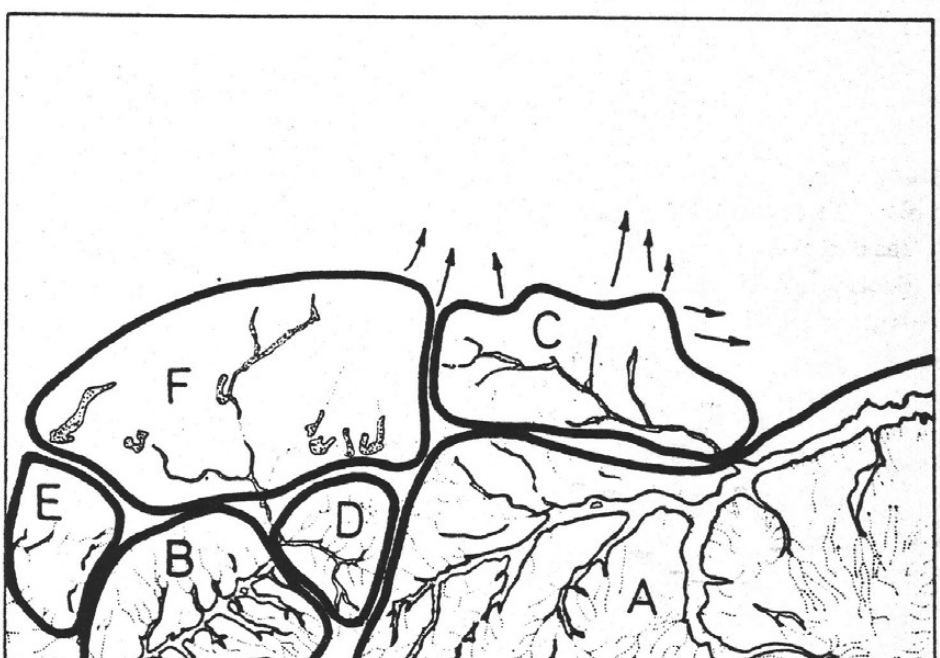
BASINS DURING LAST PLUVIAL PERIOD

Fig. 30



PRESENT - DAY BASINS

Fig. 31



A... KHOR ABU HABL
B... WADI GHALA
C... KHOR TAGERGER
D... ABU ZABAD
E... SMALL KHORS
F... SANDY PEDIPLAIN WITH LACUSTRINE SERPENTINES

211. The Abu Zabad basin (Fig. 31, D) ends in the Abu Zabad Turda (Lake) and it is only in exceptionally rainy years that this lake over-spills the bar at its downstream end (S. W.) and sends water down as a contribution to the Wadi Ghala, B. But before the climate changed after the last pluvial period, this area D must have been (see Fig. 30) a small section of the Wadi Ghala's upper basin.

212. Fig. 30 suggests that the areas F and D were at that time integrated hydraulically, being the head-waters basin of the Wadi Ghala system. As the climate got drier, and as the sand blew from the north, area F was choked with sand, and then the lakes dried up, while area D, fed by higher rains from the mountains round Dilling (Fig. 32) escaped being choked, but turned into a closed system ending in the sump at Abu Zabad.

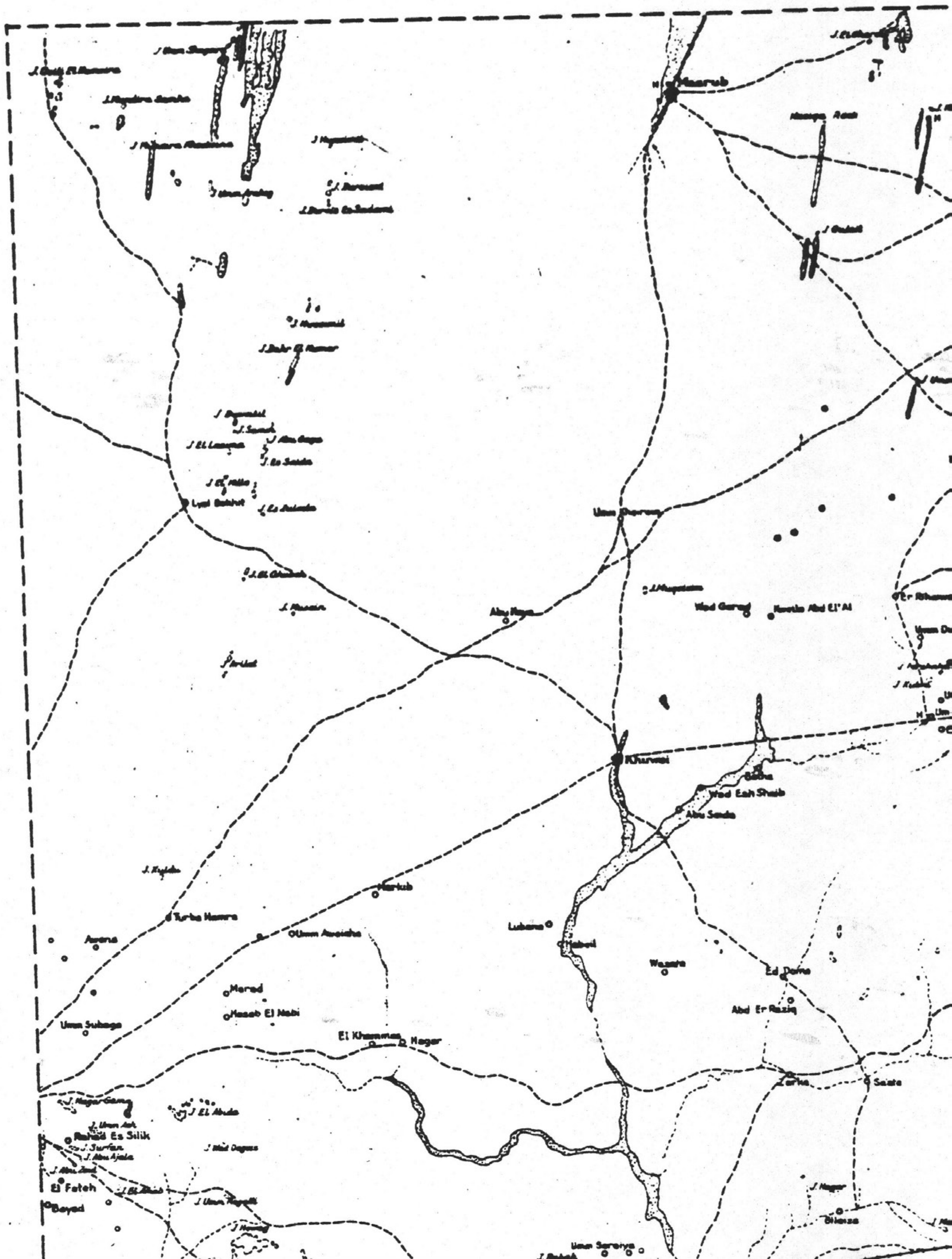
213. Area E in Fig. 31 seems to represent a stage of change inter-mediate between D and F. Unlike F, there are a number of surface drainages which still flow in the rainy season, running N. E. to S. W. But they no longer join into one channel, as still happens in D; it is as if the process of sand-submergence has obliterated the main channel and has isolated the small tributaries, separately.

214. Each of these small, closed systems in area E is similar. It rises on the junction (to the N. E.) of the sandy pediplain and the clayey pediplain. Several small tributaries run together and join into a single channel. Then the soil changes. The stream meets the S. W. belt of sand, laid down by the wind, which has submerged the entire lower part of the drainage system. Permeability is high. The stream struggles on, losing volume. The slope flattens and then reverses as the wind-blown bed of sand deepens. The stream dies. Where the stream flattens out and ponds up, in the S. W. sands, there may be accumulated groundwaters.

215. Zone F is the island of sandy pediplain, which represents the stage when the river valleys have become a string of lakes, and wind-blown sand has submerged almost the whole system, leaving only the broad sallow depressions. Finally the lakes dry up and leave the fluvio-lacustrine deposits which are exposed in the present age.

TOPOGRAPHY

14-07-30°



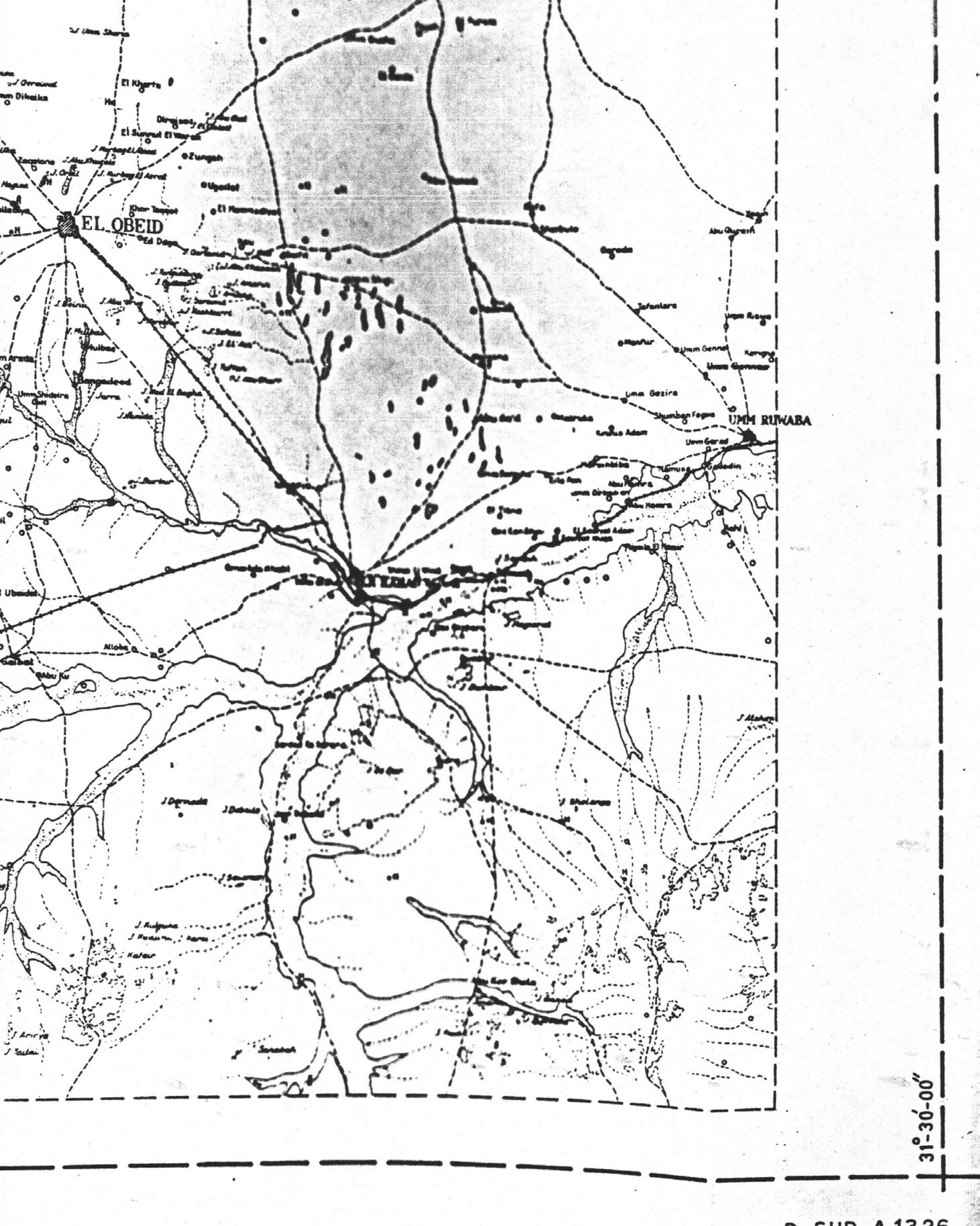

EL OBEID
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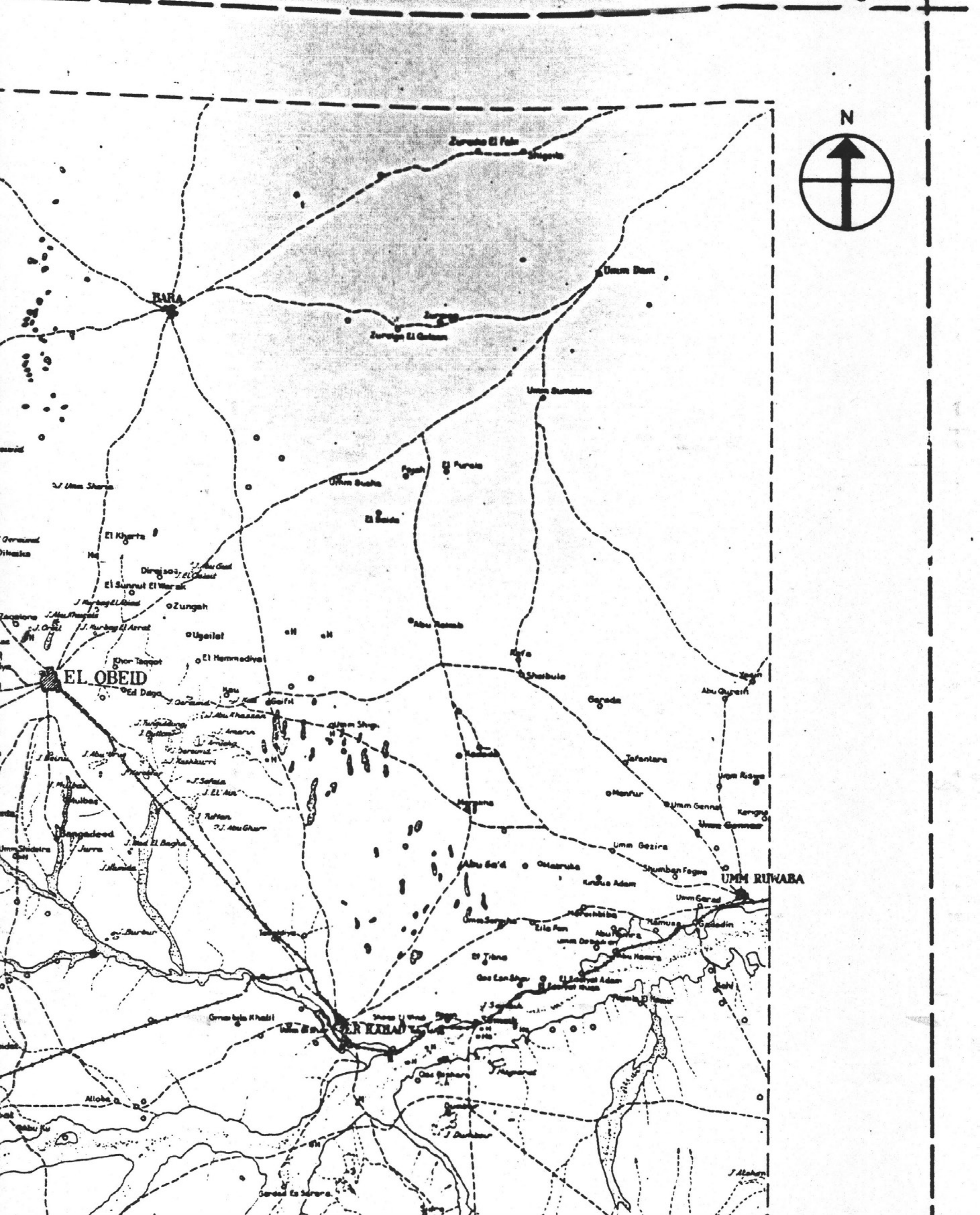
Fig. 32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Tafantara
Abu Qureih
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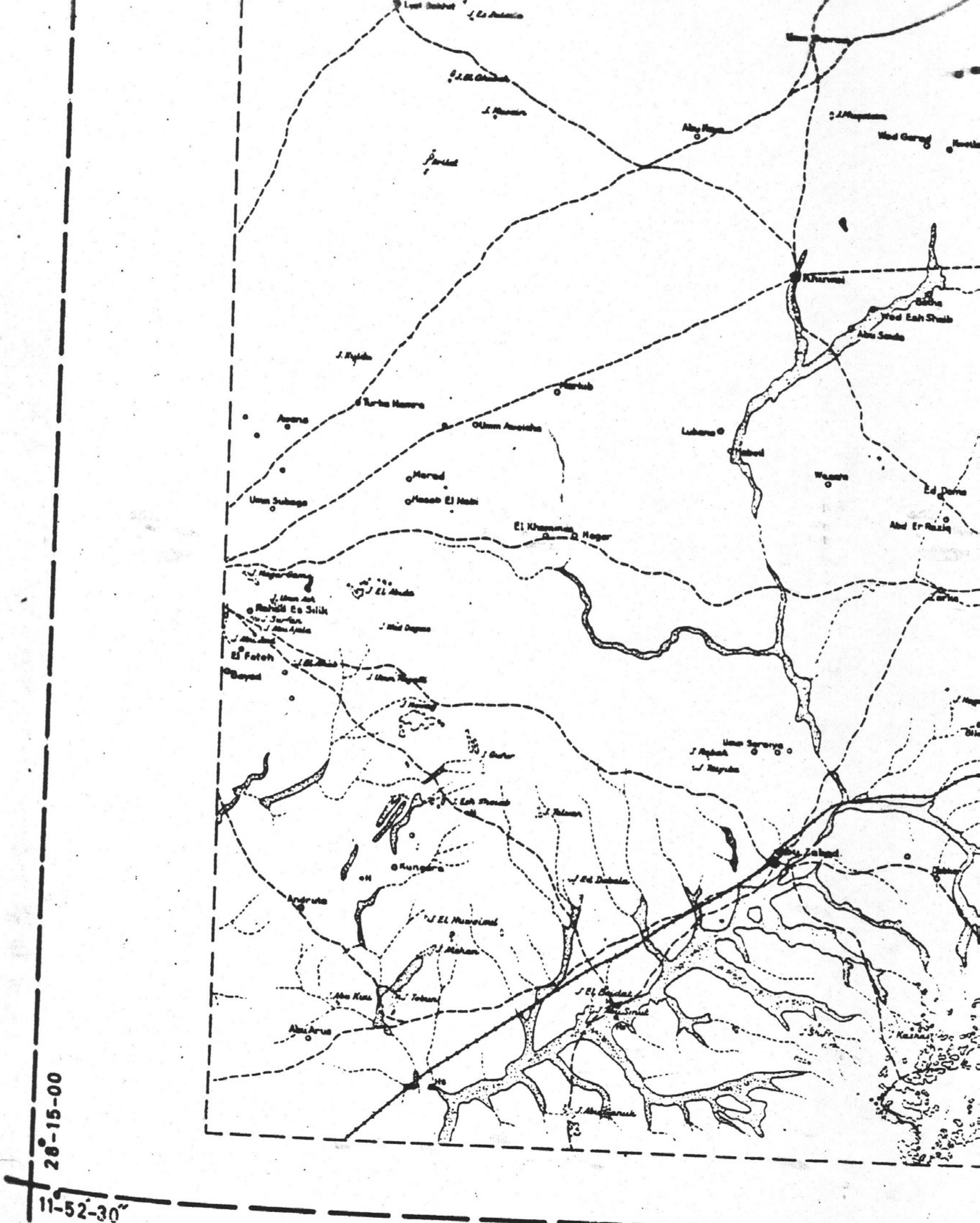

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Reduced in scale from the 1963 m
Hunting Technical Services, London
colour at 1:250.000 (four sheets)
Sudan Surveys Dept.

216. Figs. 30 and 31 also convey the suggestion that in former times there were well-marked surface drainages flowing northwards from the main E-W watershed, towards a belt of sandy goz which, at that time, lay much further north. Sketch 31 suggests that in the intervening period the wind-blown goz has advanced further south, to its present position. It is interesting to note that in the neighbourhood of El Obeid (which is on the E-W watershed) there are still some flowing drainages which run northwards, on gardud soils, and get lost in the fringes of the goz.

217. It should be noted that the general topographic map, included here as Fig. 32 to a scale of 1:1,000,000 does not illustrate the hydrological pattern outlined above. The reason is that the topographic system of valleys as portrayed by the topographic map corresponds (in a large part) with the former state of affairs in the pluvial age, when the valleys contained perennial rivers; and the present discontinuity, which is hydraulic rather than topographic, does not show on the map.

HOW WIND HAS SHAPED THE LAND FORMS

218. There are several topographic features which have clearly been formed by the wind. The most obvious are the dunes themselves, as indicated, in particular, by the long strips of cultivation between the longitudinal dunes, and the lacustrine depressions which lie in the lee of the jebels in the sandy goz country.

219. In Fig. 33 these sets of features have been selected so that they can be seen in isolation. In Fig. 34 a simplified pattern has been made by drawing a directional arrow along the features shown in Fig. 33. The result should be studied in the context of the wind data, especially the directions (Fig. 18) and speeds (Tables 2 and 3).

The Spreading Wind-pattern in the Goz

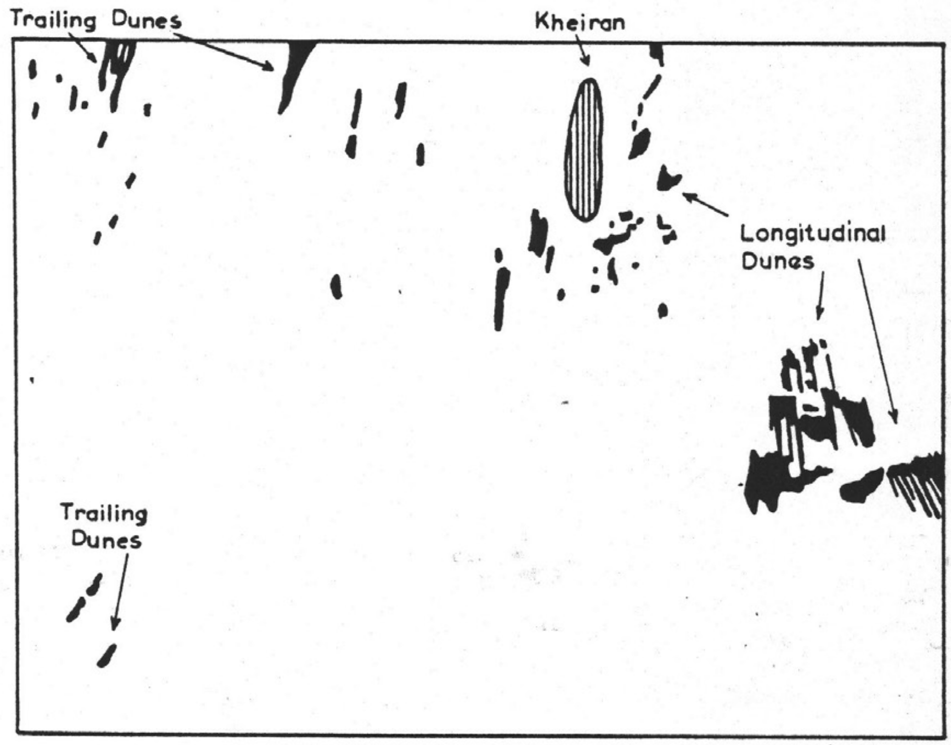
220. The predominant pattern is clear enough; a spreading out, from north to south, with an axis of symmetry running almost exactly on the N-S direction.

The Kheiran Unstable Dunes

221. This N-S axis of symmetry runs down the middle of the Kheiran. In this respect the Kheiran is a unique geomorphological feature. The Kheiran is also unique for another reason. It is the one area, in the whole of the Project Area, where there are sand dunes, of large size, whose unstable character is unquestionable.

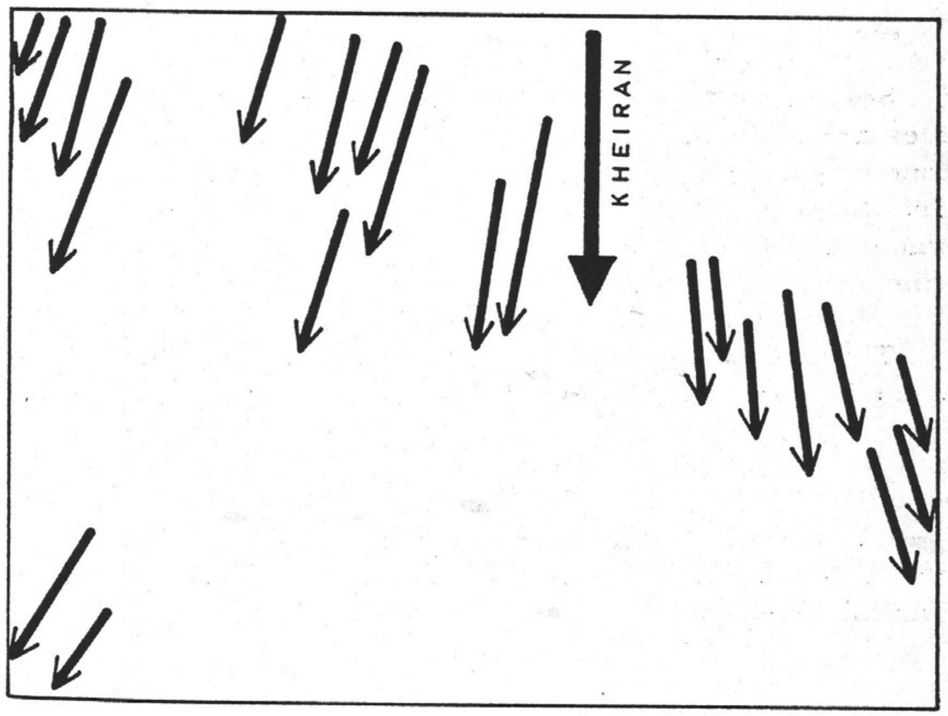
WIND - BLOWN GEOMORPHIC FEATURES

Fig. 33



DIRECTIONAL CHART

Fig. 34



WATER SOURCES

222. The various characteristic types of water sources are itemised below. It will be noted that there are no springs.

Turdas

223. These are natural lakes, which fill up during the rainy season and usually contain water throughout the dry weather. The two most important turdas in the Project Area are at Rahad and Abu Zabad.

Hafirs

224. Naturally it is in the surface drainages and depressions, where there is flowing water, that the artificial "hafirs" have been constructed by the Government over the last twenty years or more. They are large excavated reservoirs of ten or twenty thousand cubic metres or more, which are filled during the rains from natural flowing surface waters. Fig. 35 shows all the hafirs in the Project Area superimposed over the complete system of surface drainage and fluvio-lacustrine depressions.

Dug Wells and Boreholes

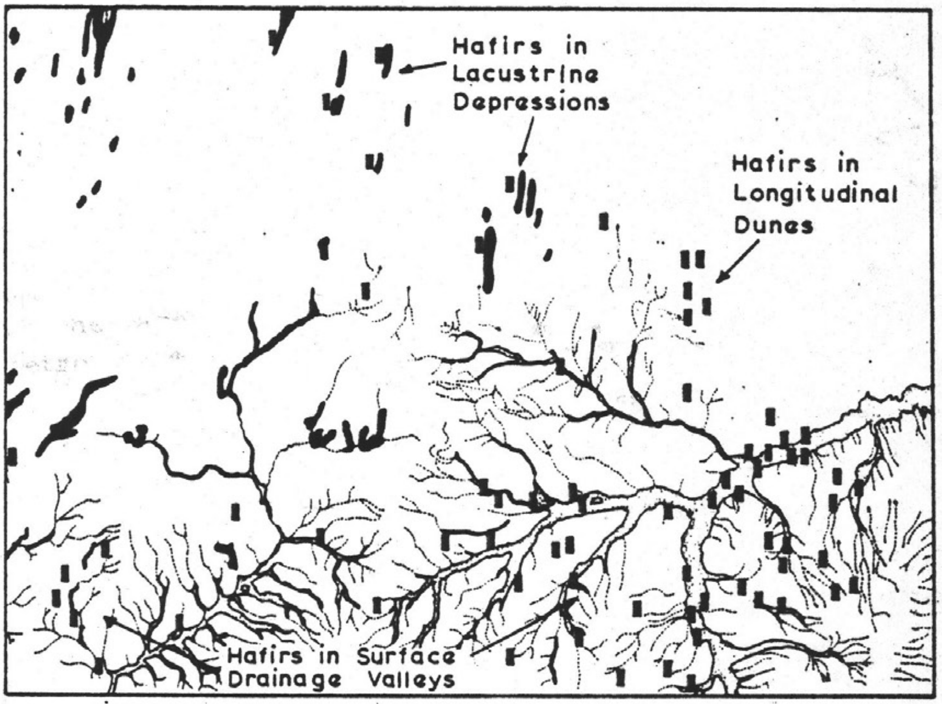
225. Wherever water flows in streams in the rainy season, or tends to collect in depressions, there is naturally a presumption that there may be groundwater which can be tapped. So Figs. 36 and 37 show all the natural surface water features and also all the dug wells and boreholes, with the geology as well.

226. Several features stand out clearly from the maps. First, the boreholes are associated, almost exclusively, with either the Nubian Sandstone or the Umm Ruaba series, or with surface depressions. Secondly, there is a zone in the north-easterly quarter of the Project Area where dug wells are particularly numerous, and this zone lies within the envelope of the Umm Ruaba series.

227. Thirdly, there are many dug wells, and well-fields, over the area of the basement complex; but also there are large basement complex areas with no dug wells and no boreholes. Fig. 36 shows that wherever there are wells over the basement complex, they are always associated with either a surface drainage or a depression. This is a statement of observed fact, displayed by the new mapping details; it does not of itself prove that there are no groundwaters to be found in the areas overlying the Basement Complex where no sources now exist.

HAFIRS AND SURFACE DRAINAGE FEATURES

Fig. 35



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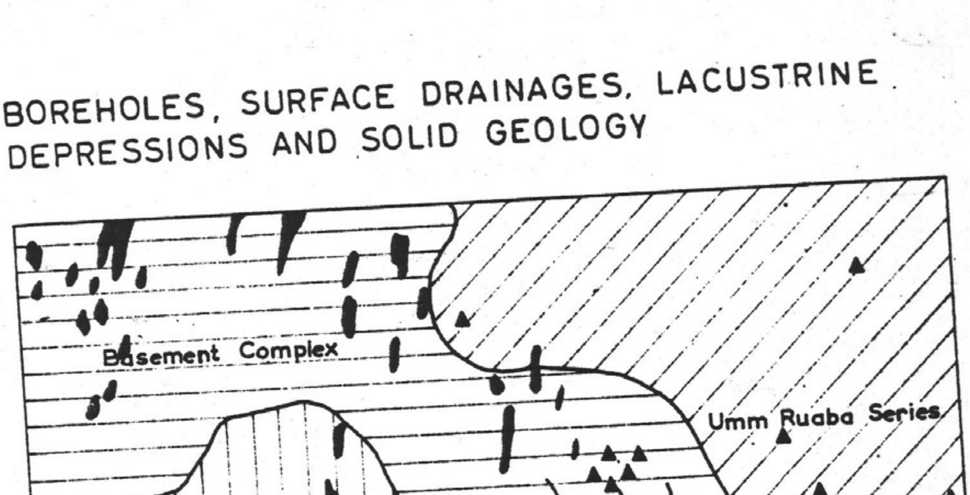
36 DUG WELLS, SURFACE DRAINAGES, LACUSTRINE DEPRESSIONS AND SOLID GEOLOGY

The red areas are the "3km„ envelope of the all-season water wells, that is, the envelope of circles of radius 3km with the source as centre.

Fig. 37 BOREHOLES, SURFACE DRAINAGES, LACUSTRINE DEPRESSIONS AND SOLID GEOLOGY



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CHAPTER 5

PRESENT USE OF LAND AND WATER

INTRODUCTION

228. Chapter 4 described very generally the land and its waters and how they behave under the forces of nature. This Chapter presents an explanation of how the various ways of using the resources fit together into a composite pattern of "Present Land and Water Use" as a whole.

CULTIVATION AND THE "INHABITED AREAS"

229. It is the settled population, and the lands they inhabit, which provide the fundamental framework of reference for land use. There is no cadastral survey, and the following arbitrary method was adopted for constructing a map of the "inhabited areas". With each village as centre, a circle with radius 3 km. was drawn. The envelopes enclosing all these circles and over-lapping groups were drawn in. This is the "ekistic envelope". The radius 3 km. was chosen because the resulting ekistic envelope covered virtually all the cultivated areas as shown on the photo-mosaics.

230. Fig. 38 shows the cultivated lands at the time of the photo-survey, to a scale of 1:1,000,000. Fig. 39 shows the inhabited areas to the "half-page" scale. The fact that virtually all the cultivated land is situated within 3 km. of a fixed village suggests that a distance of 3 km. from the village to the field (out in the morning and back in the evening) is about as far as the farmer can manage.

231. Although the shape of this ekistic envelope is derived from the cultivated lands, the map has as much to do with forestry and animal husbandry as it has with agriculture, because the peasant land-use system is a combination of all three.

SOILS: A SIMPLIFIED CLASSIFICATION

232. A simplified version of the "Soils and geomorphology" map is in Fig. 40. Since the soils and the geomorphology coincide geographically in their broad classifications, the geomorphological nomenclature is used, because it is descriptive whereas the soils nomenclature is not.

RAINFALL

233. Rainfall data were given in Chapter 4. For the convenience of reference in the immediate context of Land Use Zones, the mean annual isohyets are shown on the "Land Use Zone" map, and on the simplified soil map (Figs. 39 and 40) as well as on the map of cultivated areas (1:1,000,000) in Fig. 38.

WATER AVAILABILITY

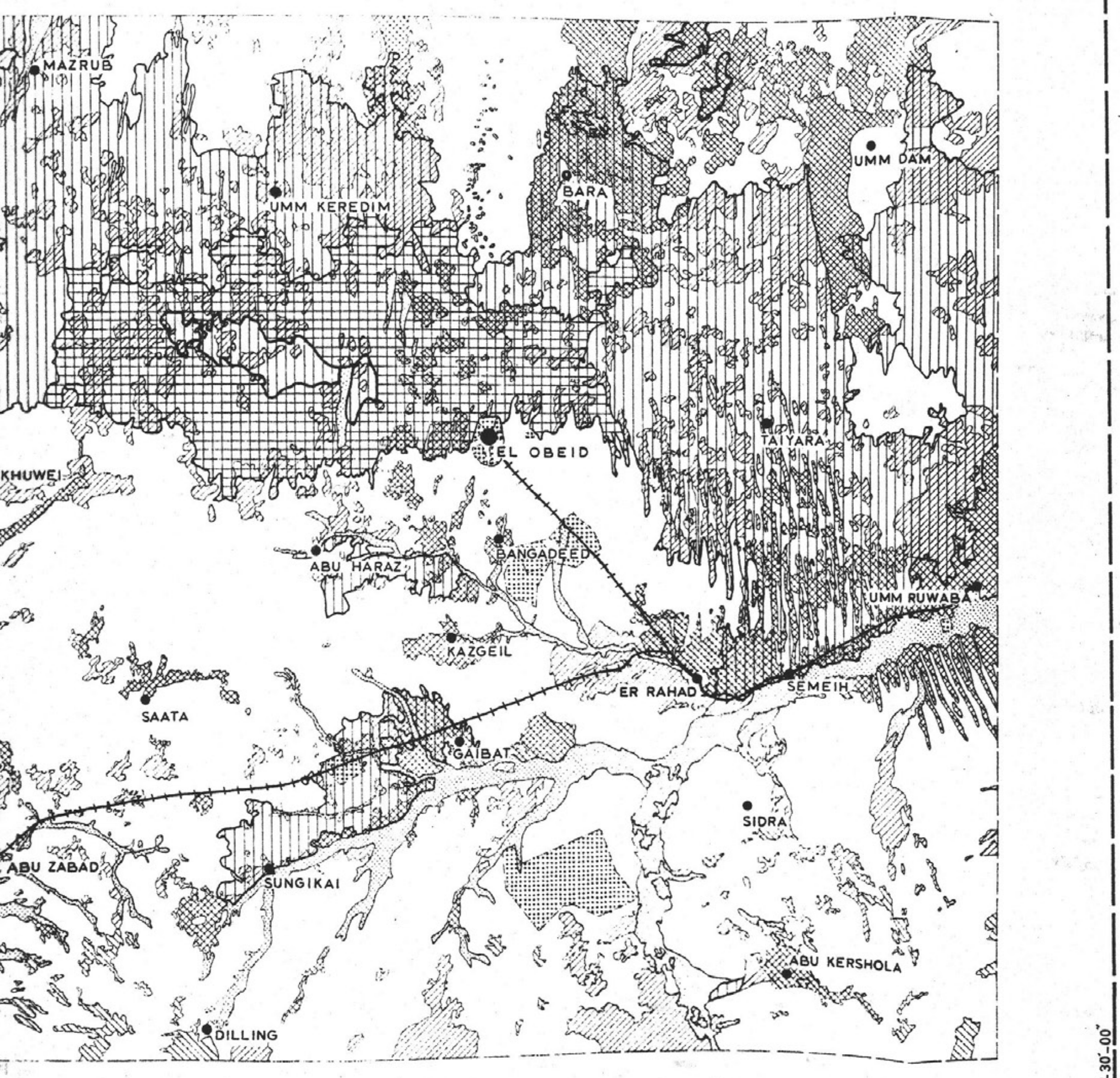
234. In Fig. 41, the inhabited areas (same boundaries as Fig. 39) are shown with three separate hatchings indicating different degrees of "water availability".

235. First there are certain areas, where water supply is adequate, both in quantity and in accessibility. The explanation is seen in Figs. 35, 36 and 37 in Chapter 3, and the accompanying text; there is something like a general water-table in these areas, and almost every village has its dug wells.

236. Next, there are areas where most villages are situated at a distance from the nearest water source, and get their water during the dry weather by sending members of the family with donkeys or camels to fetch water and carry it back home in skins.

237. Thirdly, there are areas where the villagers get water during the dry season from tanker-lorries. These lorries fill up at El Obeid, Khuwei or some other major source, transport the water to the villages, and sell it at the roadside by the four-gallon tin. The price varies from 2 piastres to 8 piastres. This is equivalent to a price of £5.0.0d. to £20.0.0d. per thousand gallons ($15 to $60).

Fig. 36



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NOTES

1 Reduced in scale from the 1963 maps prepared by Hunting Techical Services, London and printed in colour at 1:250,000 (four sheets) by Sudan Surveys Dept.

2 The gum distribution is shown as on the original survey maps, 1963. Further explorations by G.A. Booth 1965 led to modifications: see Figs 24, 50, 51 and 52.

LEGEND

- Forest reserve
- Major gum
- Minor gum
- Jebel arable
- Arable - dense cultivation
- Arable - light cultivation
- Wadi, Khor, Depression

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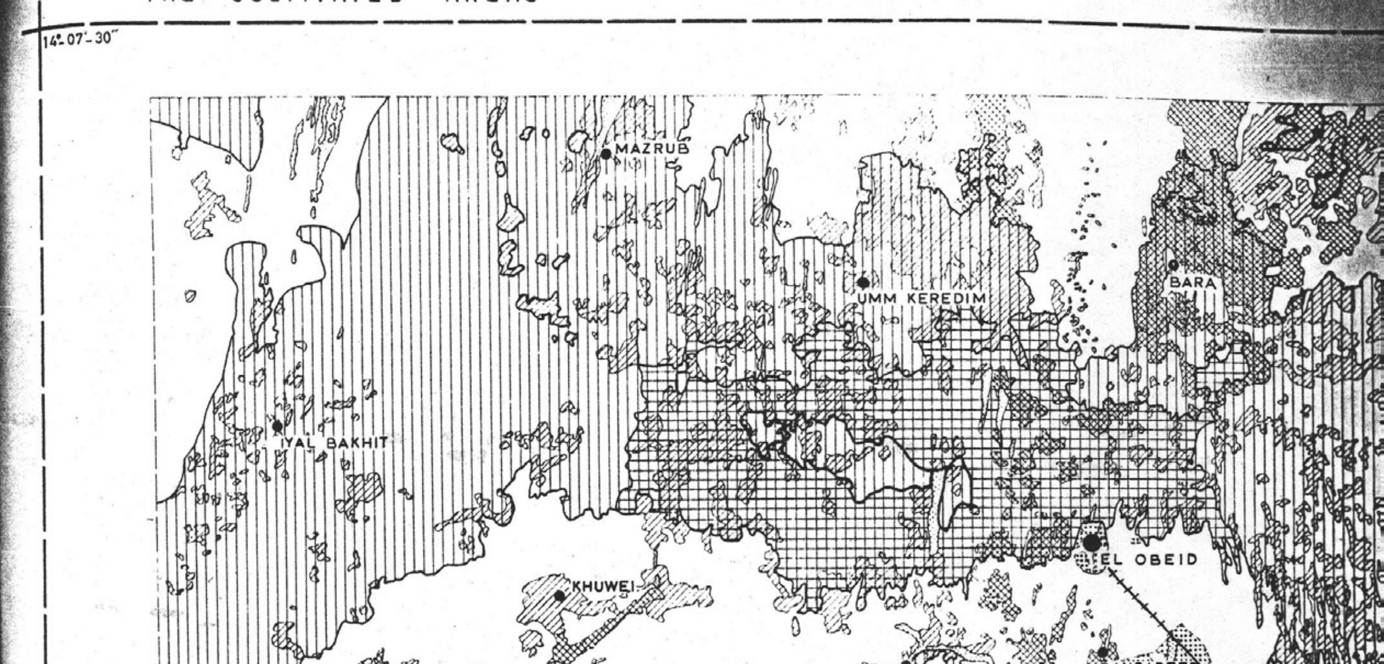
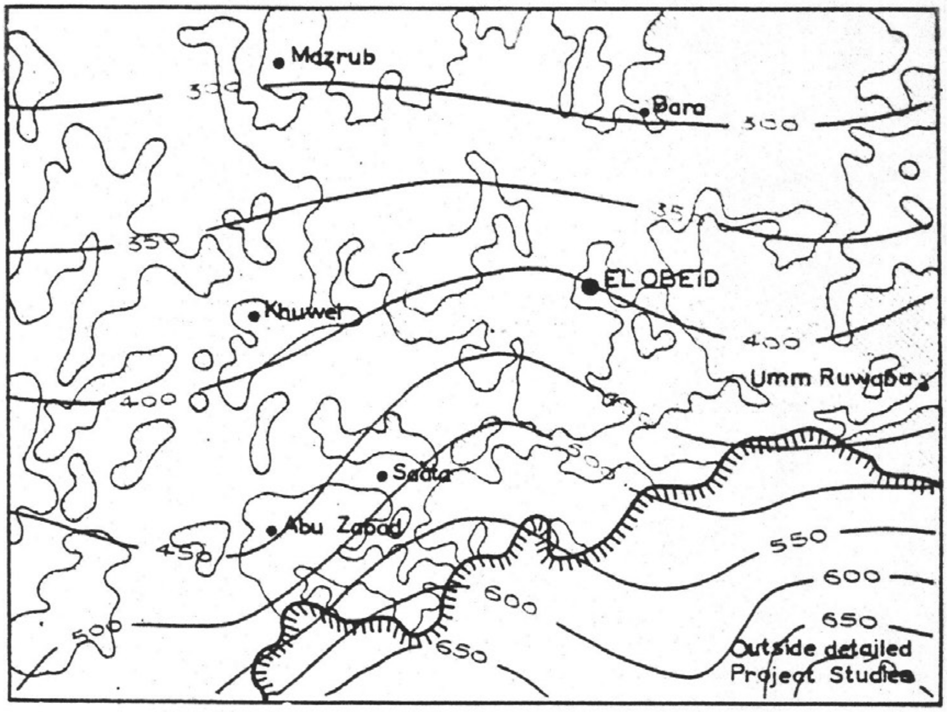
THE CULTIVATED AREAS

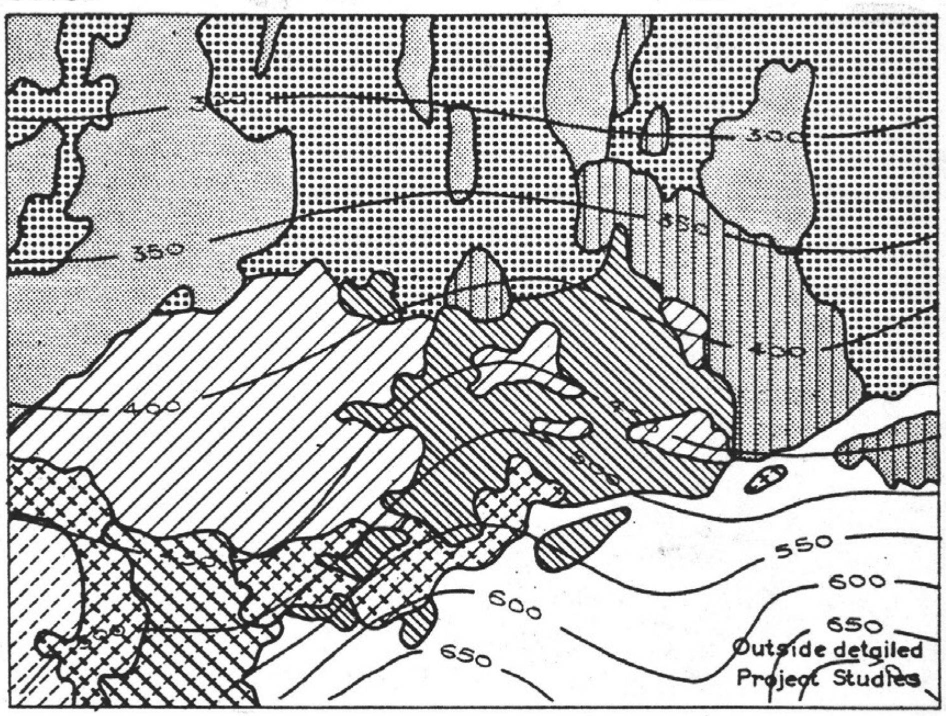




500 Isohyets

SOILS

Fig. 40



500 Isohyets

Sand sheet and Low Dunes..................	"Goz."	
Longitudinal Dunes...		
Other Dune types.........		
Sandy pediplain over Nubian Series......	"Nubian Pediplain."	
Clayey pediplain..........	"Gardud."	
Alternative clay, sand and alluvium, minority sand	"Broken Gardud."	
Ditto, mostly sandy..........	"Broken Sandy Pediplain."	
Sandy pediplain over Basement Complex....	"Pediplain Coz."	

238. During the rainy season, people and animals get all the water they need without much trouble. When the rains cease in September or October, there is still plenty of water in most places because fulas (rain-ponds) still have water, and the dug wells are yielding freely.

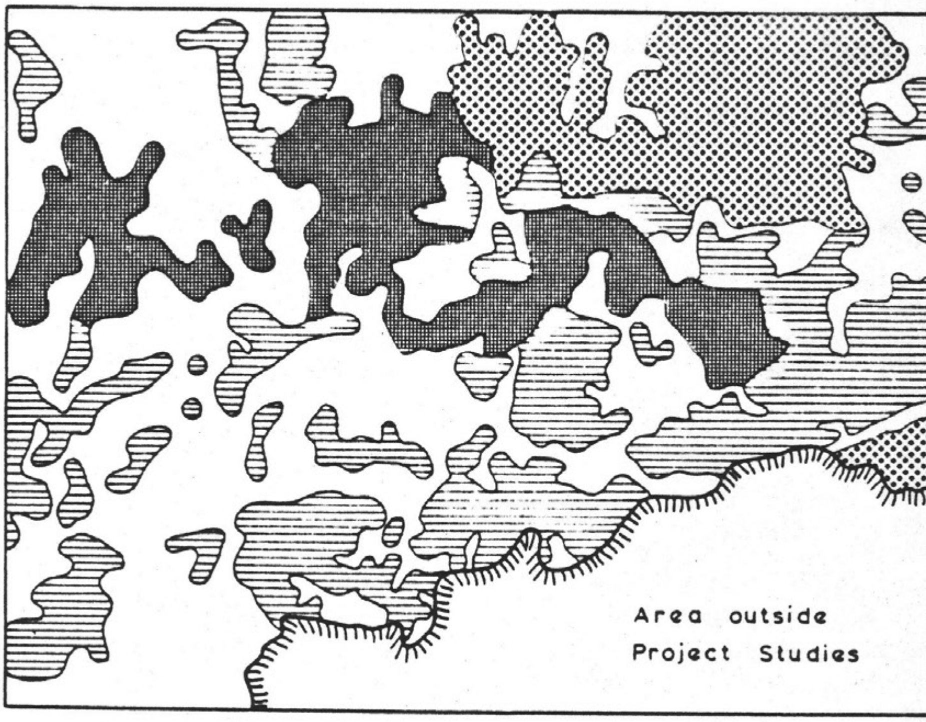
239. The areas where fulas are plentiful are shown in blue in Fig. 42, over a simplified and selective soils envelope. Fulas predominate in the gardud country where the hard red soil is relatively impermeable, and also in the areas of longitudinal dunes where the inter-dune valleys have relatively impervious soils, brought about by millenia of drifting and leaching of the fine particles from the dune slopes downwards.

240. As the dry season advances, water-supply difficulties grow. Fulas dry up. Sometimes, if the season's rains have been poor, a few hafirs may dry up. Some of the dug wells, sunk in small groundwater bodies, yield less and eventually fail.

241. But while water sources are tightening, the weather gets hotter and drier. By the end of the dry season, in the period just before the rains (normally in June) only the all-season sources are still yielding, and it is from these that all the people and all the animals must get their supplies.

242. It is at this time, when the water supply is at its worst, and the weather at its most exacting, that the peasants must get their fields ready for the rains. The burden of water transport, whether paid for in labour or cash (which has to be earned from their labour) is a decisive obstacle in the way of agricultural improvement. There are several practical ways for removing the obstacle and the sooner it is done the better because the peasants cannot put their labour and cash into investment for productive development if they have to use so much of it simply to get water.

243. When water is transported from source to village by animal - usually with boys in attendance - the equivalent cost for distances of 5 to 10 km. is about 1 1/2 piastres or so (15 mils) per four-gallon tin, reckoning a boy's wage at 5 piastres a day and a donkey at 4 piastres a day. Volume IV contains details of costs.



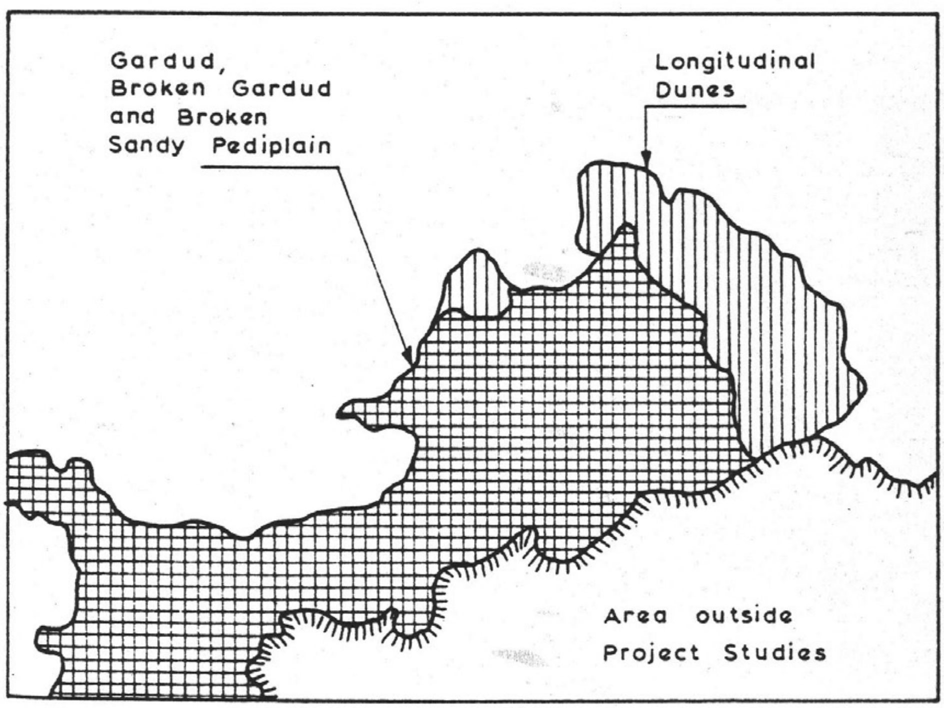
Plentiful Dug wells, at almost every Village

In these areas most villages are distant from all-season water sources, and in the dry season they have to send animals to fetch water borne inskial

In these areas the villages buy water for cash, from tanker-lorries which ply back and forth from major sources.

SIMPLIFED ENVELOPES OF FULAS (5 Km radius) AND SOILS

Fig 42



244. When the villagers get their water from a natural communal well-yard, or government hafir, they pay nothing for it at the source. When they get it from El Obeid or from a government borehole, they pay 2 mils per four-gallon tin, or 1/5th piastre. But so far as domestic water is concerned, it is the cost delivered actually into the villages and into the household itself that counts. When the cost of carrying it from the source to the household is 15 mils per tin (or more if transported by lorry) it only makes a minor difference whether they get it free at the source, or pay 2 mils per tin.

245. Naturally enough, when Government began to launch programmes of hafir-building and drilling, the new sources were provided at places where there was greatest need. Equally naturally, the places of greatest need were those where people were already living, places which already had access to water but where increasing population was creating difficulties.

246. These difficulties might be of one or two kinds. The increasing demand might overstrain the capacity or yield of the source itself. Or, the difficulty might arise because the farming villagers were obliged to open up new farming lands, further and further from the source; so that although the supply at the source might be ample, the increasing distance of the farming villages, hived off into new lands, began to impose an excessive burden.

247. In either case the effect on land use was much the same. It meant that too little land had to support too many people simply because there was a limit to the price the villagers could afford to pay, in cash or labour, to transport water to villages lying further and further away.

DELINEATION OF "LAND USE ZONES"

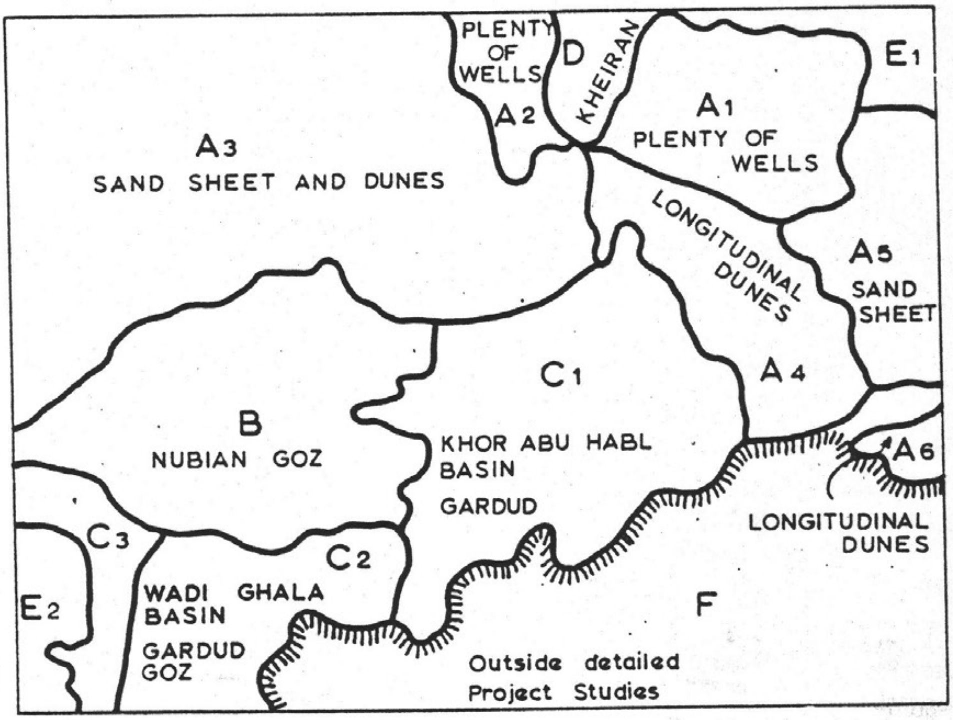
248. The combination of factors which have now been illustrated in the Figures leads on to a system of "Land Use Zones" which are shown in Fig. 43. They are predominantly decided by soil, geomorphology, and water availability.

<u>Zone A</u>: This is the goz area of Fig. 38, with the exception of the Kheiran, which is called Land Use Zone D; the Kheiran is separated because it has unique features which have been touched on in Chapter 3. Sub-Zones A_1 and A_2 are basically defined with relation to water-availability (see Fig. 41) Sub-Zones A_3, A_4 and A_5 correspond to the soil classifications.

<u>Zone B</u> is the "Nubian Pediplain", belonging to the Abu Zabad soil combination. It is the big island of acid open sandy soil which overlies the Nubian Sandstone, and was formed <u>in situ</u>.

LAND USE ZONES

Fig. 43



Zone C comprises the region where surface drainages form, which is therefore cut by water courses, in marked contrast to Zones A and B which have virtually no surface drainage lines because the soil is so permeable that the water soaks straight in. Zone C is gardud, with pockets of sandy pediplain/goz (see Fig. 40 legend). Sub-zone C1 is the Khor Abu Habl basin (see Fig. 26). Sub-zone C2 is the Wadi Ghala basin. Sub-zone C3 is the area of small "closed" basins described in Chapter 3 (see Figs. 30 and 31).

Zone D, already mentioned is the Kheiran, the area of unstable dunes with alternating valleys, some of which have wells.

Zone E1 and E2 are too small, and too marginal, to be classified satisfactorily for the purposes of the present Survey.

Zone F. Finally, Zone F is the clay plain which belongs to a different system of soils and land use, which was omitted from the detailed studies as explained in Chapter 4.

PEASANT FARMING

General

249. Apart from a few thousands of acres under mechanised cultivation and a few hundreds of acres under irrigation, all the cultivation is done by hand-power (without using animals), by peasant farmers. They cultivate the sandy goz soils because although these are inherently less fertile than the clayey pediplain, these latter soils (the gardud soils) are too hard to be worked by hand.

Peasant Cultivation and the Sandy Soils

250. The areas cultivated when the air survey was made have already been referred to, and are shown to a scale of 1:1,000,000 in Fig. 38.

251. For analytical purposes the map of inhabited areas is convenient because it takes in all the areas shown as cultivated, and also covers all land within 3 km. of any village. Outside the ekistic envelope there is no cultivation and no villages.

252. Fig. 44 shows the inhabited, farming areas in green, with the dotted areas indicating all the soils which are sandy. There are only a few places where the inhabited area lies over any other soil except a sandy soil. The two overall envelopes are in good register. The inhabited areas bulge over the edge of the sandy boundary in a few places, and overlap onto the gardud soils.

Dense Cultivation

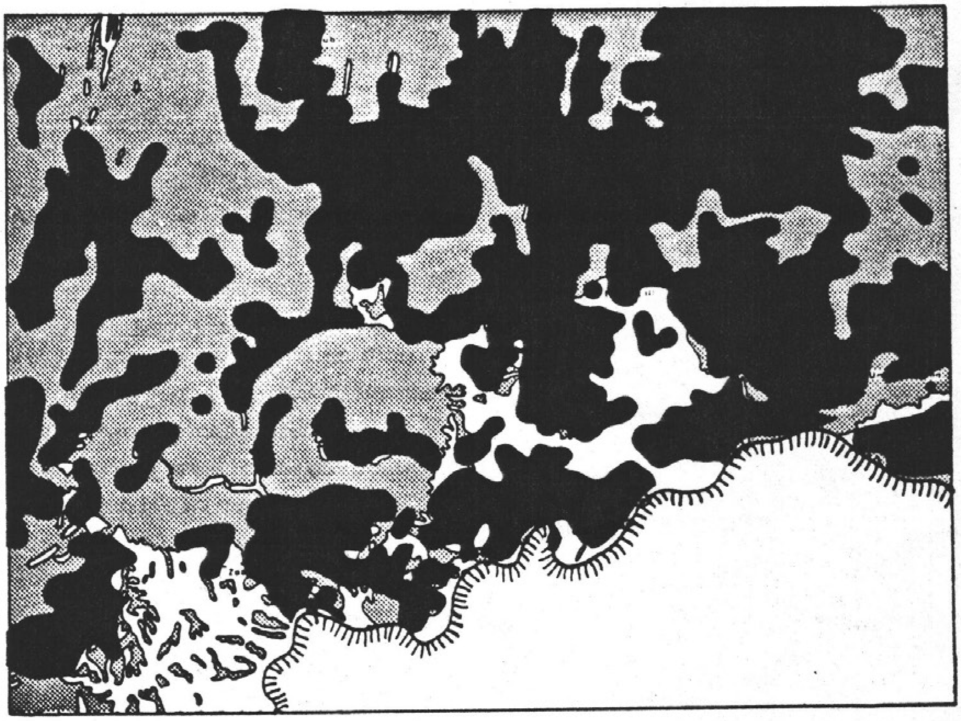
253. The densely cultivated areas are shown, within generalised envelopes, in Fig. 45, together with the Land Use Zone grid.

254. The biggest concentration of dense cultivation are in Zones A_1 and A_2 and in the southerly parts of Zones A_4 and A_5, and in Zone A_6. This is partly because of water availability (Zones A_1, A_2 and A_6) (see Fig. 41) and partly because of railway communications: (A_4 and A_5).

255. In Zone C, there are islands of dense cultivation, corresponding with the "Broken Sandy Pediplain" soil pockets (see Fig. 40) and with water-availability (Fig. 41). These pockets are bordered by hard gardud soil, too hard for the peasants to cultivate by hand-power.

INHABITED AREAS AND SANDY SOILS

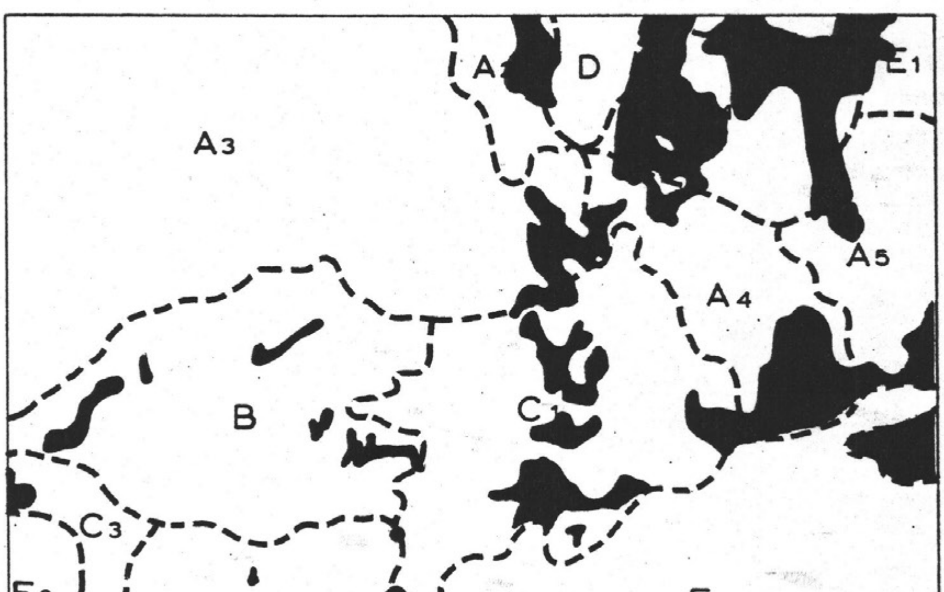
Fig. 44



All the sandy soils are shown, un differentiated.

DENSE CULTIVATION AND LAND USE ZONES

Fig. 45



256. As can be seen in Fig. 38 (1:1,000,000) most of the cultivation in Zone C_1, is dense, indicating a pressure. The available sandy soil, favoured for hand cultivation, has mostly been used up and the peasants expand into the heavier gardud soil so far as they are able.

The "Land Rotation" System

257. The "Land Rotation" system, which is followed generally in the Project Area, is the following. A farmer cultivates a piece of land, usually 10-15 feddans, continuously until the yields drop to an uneconomical level. Then he leaves it for fallow and shifts to another place which has already been lying fallow ever since it was last under its turn for cultivation. The restoration of soil fertility is accomplished only by the period of bush fallow, which varies from area to area, from village to village in the same area, and from farmer to farmer in the same village. Two factors affect the period of continuous cultivation and/or of fallowing: The population density of an area, and the soil type. The higher the population of an area, the longer the period of continuous cultivation and the shorter the fallow period. On the other hand, the less fertile a soil is, the shorter the period of continuous cultivation and the longer the period of fallow. For example, in the heavy population areas of Umm Ruaba, and Umm Dam, the period of years under continuous cultivation is reported to be more than ten. In general, the period of continuous cultivation varies from 4 to 8 years according to the land use pressure of the area.

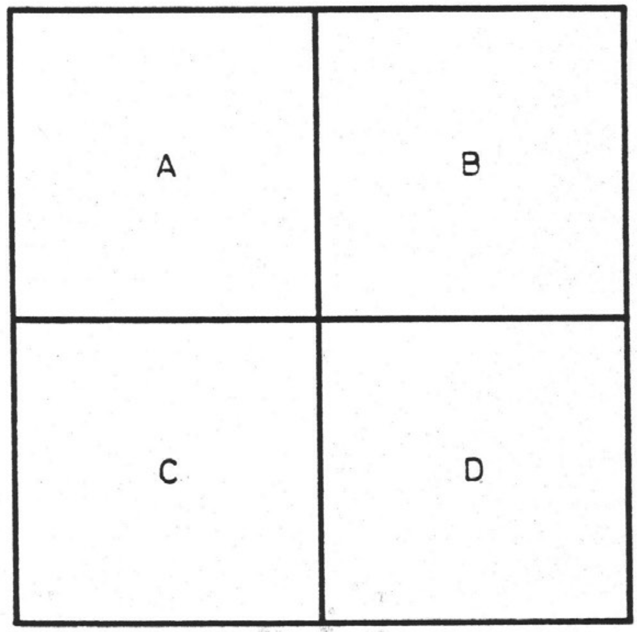
258. Though it might seem strange to speak about land pressure in an area where the relationship between population and land is so low, nevertheless land pressure is a phenomenon that occurs in certain parts of the Project Area. It is due to the scarcity of water supplies, which forces the farmers to concentrate around water points. The land pressure of Umm Ruaba mentioned above is a typical example. The system is illustrated schematically in Fig. 46.

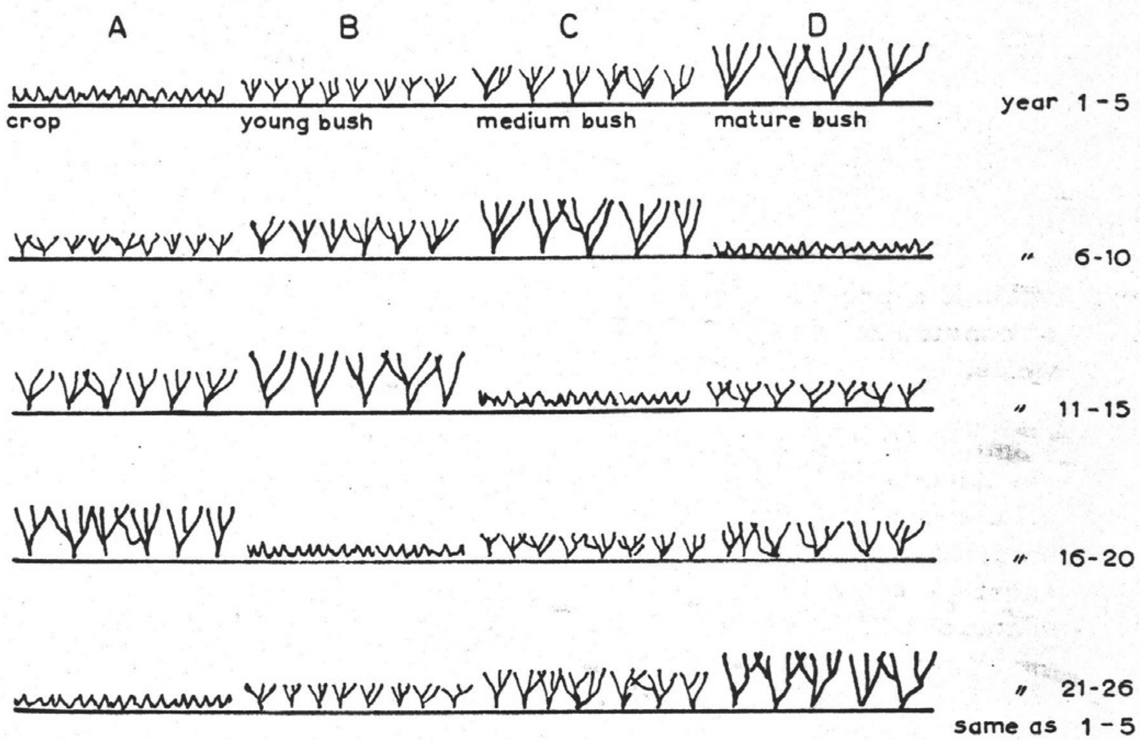
The Disappearance of True "Shifting Cultivation"

259. This land rotation system is sometimes called "shifting cultivation", but the more precise term is preferred. Within living memory there was true "shifting cultivation" in this region. That is, cultivators cleared the bush and set up temporary settlements. When the land was exhausted they moved off to another place, with fresh fields, and also, a fresh encampment.

LAND ROTATION — IDEALISED SCHEMATIC

Fig. 46





At any given time, a quarter of the farm area is under cultivation, a half is under gum acacia old enough to produce gum and a quarter is newly growing gum acacia.

260. Such a system implies a certain freedom of choice. It implies, in particular, that the rotational encampments - temporary villages - are acceptably near to sources of water. When a village community has lived for (say) 5 years in encampment A and it is now time to move to encampment B, the system pre-supposes that there will be water available for encampment B, i.e. that there is not already another settlement in possession. This could only work if B is "vacant" at the time. The system therefore implies that there are enough water-points for all, or rather more than enough.

261. In other words, the true "shifting" system implies, by its nature, that shortage of water supply is not a decisive factor. As population increased this "shifting" cultivation ceased. The "land rotation" system, (already described in outline and illustrated in Fig. 46 took its place, a system based upon fixed villages.

Effects of Water Shortage

262. As soon as there were more communities of shifting cultivators needing water sources to encamp at than there were water sources, wholesale shifting ceased to justify itself; indeed, it ceased to be practicable.

263. There must have been a phase when the ekistic envelope and the water source envelope coincided - that is, when all the fixed villages were served by an all-season source, situated at the village or very near to it. This phase of balance must have been at some period before the second World War because by the end of the war, water shortage had become a pressing problem and Government launched its programmes of constructing hafirs and drilling boreholes and - later - digging shaft wells.

264. Up to that point in time, presumably, peasants could still find new sources of water by digging wells in likely-looking places, when village communities wanted to shift to new land, or when new village communities were "hived off". After that critical period of equilibrium, shortage of water became the main decisive factor in determining the shape of the ekistic envelope.

265. This historical reconstruction has a particular significance, because (apart from the areas relying on Tebeldi-tree storage or water-melons), wells excavated by hand were, almost universally, the source of dry-season water. The techniques for digging, maintaining and using these dug wells are a part of the indigenous inheritance, and it is obvious enough that these peasants were - and are - well aware of the surface indications to look for when searching for good places to dig for water.

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266. When they ceased to find new groundwaters to dig into, it was because they had used them all up, not because they did not know how to find them.

267. This is why there is such a close correspondence between the distribution of dug wells, and the features which are known to indicate the presence of groundwaters which can be reached by dug wells. Wherever dug wells exist, the data produced by the Project provides an explanation; conversely, wherever there are no dug wells there is also an absence of favourable indications from the Project investigations.

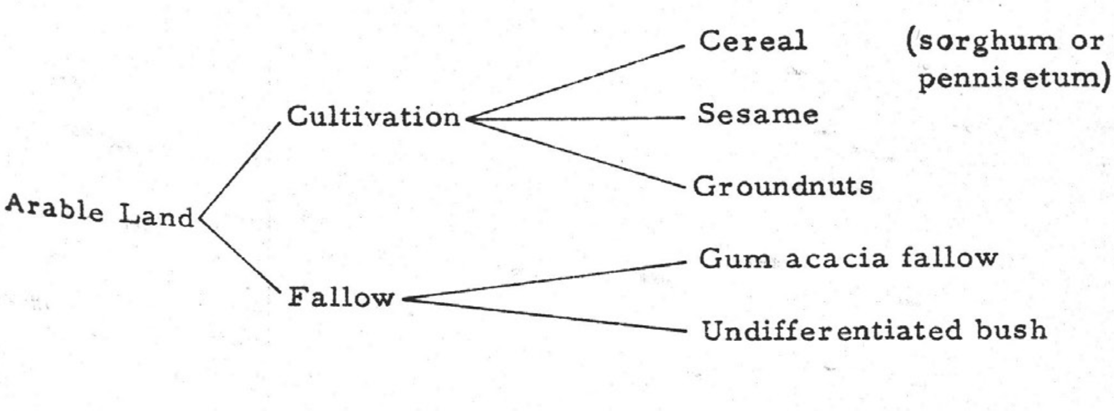
The Ekistic Envelopes, 1935 and 1958

268. In Figs. 47 and 48 the ekistic envelopes for 1935 (from the 1935 Survey map edition) and for 1958 (The Project air mosaics) can be compared. The changes in the span of 23 years illustrate clearly the above diagnosis. The disposition of the main all-season water sources is much the same, simply because it is determined by nature, according to the places where she has provided sources which can be tapped. But the land-areas which are inhabited and depend on those sources have increased. The result is a general in-filling of the gaps which existed in 1935 and a general "fattening" of the envelope.

269. The problem at the present time is more or less general. The ekistic envelope represents the limit of expansion of cultivation in relation to present water-supply availability. Outside the ekistic envelope there is land which could be cultivated if there were water supplies. Inside the ekistic envelope the pressure grows.

Methods of Cultivation

270. Under the "Land Rotation" system, the arable land of the Project Area may be either under cultivation or under fallow, which can be either bush or gum acacia fallow, as shown below.



271. The sequence of crops within the cultivation period depends on the kind of crops cultivated in each particular area The local farmers, though scientifically ignorant about what should be a proper crop sequence, are conscious of the fact that cereal-after-cereal is a sequence they should avoid. There are however, some factors that can affect the sequence of the crops. Among these factors the most important are the particular needs of the farmers and the incidence of pest and disease.

272 More than 99% of the total arable land of the Project Area is cultivated with hand tools These tools were designed by the local farmers to meet their needs during the different stages of land cultivation. The stages or sequences of land cultivation are the clearance of the land, sowing, thinning, weeding and harvest. Every one of these operations is an important factor within the agricultural system and affects directly the yield These operations affect also the area that a family can cultivate. Sowing is usually carried out with the first rains of June-July but there are also some extreme cases. Occasionally some of the farmers sow on dry land during May with the hope for an early start of the rainy season. Also sometimes the sowing can go up to the end of August and even the beginning of September. However these two extreme cases are very liable to fail.

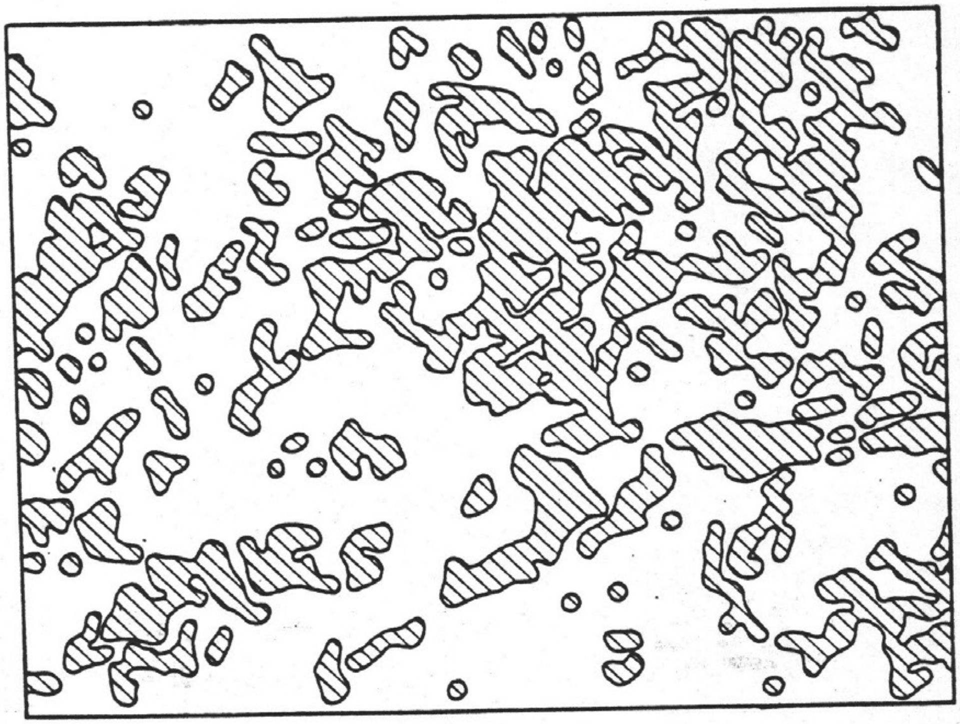
273 The number of weedings performed usually is one or two; but in general it depends on the growth of the weeds themselves, on the efficiency of the farmer and on the time he can afford in relation to the total area he has sown. The weeding phase is usually the most difficult one of the cultivation cycle as it is in this phase that the "muscle-barrier" problem becomes more acute.

Crops and their Geographical Distribution

274. The main crops cultivated in the Project Area are four, namely, sorghum, pennisetum, sesame and groundnuts. Other crops of minor importance such as watermelons, karkadeh (Hibiscus sabdarifa), cotton and lubia (Dolichus spp) are also grown. Maize is cultivated at a small scale in certain places in the southern quarter of the Project Area. Also vegetables, citrus, mangoes guavas, pawpaws and custard apples are grown in the irrigated spots: Bara, Bangadeed, Abu Zabad, Kheiran and Semeih.

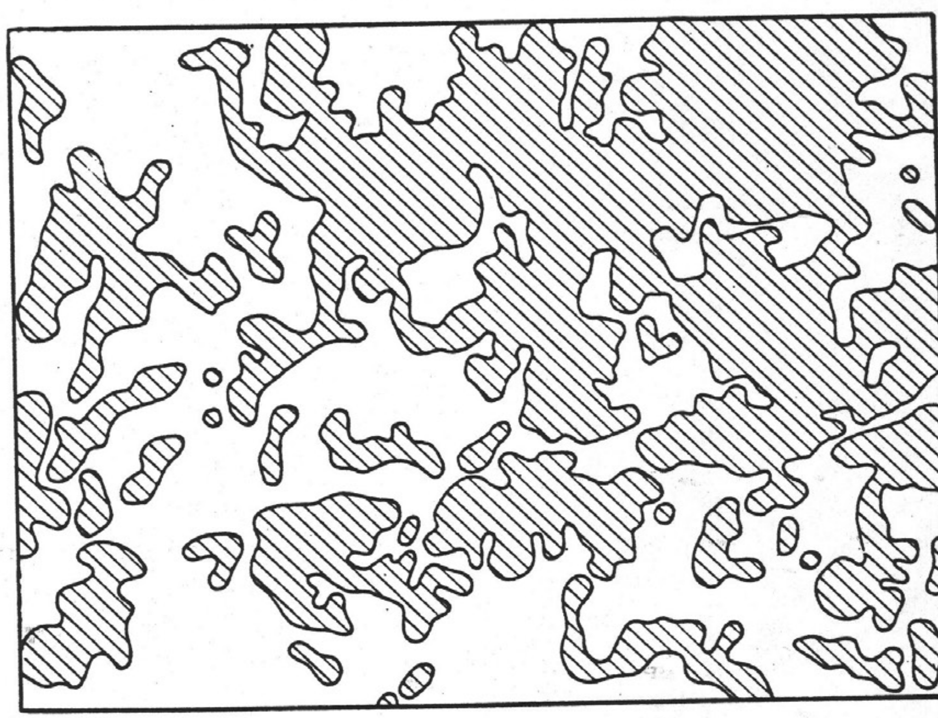
EKISTIC ENVELOPE 1935

Fig. 47



EKISTIC ENVELOPE 1958

Fig. 48



275. The geographical distribution of the four main crops is shown in the series of diagrams in Fig. 49. At the bottom the mean annual rainfall is shown, and the mean effective length of the rainy season, with the Land Use Zone framework.

276. Zone A, as a whole, is the sandy goz soil, rainfall 250/400 mm, length of season 70/90 days. The "high proportion" crops are Pennisetum and sesame; the "low proportion" crops are sorghum, and groundnuts. In sub-zone A_1 sesame predominates over all others, grown as a cash-crop.

277. Zone B is the Nubian sandy pediplain. Cultivation centres on the lacustrine serpentines. Rainfall 350/500; length of effective rainy season 90/110 days. The high-proportion crops are groundnuts and pennisetum. Sesame and sorghum are medium-proportion.

278. In Zone C, the soils are sandy pediplain pockets within the gardud pediplain. Rainfall 400/550, effective length of season 90/120 days. The high proportion crops are groundnuts and sorghum; pennisetum and sesame are medium-proportion.

279. The distribution of the other crops which are cultivated in smaller scale in the Project Area is also affected by the soil or the water factors, e.g.:

Cotton

Cotton is cultivated only on the clay soils of the south-eastern part of the Project Area, where it covers 20-30% of the area under cultivation. This crop is the main cash crop of this part of the Project Area. The reason is that neither groundnuts nor sesame, which are also considered as cash crops, can compete with cotton as far as the economic returns are concerned.

Watermelons

This crop is very important as a partial substitute of drinking water for humans and animals in the northern part of the Project Area where the rainfall is low. It is often inter-cropped with pennisetum or sesame. Watermelons are found almost everywhere in the goz and Abu Zabad soils.

Karkadeh

It is one of the cash crops but the area cultivated varies considerably from year to year according to the market's demand and the prices. It is usually incorporated with sesame and it is found in the goz, the Abu Zabad and the gardud soils. It is a hibiscus, whose dried fruit yields a brilliant red infusion which makes a refreshing drink, hot or cold. There is a demand in Europe also, for making beverages.

Vegetables and Fruit Trees

Vegetables and fruit trees are cultivated in the irrigated spots of the Project Area, i. e. Bara, Bangadeed, Abu Zabad, Kheiran and Semeih. Tomatoes, egg-plants, pepper, green beans and a variety of other vegetables growing under irrigation in these spots form the main source of vegetable supply for the consumption needs of El Obeid and other large towns of the Project Area.

280. Apart from the vegetables grown under irrigation in the spots mentioned above, the majority of the farmers have a small garden next to their huts on which they grow okra, beans and maize during the rainy season for their own needs. During most of the year they have no fresh vegetables or fruits.

281. In El Obeid itself, all kinds of fruit trees are grown in private household gardens for domestic use. During the dry season they are irrigated from a hose from the piped water supply. This is an entirely new development within the last ten years, i. e. since the piped supply was installed, fed from El Ain Reservoir. It is exceedingly significant and important that fruit trees such as mangoes, citrus, figs, custard-apple guava and grapes have been proved to thrive and yield excellent results, rooted in the goz/gardud soil and with minimal irrigation by hand during the long dry season.

Crop Yields

282. Estimations of average yields are given in Table 7 :

TABLE 7

AVERAGE AND MAXIMUM YIELDS OBTAINED IN THE PROJECT AREA BY LOCAL FARMERS

Crop	Average Yields Kg/Ha	Maximum Yields Kg/Ha
Sorghum	535	770
Pennisetum	470	675
Sesame	305	440
Groundnuts (Unshelled)	880	1580

GUM ACACIA

Geographical Distribution

283. The acacia senegal or gum acacia is not only the tree which produces the world's supply of gum arabic. It also plays a major part in the maintenance of soil fertility and in providing minor forest products. Distribution in the Project Area is shown in Fig. 50. Three classes of density are identified: High, Medium and Low.

284. In Fig. 51 the whole gum acacia area, coloured a uniform yellow, is superimposed on a highly simplified soil map.

285. Gum acacia is distributed over all the types of sandy soil except the "Nubian pediplain" - i.e. the sandy pediplain, acid soils, overlying the Nubian (geological) Series. The gum acacia avoids the gardud (clayey pediplain) and the clay plain.

286. Within the Nubian Pediplain (Zone B), there is a medium gum acacia density along the shallow serpentine depressions of the old surface drainage system, where the soil is lacustrine deposits or goz soil with a higher clay percentage. These "corridors" of gum emphasize its absence on the open stretches of sandy pediplain in Zone B.

287. Gum acacia is also found in Zones C_2 and C_3 (S-W corner) where there is alternating sandy pediplain and gardud.

288. Within Zone C, the cultivated pockets of sandy pediplain carry gum acacia.

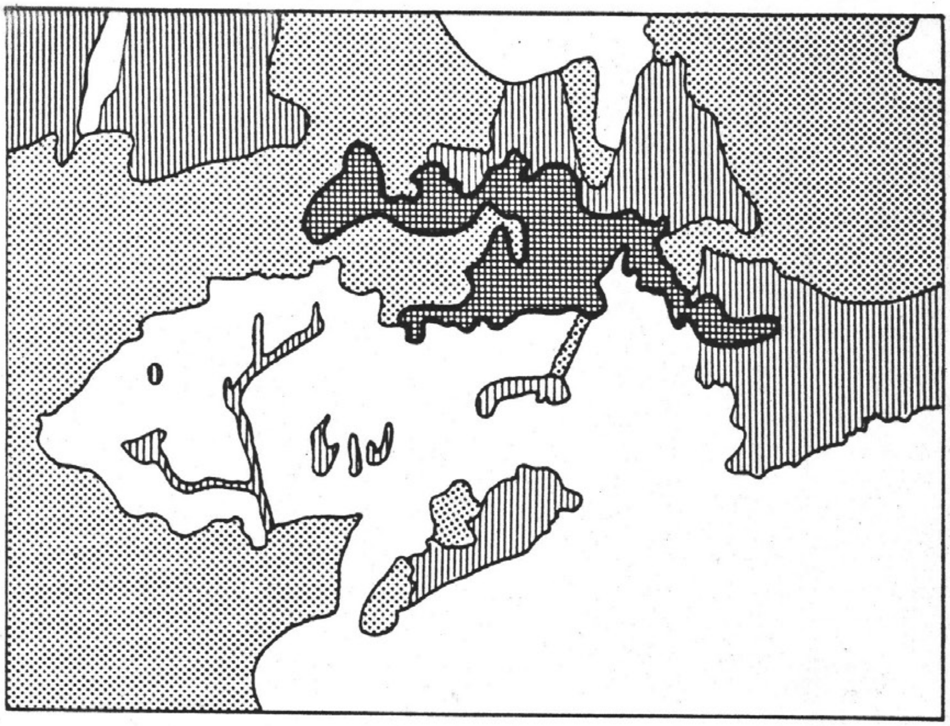
The High Density Gum Areas in Relation to Water Supply

289. It is seen from Fig. 52 that the areas where drinking water supply is transported to the village by lorry and sold by the four-gallon tin for cash, are also, very largely, the high density gum areas.

290. This illustrates a very important exception to the normal rule that cultivation tends to concentrate round water sources. In this tank-lorry area the land is cultivated, and there are settled villages, in spite of the fact that there are very few all-season water sources.

CUM ACACIA DISTRIBUTION

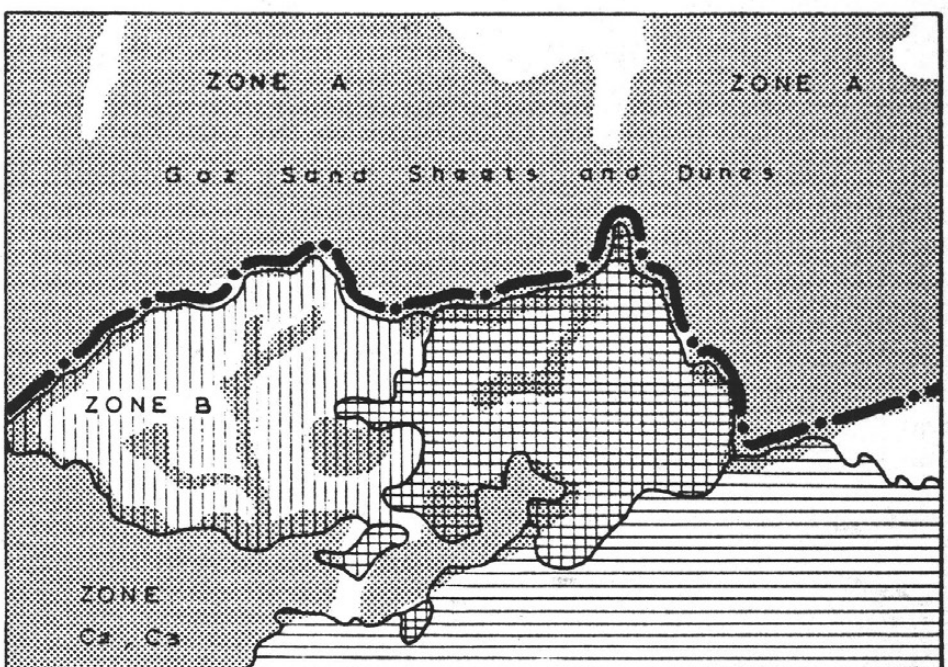
Fig 50



High Medium Low

CUM DISTRIBUTION AND SOILS

Fig 51



Sandy Pediplain over Nubian Series

Clay Plain

Gardud (Clayey Pediplain)

Gum

Southern boundary of the Goz Sandy Soils

291. The reason is that since the peasants want to gather the natural gum, a valuable cash crop, as well as to farm, they have to live and farm where nature has put the gum acacia.

292. The historical sequence is fairly clear. When gum became commercially important at the beginning of the nineteenth century, settlers moved into the gum acacia areas where, for lack of wells for the critical dry season, they grew fields of water-melons, or hollowed out the trunks of the tebeldi trees where they existed to make storage tanks for water.

293. When the population began to rise sharply, in the present century, and standards began to rise also, these sources did not suffice. These villages had been originally settled with their own dry-weather supplies at each village - either tebeldi tree tanks or melon fields - and when these no longer sufficed, they were too far from all-season sources to be able to get supplies by animal transport.

294. Since this situation coincided, in time, with the introduction of motor transport, this enabled the problem to be solved. The cost was high and it had to be paid in cash, but these particular peasant communities were able to pay because they had gum arabic as their cash crop. They began to turn increasingly to growing annual cash crops such as sesame and groundnuts, as well as the gum.

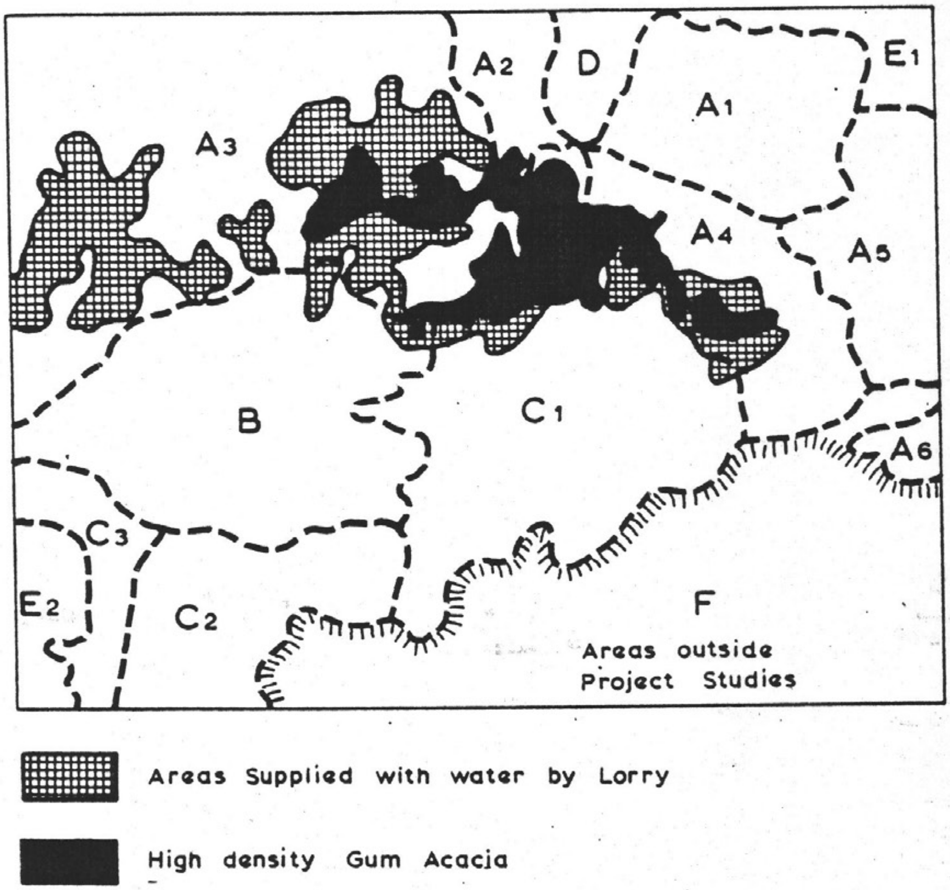
295. The situation is vividly illustrated by the fact that tank-lorries are filled up with water (Plate 12) and deliver it to the villages where it is sometimes off-loaded into tebeldi-tree storage tanks, where it is held temporarily. Here we see, in its extremity, a combination of an unacceptable cost in cash added to an unacceptable cost in labour. The tree-trunk has to be excavated to start with; every drop of water in it has to be carried up, skin by skin, by a man climbing the trunk; for every skinful used, a man has to climb the trunk again, extract the water by a bucket on a rope, and climb down again. Then the skin has to be carried home on a donkey. And now, on top of this cost in labour, they have to pay cash, at the high prices already quoted, to buy the water to fill the tebeldi-tree storage tank.

Gum Acacia and Soil Fertility

296. The part played by the gum acacia in improving soil fertility has still not been fully explained, though it is fully accepted that it does so. Data show an improvement in nitrogen content under the acacia trees, which is important because the soils are deficient in nitrogen, as well as phosphorus.

HIGH DENSITY GUM ACACIA AND WATER SUPPLY

Fig. 52



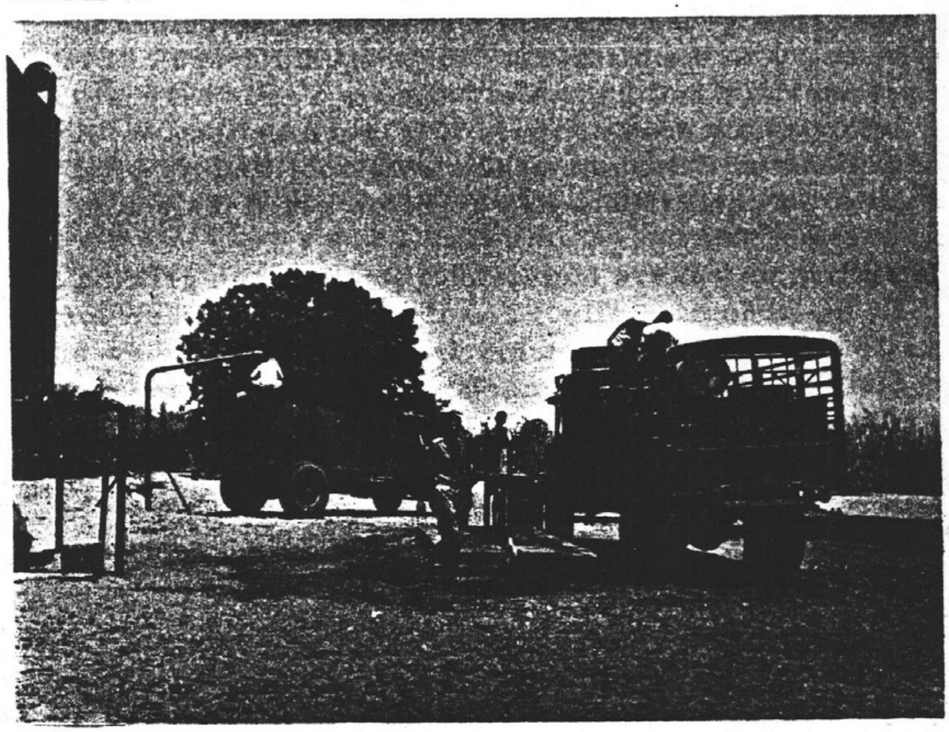


PLATE. 12

Tank lorries filling up with water to be delivered to the villages

Regeneration of Gum Acacia after Cultivation

297. Opinion has varied about the manner of regeneration when a field has been left to revert to bush. An extreme view is that regeneration is almost entirely by coppicing and that regeneration by natural seeding is negligible.

298. There is no quantitative data on this question, but observations during the period of the Project revealed no lack of cases where regeneration by natural seeding was clearly established.

The Impact of Cultivation on Gum Culture

299. So long as the farmers are not pressed for land, it seems that cultivation is complementary to gum growing, not competitive. Provided the farmer has enough land to grow the field crops which are essential to his economy, he welcomes and encourages the gum acacia, and favours it above other trees. It gives him a cash-crop, in return for work done in the dry season, i. e. the off-season for the field crops. It regenerates his soil. It provides building poles, firewood and charcoal, and some browse for the animals which does no harm if it is not excessive. It gives some shade for animals and the gum acacia's competition for shallow soil moisture does not drive out the grasses and herbs on which the animals graze.

300. In fact, gum culture and field cropping, with grazing for the farm animals, fit together naturally. The three land-uses are complementary, and mutually reinforce one another, from the point of view of soil fertility, distribution of the farmer's workload over the calendar, and economically.

301. Where cultivation has "driven out" the gum acacia, there is every reason to suppose that the farmer himself is the first to regret it. The difficulty is that a certain minimum of field crops per family is the essential basis for subsistence, and if land pressure goes beyond a certain point, the farmer has no option; the gum tree has to go. The actual area where this has happened is a small proportion of the whole area of land where the gum acacia thrives.

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Classification of the Gum producing Areas

302. There are about 20,000 square kilometres of the inhabited areas (i. e. the area within the ekistic envelope, Fig. 39). Practically all of this is sandy land where the gum acacia either grows naturally or is developed as a consequence of the farming system of land rotation. This 20,000 square kilometres can be classified as follows:

20% = 4,000 sq. km.	:	Dense cultivation
30% = 6,000 sq. km.	:	Full gum cultivation cycle
20% = 4,000 sq. km	:	Partial gum-cultivation cycle
30% = 6,000 sq. km	:	Unallotted or held by big landowners

Production of Gum

303. The average production from Kordofan province over the last few years has been about 20,000 tons per annum. The 1956 census gave a population (in the gum area) of 72,000 families. The average production per family must have been about 6 kantars p. a. (1 kantar = 99 lb. or 45 kg.). In 1964/65 the 6 "family" kantars would have brought in up to L. S. 19 for the best price paid in El Obeid.

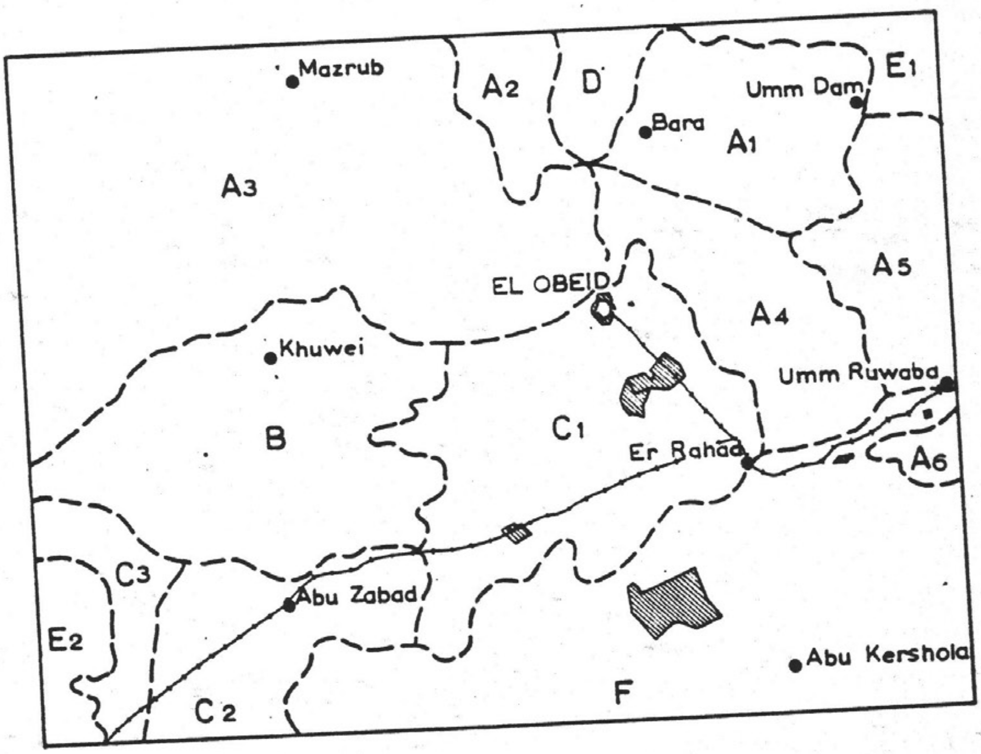
304. As regards gum production in the Sudan as a whole: "Trade in gum, which had reached 7,500 tons by 1881, stopped during the years of war, and on the resumption of trade in 1899, only 1,900 tons were exported. By 1914, the level was about 14,000 tons and continued at this until 1922. From 1923 to 1939, the average has been about 20,000 tons. Since the Second World War, the total has risen steadily to the current average of 42,000 tons." (Volume VI). The export value at present is about L. S. 5,000,000 per annum.

OTHER FORESTRY PRODUCTS

305. In the rural areas the main needs are building-poles for huts, and forewood: in the towns, poles and charcoal. The current need, based on Kordofan Province and the 1956 census, has been estimated at 1,197,000 cubic metres per annum for roundwood, firewood and charcoal. A projection to 1981 suggests a corresponding figure of 2,849,000 cubic metres.

Fig. 53

FOREST RESERVES



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PASTURES AND LIVESTOCK

Four Categories of Grazing

307. Four distinct categories can be distinguished, i. e. Tribal Nomadism and semi-nomadism; semi-nomadism with village livestock; semi-nomadism with merchants' livestock; and settled village livestock communities.

Tribal Nomadism: Camels and Sheep

308. There is only one tribe, so far as the Project Area is concerned, which can really be called nomadic, without semi-nomadic (or semi-settled) features. This is the Shenabla, who raise camels and sheep; with some goats, of course, which are almost universal in the Project Area.

309. Their migrations (with those of other tribes) are illustrated in Fig. 54. During the dry weather they are based on the major well-fields and borehole sources in the Project Area. The envelope of these dry-season grazing areas are shown in Fig. 55. There are very few in the Sandy Zone; only in Zone A_1, A_4, and A_5.

310. The other camel and sheep tribes the Hamar and Maganeen, also graze in the areas shown in Fig. 55 during the dry season, but they are not strictly nomadic, because a big proportion of each tribe are settled farmers.

Tribal Semi-nomadism:. Camels and Sheep

311. Both the Hamar tribe and the Maganeen have sections which are settled farmers, and sections which are nomadic in the sense that they are generally on the move with their animals.

312. In the rainy season they move into the semi-desert to the north of the Project Area to eat the fresh pastures, with reasonably easy water supplies. During the dry season they come back south, in the Project Area, and they concentrate, of necessity, round the water sources as shown in Fig. 55.

Tribal Semi-nomadism: Cattle

313. These are the Baggara (cattle-owning) tribes, i. e. the Hawazma, Messeriya and Habbaniyah. Their migrations are shown in Fig. 54. All three are more properly termed "semi-nomadic" rather than nomadic, because all three have organic links with settled agriculture. Most of the people belonging to these tribes are settled farmers.

314. The Habbaniyah are mainly farmers but they have more cattle than they can graze around their villages all the year round, so in the rainy season they move northwards into the rainy-season grazing grounds of the Project Area.

315. Both the Hawazma and the Messeriya are tribes whose members are mostly settled farmers, the semi-nomadic cattle herders being in the minority.

316. These two tribes spend the dry season in the plains to the south of the Project Area, down as far as the Bahr al Ghazal, tributary of the Nile.

317. As the rainy season approaches the animals are moved north. By mid-July they are in the grazing grounds in the Project Area, indicated in Fig. 56.

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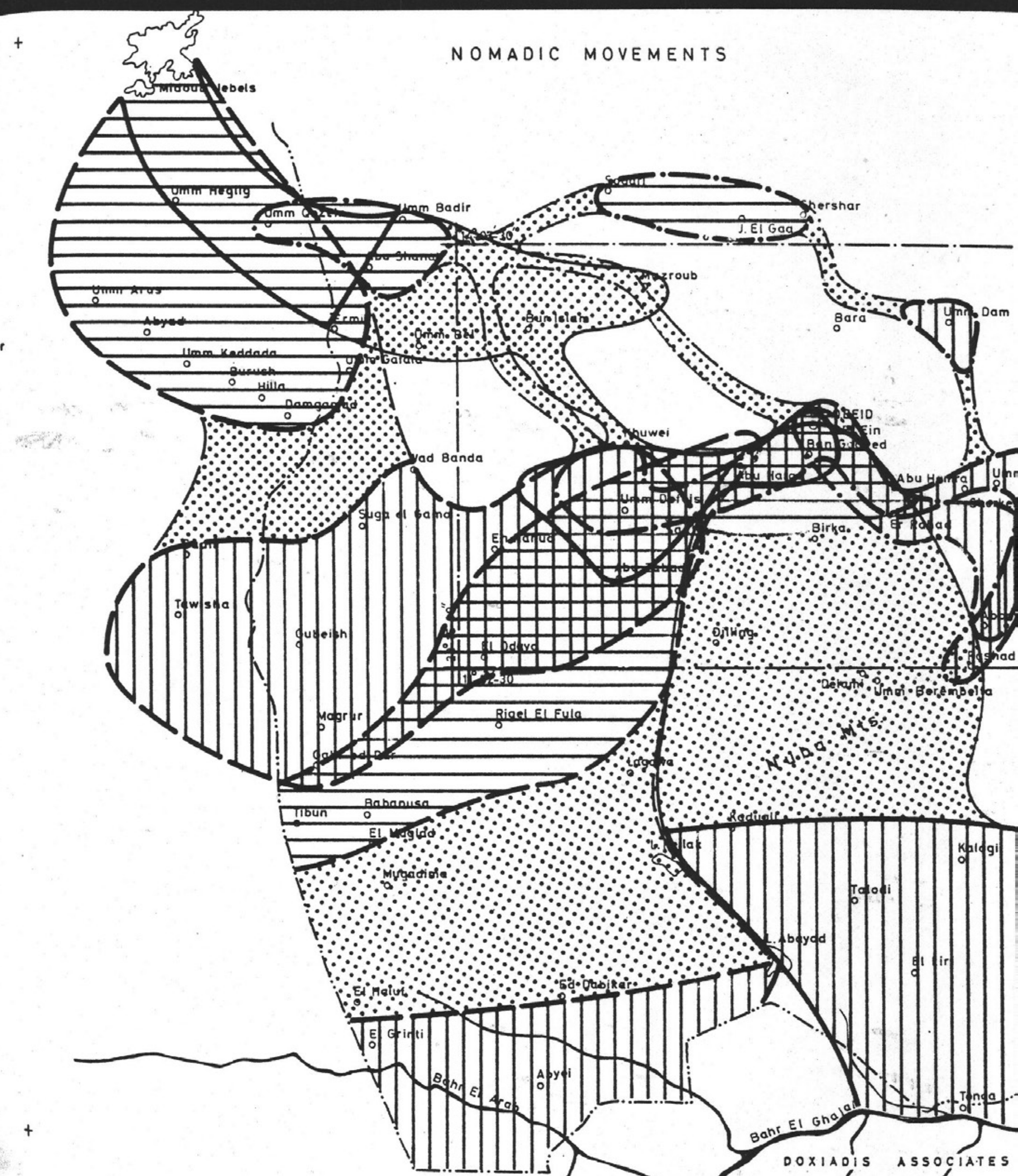

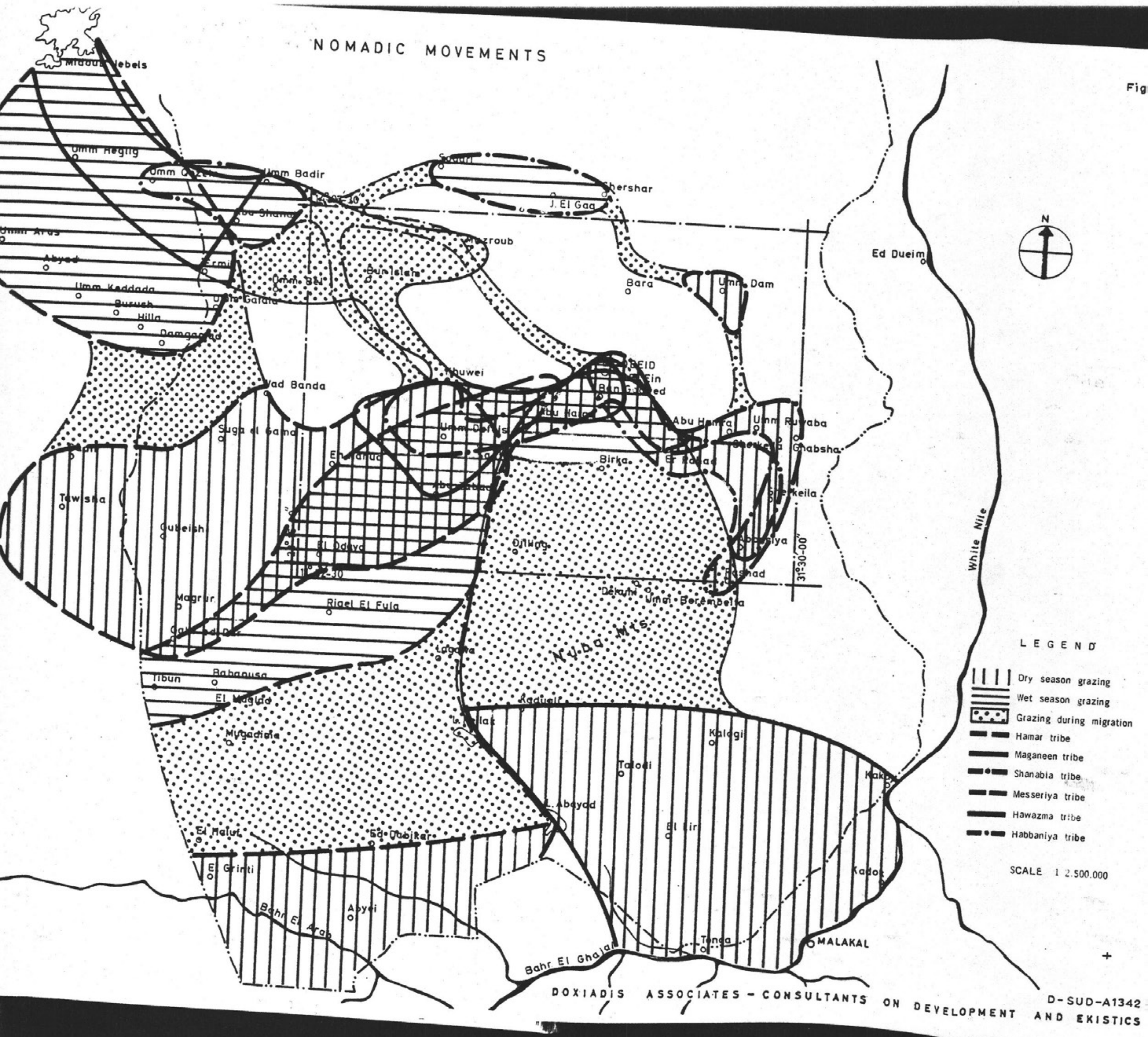

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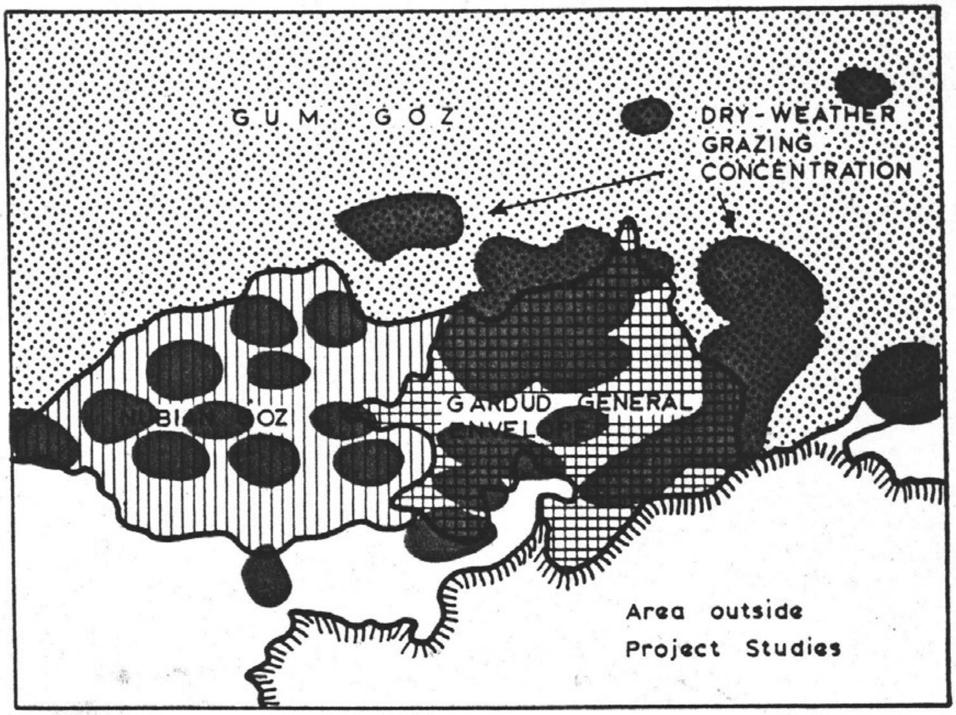
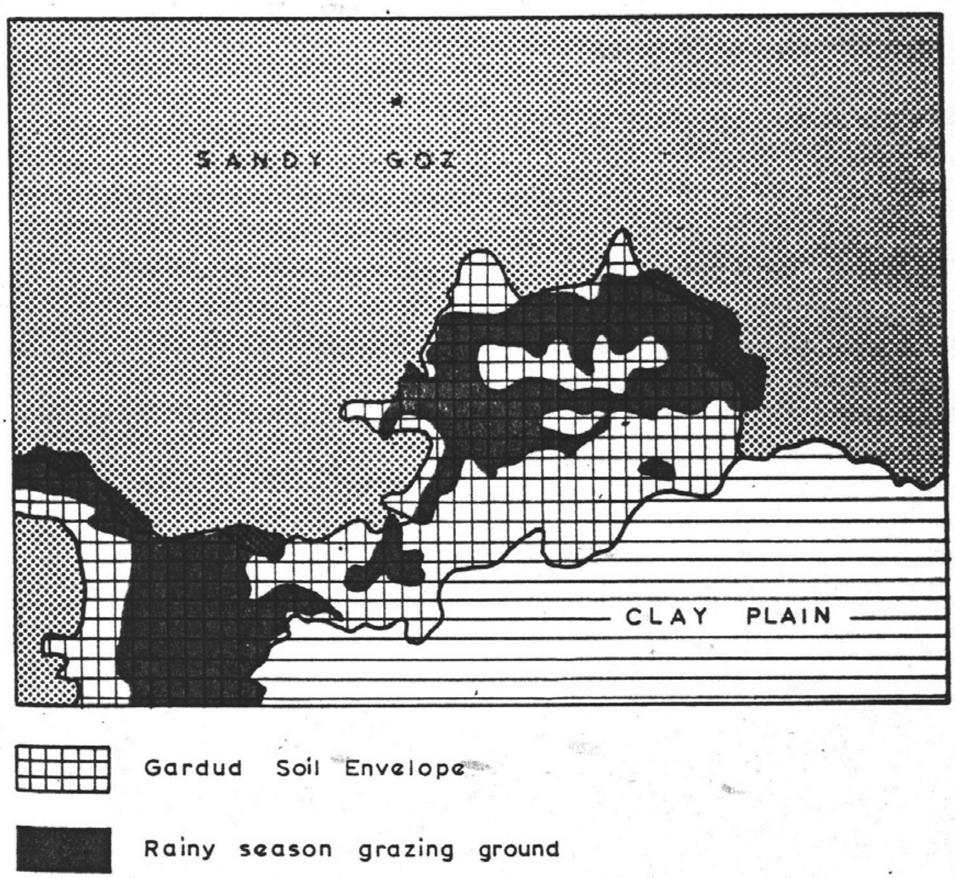
DRY-WEATHER GRAZING CONCENTRATION IN RELATION TO SOILS

Fig. 56



RAINY SEASON GRAZING GROUNDS OF THE BAGGARA CATTLE NOMADS AND SIMPLIFIED SOIL MAP

Fig. 56



Semi-nomadism with Village Livestock

318. The livestock belong to the farming villages but are herded off in the dry season to distant water-sources because there is not enough water in the village.

Semi-nomadism with Merchants' Cattle

319. These are livestock which have been bought by merchants, usually from the tribesmen. Under the merchants' management and ownership these animals are sent out on migration after good grazing in the wet season, and after water in the dry season.

"Resident" Farm Livestock

320. Within the farm and village economy, there are animals which belong organically to the peasant farming system - cattle to serve the household, donkeys or camels for transport, sheep and goats for their products.

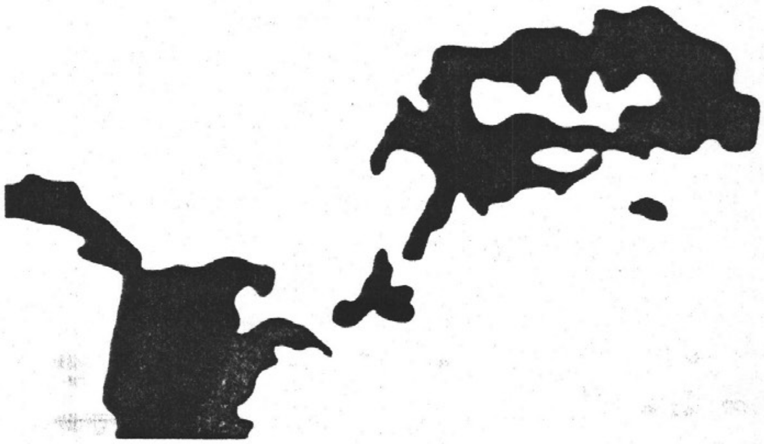
321. These animals belong within the inhabited areas. They graze or browse in and around the village lands. They are not herded off to distant water sources in the dry weather.

The Baggara Grazing Grounds in the Rainy Season

322. These rainy season grazing grounds are in the gardud areas. This is because these soils are relatively impervious, so that the rain forms pools, from which the cattle drink. The general envelope of the land where fulas are found is shown in Fig. 57 with the rainy season Baggara grazing grounds.

323. These gardud soils generally have a better potential for pasture than the goz because the clay when it is wet will retain moisture for longer periods than the sands. There are perennial species of grasses and legumes present where grazing has not been too severe to eliminate them. The presence of this varied flora of both perennials and annuals and, in addition, a balanced diet of grasses and legumes, makes this clayey pediplain and the Abu Zabad repeating pattern of soils most attrattive to the nomads.

324. These soils are also relatively hard under foot compared with the clay plains further south, and the area is comparatively free from flies and othe r pests. For the period of the rainy season, in fact, the lands within the gardud envelope (Fig. 56) have naturally favourable qualities as grazing grounds.

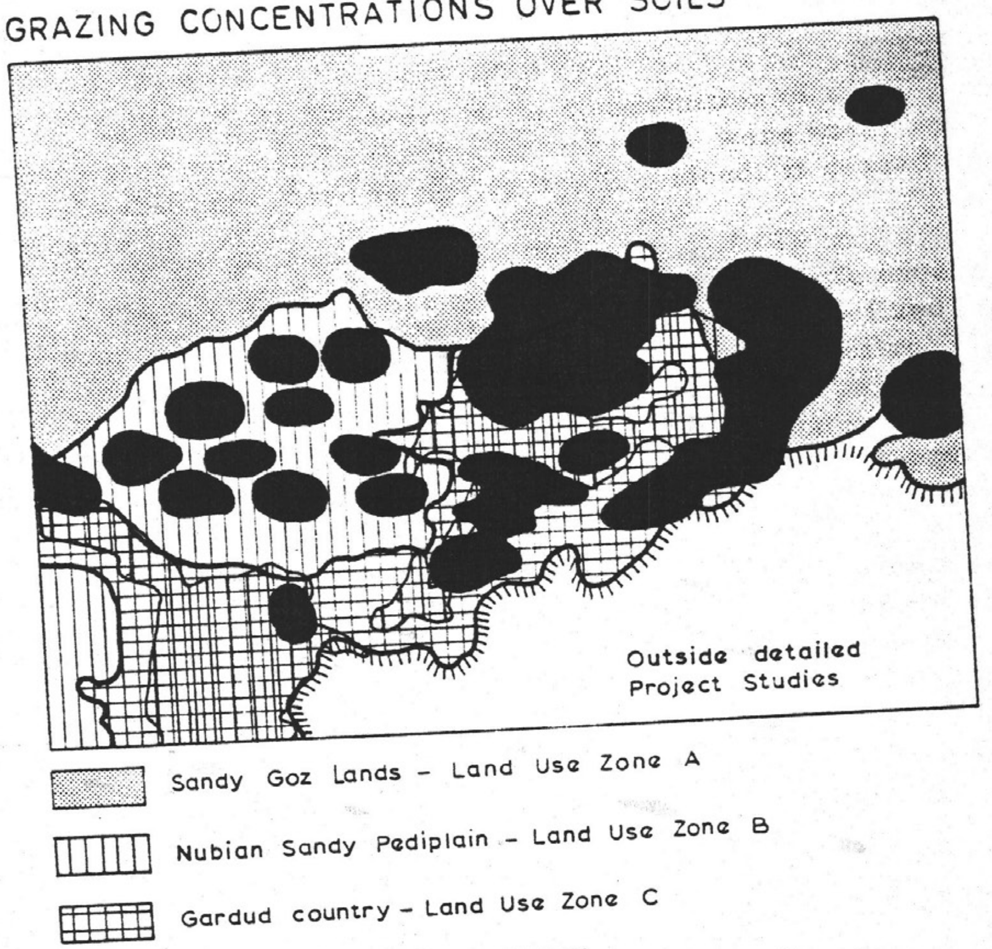


The Impact of Grazing on the Pastures and soils

327. From general observations both from aerial photographs and ground traverses, it would appear that overgrazing in the goz country is mainly a village phenomenon. This is to be expected where communal grazing is practised and the daily movement of flocks to and from grazing grounds tends to exert pressure in increasing circles away from the village as forage becomes less abundant. The smaller animals, which do not forage so far, especially those such as goats, which browse as well as graze, do most of the damage near a village. Goats provide a good deal of the milk for the village. Denudation is also caused by the villages cutting wood to burn.

328. Thus the overgrazing in the sandy goz country, which contains the great bulk of peasant population, is a minor phenomenon when reckoned in terms of proportional areas over-grazed. This is illustrated in Fig. 58, which shows the combination of their rainy season and the dry season grazing areas, in relation to the main soil types and the Land Use Zones.

Fig. 58 COMBINATION OF RAINY SEASON AND DRY SEASON GRAZING CONCENTRATIONS OVER SOILS



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329. Land Use Zone A is the goz proper. There are some grazing concentrations, associated wi.h centres specially well supplied with water.

330. Zone B is the sandy pediplain overlying the Nubian sands'one. The proportion cultivated is small, and water supplies are good, though limited to areas round the boreholes, which provide the bulk of the supply. Round these boreholes there are concen rations of grazing in the dry season, but the area generally is subject to very light grazing.

331. Zone C is the gardud country, with sandy islands. It is the area for rainy season grazing, and since it contains some plentiful well-fields , supplied from dug wells in the flood-terraces, there are also dry-weather concentrations. .

332. In Zone A_1 and A_5, there are also good supplies of water from wells or boreholes, and consequently these attract dry-weather grazing concentrations.

333. The absence of dry-weather grazing concentration elsewhere in the goz country is due, no doubt, to the paucity of water sources and the vefy limited supply from those that do exist.

334. The goz away from villages is generally not heavily grazed because of lack of water supplies, Such grazing is usually carried out by sheep and camel owners as camels can go without water for 8-10 days and the desert type of sheep can go from 3-5 days. Consequently they can graze further afield than cattle and goats. Usually the camels and sheep are part of nomadic or semi-nomadic herds. In other words, grazing in the goz and outside the normal range of the village-based animals is mostly done comparatively sparsely by the nomadic and semi-nomadic herds.

335. Camels and goats browse on the gum acacia and may harm the young trees but the mature trees are little affected by either animal and so, judicious grazing control of developing gum should be exercised.

336. Under heavy grazing in the goz country the palatable perennials disappear, leaving the annuals and the unpalatable perennials without competition and these increase. Fire has the same effect, so the effect of frequent burning and/or heavy grazing is a pasture dominated by annuals which will make full use of their limited seasonal water, mature early, and shed seed for the perpetuation of the species.

337. During the rainy season the sandy soil of the goz is firm but porous. Under the pressure from the animals hooves the wet sand particles are displaced but the soil remains porous and the seeds will germinate. This explains why there is little visible overgrazing in the goz except round villages. Even here the soil is usually stabilised by weedy species.

he Impact of Grazing on the Gardud Pastures and Soils

38. The gardud soils are non-cracking clays or areas in which non-cracking lay alternates in some areas with sandy surfaces. These soils contain clay n varying proportions and at varying depths in the profile, even though the urface may be sandy.

339. The processes by which these soils were formed, and modified by grazing, leads to unevenness in fertility and permeability. Nevertheless, these gardud soils have a better potential for pasture than the goz because the clay when wet retains the moisture for longer periods than the sand. There are perennial species of grasses and legumes present where grazing has not been too severe to eliminate them. These areas provide the best grazing in the Project Area. A "saltiness", through high mineral content in the legumes and herbs, is coupled with the fact that they are growing on soil rich in calcium and sodium in the subsoil.

340. The nomads converge on these gardud soils in the rainy season to capitalise on this excellent grazing and widespread water in the fulas and mutruks, and also in most cases to be near settlements where they can sell the milk of the animals, and old cows and bulls, to earn money to pay taxes. They are careful to avoid cultivation but as cultivation spreads they find it increasingly difficult to find grazing.

341. In the process of grazing they stock their grazing soils very heavily. This heavy grazing plus puddling has a deleterious effect on the gardud soils and with the first use of the land in the rainy season the nomadic cattle probably get most of the legumes and palatable herbs. Data collected from Hawazma tribe grazing areas in 1965 indicated an average of 4.25 acres per head of cattle. On the other hand, as the nomads withdraw their cattle from these gardud grazing areas when the water-pools dry up, and move south to their homelands where there is water and forage is still green, there is still plenty of pasture left.

342. The contrast between the rainy season grazing and the dry season grazing in these gardud areas is very marked. Since the rainy-season Baggara tribes water their animals at the innumerable rain-pools the grazing load is automatically spread. In the dry-season, on the other hand, these pools have all dried up and the animals must, of necessity, concentrate within range of the comparatively few all-season water sources of sufficient capacity.

343. For this reason the worst over-grazing in the Project Area is found round the biggest water sources in the gardud soil areas, and the most extreme cases are at El Obeid, Nahud, Abu Haraz and Bangadeed. In these areas some action is needed to protect the land for posterity. There is water-erosion near El Obeid and Nahud, caused by denudation through over-grazing. Fig. 59 is a "grazing pressure" map.

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GRAZING PRESSURE MAP – 1965

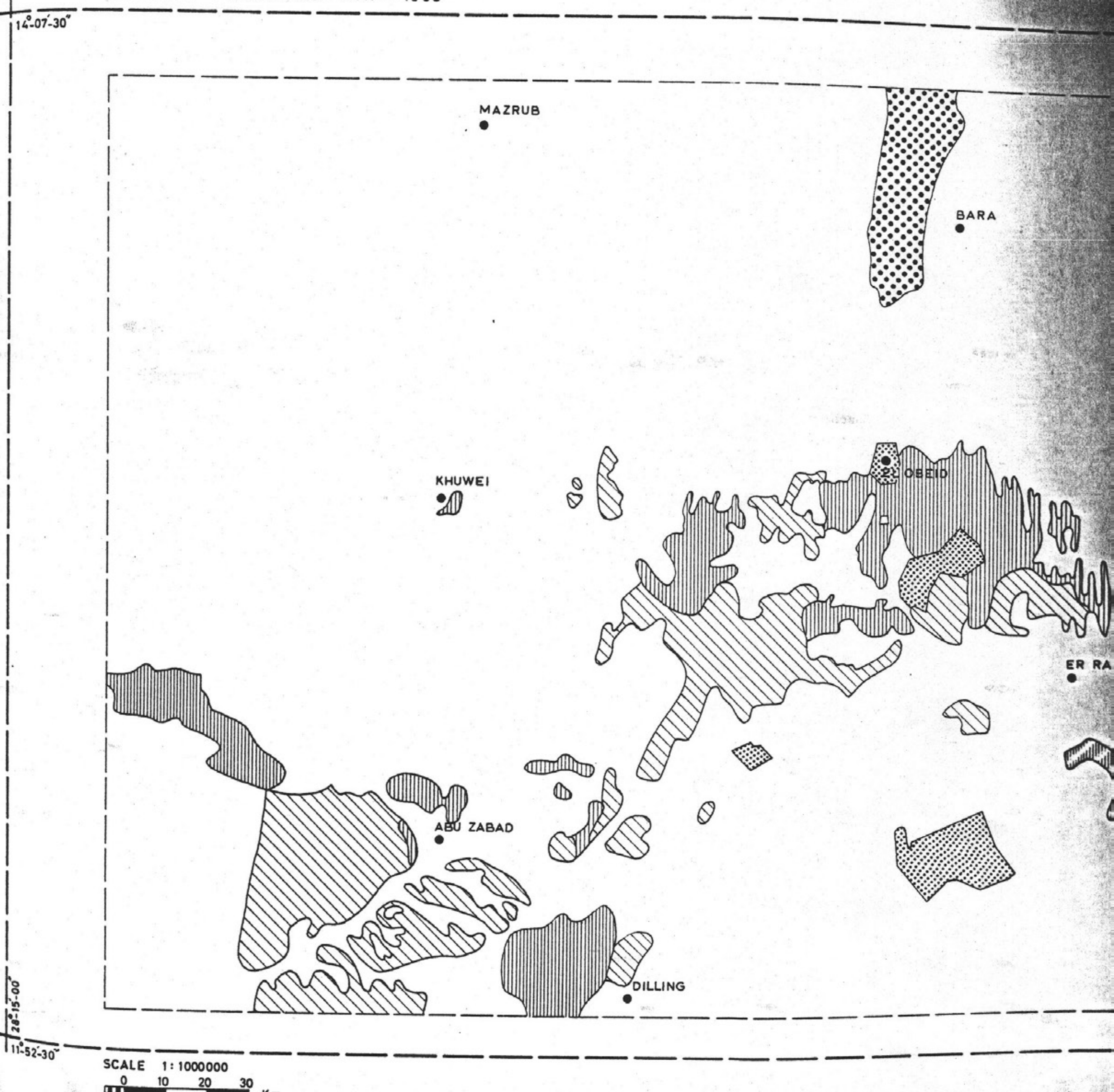
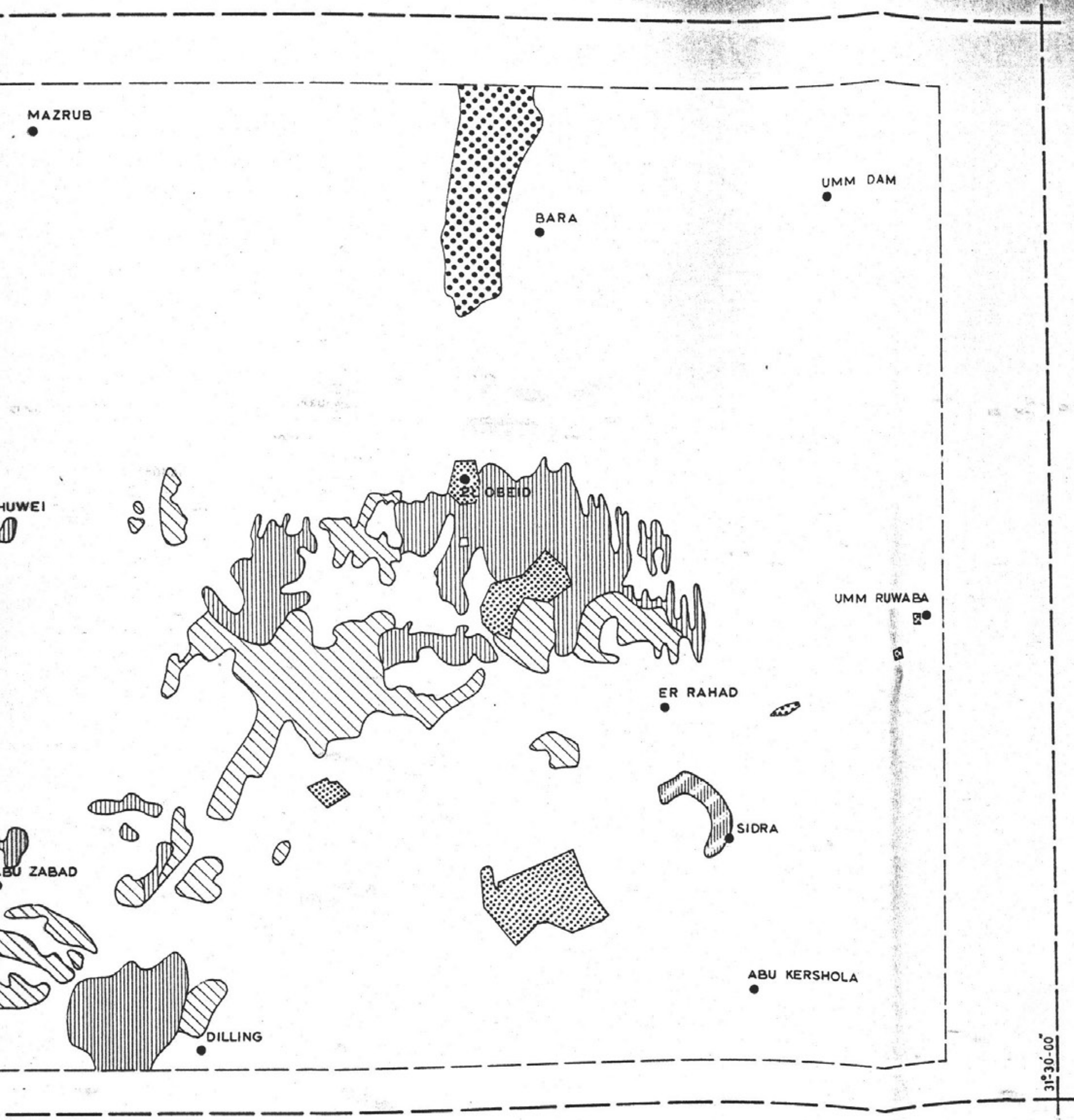


Fig.



LEGEND

- Areas of extreme grazing pressure but capable of rehabilitation by enclosure or cultivation and reseedin-
- Areas of heavy grazing pressure wich are partly protected from overgrazing by cessation of water supplies. Should further permanent water supplies be provided these areas should be enclosed and stocking conditions imposed
- Area unsuitable for grazing - live sand dunes
- Forest Reserves
- Ungrazed areas or Grazed areas with no grazing pressure problems apart from village overgrazing

N.B. Read in conjunction with the Land Use map

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Animal Production and Consumption

344. Taking the Sudan as a whole, statistics show that exports of animals and animal by-products are insignificant compared with cotton, gum, groundnuts, and sesame which together cover the overwhelming bulk of exports.

345. So far as the Project Area is concerned, and Kordofan Province, the quantities of animal produce going into the markets is small compared with the number of livestock depastured. The Baggara cattle tribes do not willingly part with their animals, and when they do, the main animals sold are old cows and bulls. They sell them to get money to pay taxes; that is, from legal necessity, rather than commercial profit. Most of the cattle and sheep produced via Kordofan seem to come from further west, from Darfur. They are purchased by agents, and taken over by herdsmen who herd them around the Nahud, Khuwei and Sa'ata area water sources (boreholes) and move them as required for export, covering some 14 kilometres per day between water points.

346. Within El Obeid, consumption of meat per capita is high, and meat prices are low. With a population of 52,000 in El Obeid, figures for year's slaughtering were: 12,811 cattle, 32,032 sheep-goats, 625 camels. The annual consumption is 42.4 kg. or 93.28 lb. per capita.

347. In the villages on the other hand, consumption is reckoned at 6.0 kg. per head per annum - meat meal once a week. There is plenty of room for greater home consumption of meat in the villages.

348. There is a good demand for sheep, especially for slaughtering for special occasions and festivals, and sheep's meat is preferred to others. Sheep are harder to rear than goats or cattle.

349. Camels are mainly raised in the north western parts of the Project Area. Goats are usually kept in the villages for producing milk. Donkeys are the universal beast of burden, especially for carrying water.

350. Horses are not numerous in the Project Area. They are used as cart horses in towns and for riding in the country. They are not important in the economy.

Milk, Cheese, Butter and Semna

351. Milk supply in the villages comes mainly from goats and cattle, and in some areas from camels.

352. During the rainy season, the Baggara cattle tribes gather close to El Obeid and sell milk. Cheese is made, and some of this milk is pasteurised and bottled.

353. The production from the dairy in El Obeid, run by the Ministry of Animal Resources, amounts to 20,000/30,000 lb. of butter p.a., 5,000/10,000 kg. of white cheese, 4,000 kg. of hard cheese, and 2,000/4,000 kg. of Semna. The dairy farm animals are fed hay and silage and go out to graze with the village cattle.

COMPREHENSIVE LAND-USE PATTERN

354. Fig. 60 is a comprehensive presentation of land use in the following categories:

a. The inhabited areas, which contain all the cultivation and all the villages.

b. The rainy-season grazing grounds (cattle tribes from the south) which are mostly outside the ekistic envelope of the inhabited areas, and mostly within the general gardud soil envelopes.

c. The dry-season grazing concentrations, which are determined mainly by water-availability.

d. The "empty" areas which are outside the inhabited areas outside the rainy season grazing envelopes, and outside the dry season area of grazing concentration.

355. This provides visually, the basis for comprehensive land use policies and plans. The objectives can be stated in very general terms: to up-grade existing land uses and to open up the empty areas.

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COMBINED PATTERNS OF LAND USE

D PATTERNS OF LAND USE

Fig. 60

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CHAPTER 6

WATER

OUTLINE OF THE INVESTIGATIONS ON WATER SUPPLY AND THE GENERAL CONCLUSIONS ON AVAILABILITY : BASED ON VOLUME IV AND ITS TECHNICAL ANNEXES

INTRODUCTION

356. Volume IV "Water Investigation and Climate" comprises a comprehensive report supported by a number of Technical Annexes. The Comprehensive Report is entitled "Hydronomic Investigations: Concluding Report on Water Availability and Recommendations". An index to all the Volumes is at the beginning of the present Report and the coverage of the Volumes was discussed in Chapter 3.

357. In this present chapter of the general Report, the conclusions stated are in very general form and are related to water availability. Proposals for action and the corresponding recommendations are dealt with later in Chapters 11 and 13, when the whole of the results for all the different technical aspects are integrated into terms of Land Use Policy and Planning.

358. The earlier chapters have described and illustrated how drinking water is being obtained at present, and how the chief problem is the distribution of water to fit the proper use of the land and avoid excessive concentration in some areas, side-by-side with large tracts of land which are virtually not used at all although enjoying a fair rainfall.

359. The maps and texts have shown that except in some specially favoured places, (Land Use Zone A_1, A_2 and A_6, see Figs. 41, 42 and 43, most of the peasants live and work in villages which are distant from all-season water sources, so that during the dry weather they have to have water transported to them either by animal or by lorry.

STATEMENT OF THE PROBLEMS

360. The problems are: how to remove this heavy burden of water transport from the peasantry so that they can increase their productive work in their existing cultivated lands; how to provide water in new places so that lands which are at present unused or little used can be developed; how to provide water for the livestock; and, comprehensively, how to do all these things in such a way that the provision of new water supplies is properly matched to the capabilities of the land and does not lead to additional over-concentration and excessive use.

361. Water supply is the key to the full and proper use of the land. No matter what the land's capabilities are for crops, pastures or trees, they cannot be used as they should unless the water supply problem is solved. The investigations covered all the existing methods and techniques for getting water, and how they fit into the pattern. That is, dug wells, boreholes, hafirs (excavated reservoirs), tebeldi trees (baobab), water-melons, fulas (pools), turdas (natural lakes). Methods of distribution were examined; i. e. animal transport, lorry transport, pipe.

362. In addition, the investigations included a programme of research and development into the methods of constructing small storage tanks in order to catch the rain at the village itself where it is needed and where it falls, and keep it till it is needed in the dry season.

SIGNIFICANCE OF THE TEBELDI TREE AND THE WATER MELON

363. In effect, the central problem was simply a research for a modernised and larger version of the tebeldi tree storage tank. The people of the region had invented the tebeldi tree techniques to "overcome the problem of water distribution" - in plain terms, to get the water at the places where they needed it. It had done its job well enough but had two decisive drawbacks. First, the tebeldi tree only grows in certain places of its own choice; second, it has to be a hundred years old or more before it is big enough to be hollowed out and converted into a storage tank. In addition it gives water of poor quality, discoloured by the living wood.

364. Thus the tebeldi tree only solves the water distribution problem within its own rigid geographical and chronological limits. The peasants' inventiveness went a stage further - the water melon. It is only a partial solution, but it can be grown anywhere so it solves the geographical problem. It is an annual plant, so it solves the chronological problem. The disadvantages as to the quality of the "water" and its quantity are obvious.

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365. They had now partially solved the problem of distribution, in a way. But in addition to the disadvantages already mentioned, there was the fact that each method involves a great deal of labour. The tebeldi tree has to be laboriously hollowed out; water to fill it has to be scooped up from the little catchment basin round the trunk and lifted up the tree to be poured in. To get water out a man has to climb the tree. In the case of the water-melon, it means, in effect, growing two crops, one to eat and the other to drink.

366. Nevertheless, these two indigenous methods are highly significant, for several reasons. Firstly, they were developed by people who knew all about how to dig wells and who, beyond all possibility of doubt, must have tried and failed to find ground waters by digging before resorting to these other methods. Secondly, the fact that the tebeldi tree method has worked in practice for generations is proof of the basic proposition that a small earth catchment basin, of the order of a few hundreds of square metres, can in fact be relied on to catch the rain which can then be put into a storage tank. Thirdly, if a modernised version of the tebeldi tree is introduced, it would be no novelty to the peasants in principle, and would give them more water for less labour; and both of these points would greatly assist the work of introducing the new techniques.

CATCHMENT TANKS

367. It will be understood from the discussion above, that the purpose behind the development of what is called the "catchment tank" was to fill a gap which has to be filled if the land resources are to be properly and fully developed, wherever this gap cannot be filled, at acceptable cost, by any other means. It was apparent at the outset that in this Project Area (which is the limit of our studies) there are places where there are no groundwaters and no flowing surface waters and no springs or lakes, but which enjoy a good rainfall and could be profitably farmed if drinking water could be provided; and where the only alternative to expensive transport by lorry (as at present), or expensive piped supplies, is a modernised form of the tebeldi tree. It follows that a complete range of solutions to the water supply problem must include the "catchment tank" technique so that it can be used wherever it is cheapest or wherever there is no other way. Comprehensive land use planning and development demands a solution by catchment tank as one of the essential tools.

368. The area in the Gum Belt where water supply is done by lorry, at excessive cost has become the primary target for the catchment tank because this is where the problem is most acute. It is referred to as the "Water Crisis Area", see Fig. 41.

Types of Catchment Tank

369. Figs. 61, 62 and 63 illustrate three types which have been developed in the Experimental Yard in El Obeid. The way they work is as follows. Alongside each tank there is a rainfall "catchment", formed artificially. When it rains the water runs off down the slope towards the tank, into which it runs.

370. In the case of Fig. 61, the "Beehive" type, the run-off water ponds up on top of the domed roof of the tank, which is covered by a bed of sand. The water soaks through the sand, which acts as a filter, and seeps into the storage-space in the cells under the domes. In the case of the "Pillared Roof" type, Fig. 62, the water runs straight into the storage capacity. In the case of the "Bottle", Fig. 63, the water soaks through a conical sand-filter.

371. Each of the three types has a well-shaft so that water can be withdrawn by a bucket on a rope (in a later stage of development, naturally, a hand-pump can be fitted). The Beehive type has a sand filter round the base of the well shaft, so that the water is filtered on its way out as well as on its way in. A similar arrangement can be provided for the Pillared Roof. No "outlet filter" is provided for the Bottle type because it is much smaller than the others (only about 5 cubic metres, 1,100 gallons) and if a filter were added it would occupy a prohibitive proportion of the storage space.

Constructional Features

372. The capacities of these tanks are geared to constructional and functional considerations. They are "units". A given village can be provided with as many unit tanks as are necessary to meet its needs, or as many as available funds can cover. A family can have as many "family-size" tanks as it can afford or wants.

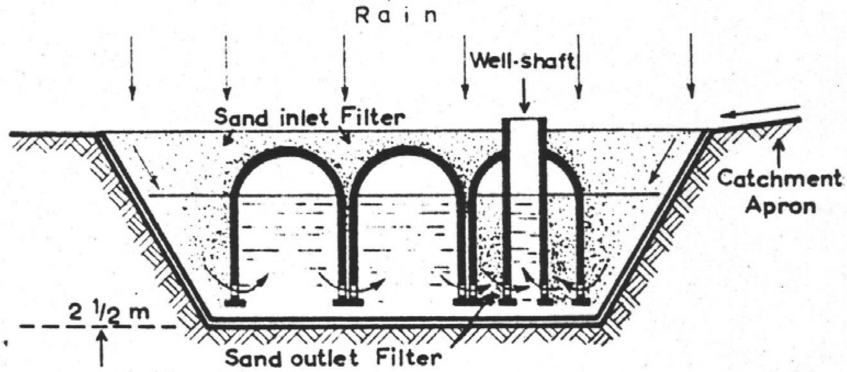
373. The essential elements of construction are an excavation in the earth, lined with an impermeable layer, and covered with a roof on a structure made of a novel form of reinforced concrete.

374. The impervious lining which was developed to suit the local circumstances was a multi-ply "sandwich" of fine-gauge polythene and clay slurry in the case of the Beehive and the Pillared Roof, and an artificial rubber bag for the Bottle.

"BEE HIVE,, CATCHMENT TANK

Fig. 61

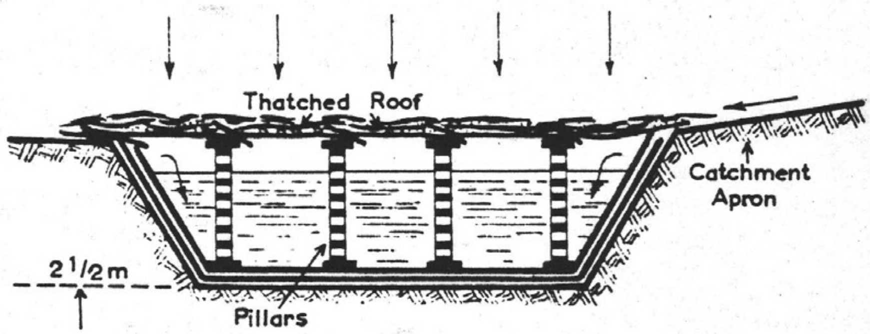
Capacity 100 cubic meters = 22.000 gallons



"PILLARED ROOF,, CATCHMENT TANK

Fig. 62

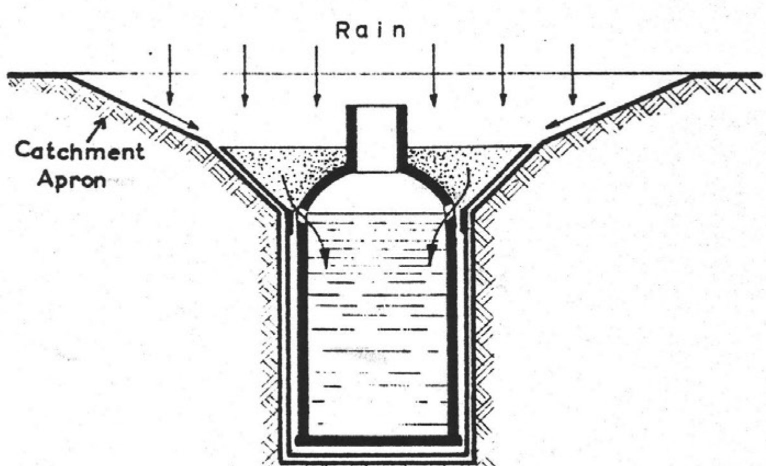
Capacity 230 cubic meters = 50.000 gallons



"BOTTLE,, CATCHMENT TANK

Fig. 63

Capacity 5 cubic meters = 1.100 gallons



375. The reinforced concrete structures to form the roof and its supports is made by "capillary-mix" or "Cap-mix" process. Tubes of very fine gauge polythene are filled with a dry mix of sand and cement, and closed up to form "sausages". The skin is perforated with fine holes and when building is to begin, the sausages are placed in a pan of shallow water. Water is sucked up into the dry mix, against gravity, by capillary tension. When the mixture is completely wetted in this way there is enough moisture to set the cement, but there is a state of capillary cohesion and the material will stand a certain compressive strength without slumping. The "sausages" can therefore be used as building units as soon as they are wetted through. The units are "mouldable" and can be patted into form by means of a wooden mallet, rather like plasticene. Reinforcing "Skewers" are driven in, piercing the sausage-like units after they have been patted into place. The construction is illustrated in Plates 13 and 14.

376. No form-work is needed because the units stand on their own owing to their internal capillary cohesion. Domes are formed by pinning successive circles of units in decreasing diameters.

377. As soon as the units are in place, and skewered, they need no more attention. No watering is needed while the concrete matures because it is enclosed inside its "sausage skin" and the evaporation is suppressed.

The Catchment Apron

378. An obvious question has to be met: what happens if the rain "misses" the catchment apron, throughout a whole season, so that no rain falls on it?

379. In the first place, wherever there is a village (with negligible exception) there is agriculture, and therefore a rainfall big enough for agriculture. With such a rainfall, it is only a matter of proper design to provide a catchment apron big enough to fill the tank.

380. Then there is the possibility that although a normal season's rain falls, it may miss the very small catchment apron. If this could happen with a catchment a fraction of an acre in area, it must be more likely still to happen with a catchment of say, a fraction of a square metre. A rain gauge is such a catchment. Table 1 shows that in an aggregate of 258 rain-gauge years covering 10 rain gauge sites, the absolute minimum minimorum of them all was 168 mm. No rain-gauge ever failed to register in any year. It can be stated that if catchment tanks had been present at each of those sites for all those years, with a catchment apron designed for a rainfall of 168 mm., every single one of those tanks would have been completely filled in every single year; that is, 258 "tank-years".

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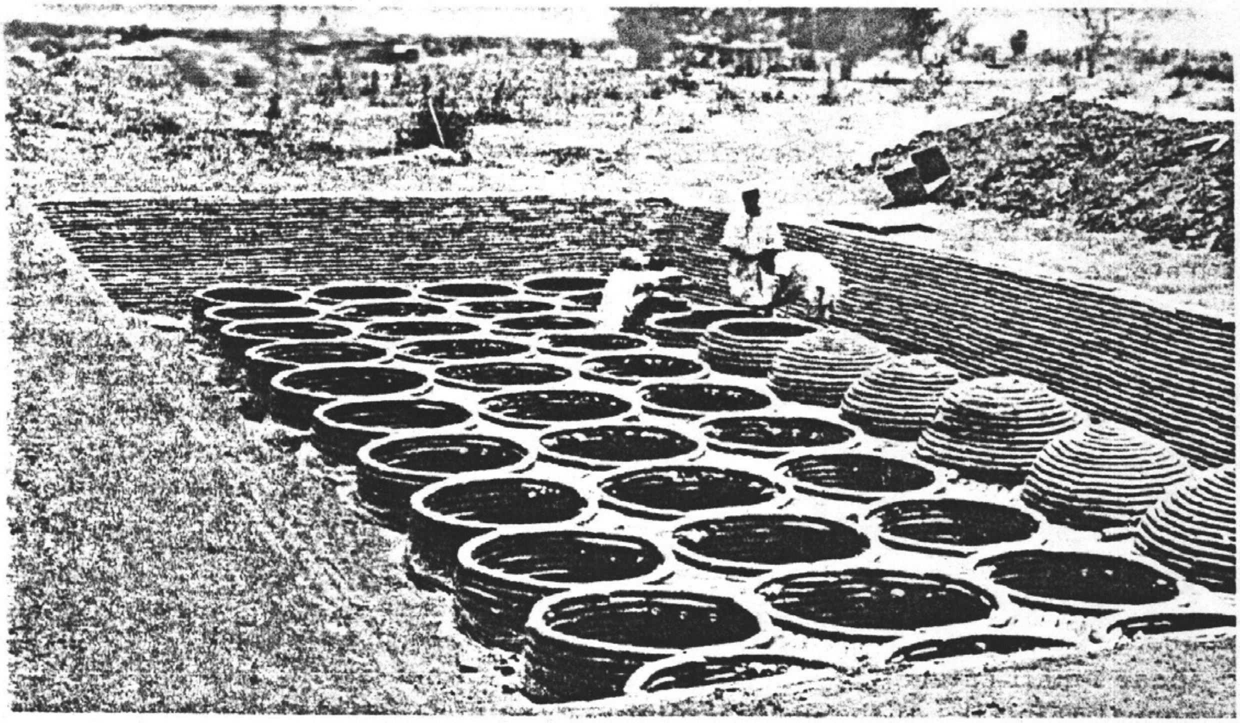

PLATE 13

Building the domes. No form work or supports are needed. Each ring of sausages. is laid with a decreasing diameter. Each sausage is impaled upon the ends of skewers which have been left extruding from the previous row. Since it is an essential quality of cap-mix that it can take an immediate loading, without deforming, the successive rings are self-supporting even though the chemical set in the sandcrete has not yet started.

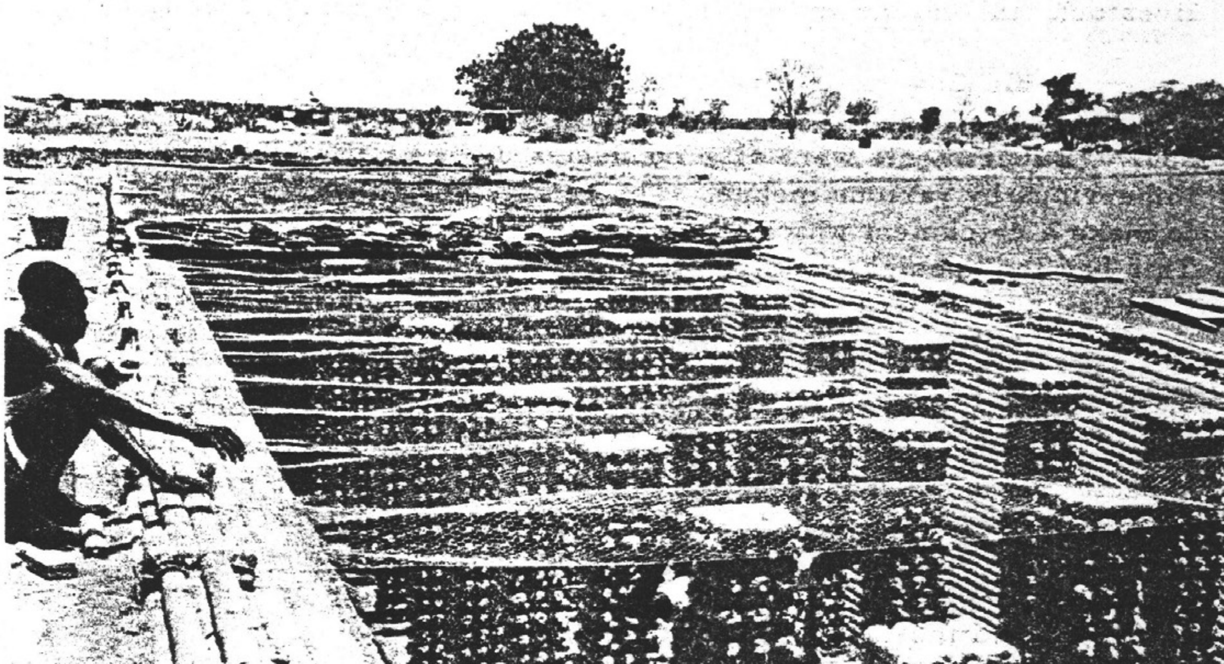

PLATE 14

The pillars are seen standing up inside the lined hafir with chicken-wire not spread and (in the back ground) thatch .

381. This method of answering the question illustrates the most important fact that the basic hydrological data for designing catchment tanks is provided by the rainfall records, which can be applied almost directly because the catchment is so small.

382. To take the limiting - but entirely practical - case; if an impervious catchment apron is provided, the yield and all the hydraulic features for a catchment tank can be determined from the rainfall statistics alone. Wherever there are rainfall statistics, hydraulic design can be done immediately, without any delay, and without any field surveys or hydrological investigations. By adjusting the relative size of the catchment area, any desired margin of safety can be provided.

383. In the circumstances of the Project Area it was found that run-off from these small catchments, made simply of rammed earth, was 50/60% of total annual rainfall. If the design-minimum rainfall is (say) 250 mm., and run-off at 50% is allowed for, then it will take 8 square metres to provide a yield of 1 cubic metre. To provide for a Pillared Roof Tank (Fig. 62) with a capacity of 230 cubic metres (50,000 gallons) the catchment area required is then 1,840 square metres, or less than half an acre.

384. The superficial areas occupied by the catchment aprons, in relation to cultivated areas, or to the village lands, is negligible. In the Project Area a fair farm holding is 60 or 80 acres. To provide water for the family and its livestock, the catchment apron area needed only a fraction of an acre.

Impermeable Coverings for Catchment Aprons

385. Experiments were also conducted using artificial catchments rendered impervious by various means. The results show that it is quite practicable to make a catchment which will respond with a few millimetres of rain. This has the special advantage that the apron will catch the very early and light rains of the season and also the very late rains, which yield little or no run-off with an earth catchment because the light rainfall is absorbed.

386. Consequently, a high ratio apron shortens the period between the end of one year's rains, and the beginning of the next, and therefore the storage capacity can be correspondingly smaller. However, the extra cost of a high-efficiency apron has to be placed against the saving. There will most probably be certain circumstances where a high efficiency apron is needed, but for the general purposes under study, experience shows that an earth catchment suffices. It worked with tebeldi trees too.

Termites

387. The termite hazard is discussed fully in the relevant reports which have been issued. There is no evidence better than actual operational experience, over a sufficient time. Two tanks built in the spring of 1963, lined with polythene and with no insecticide, were still holding water in the spring of 1966. Similarly, full-scale prototypes built in the spring of 1964, and six built in two villages in 1965 all of which had insecticide protection.

388. Tests with a multiple "Sandwich" lining (clay, slurry and membrane interleaved) over 18 months, without insecticide, showed that despite infestation by termites, the lining was hydraulically sound. Moreover, when a sandwich lining was repeatedly punctured straight through with a sword, it sealed itself up because the clay slurry was washed through and formed a cap.

389. It is considered, nevertheless, that a positive deterrent in the form of an insecticide is advisable, placed outside the impervious membrane, where it is not in contact with the water. The use of insecticides for this purpose requires all the usual care in handling to avoid contamination, which is equally necessary when protecting water to drink as it is for crops to eat.

Quality

390. A number of analyses were made of samples from catchment tanks. With the exception of one which is dealt with below, all indicated satisfactory potable quality.

391. In some cases there was a high, but not prohibitive content of organic matter. This was to be expected because the sand bed used for filtering is loose sand gathered on site. Washing would be expensive and would not be warranted because the first year's operation does, in fact, wash the sand.

392. If tests or circumstances indicate bacterial pollution in any particular cases, the whole system can be sterilised by spreading some bleaching powder on the lap of the sand filter bed, and raking it in, just before the rains begin. Chlorine will then be carried down, through the filter-bed, and into the tank.

393. The exceptional cases referred to above, were the four beehive tanks built at Magasis and Abu Khureis in 1965. The first samples to be analysed showed a high content of gammexane, which was the insecticide used to dress the earth excavation before laying the lining, to keep the termites off. The strength of the contamination was suspiciously high; so high, indeed, that it was difficult to imagine how much a proportion could have got into the water.

394. A second set of samples was taken, under specially close supervision, and all of them were free from gammexane. The first set had been taken from the well shafts; the second set were taken by breaking open one of the domes in the body of the reservoir.

395. The tests showed, therefore, that the water taken from the well-shaft was contaminated, while the water in the body of the reservoir was not. But if the contamination had come from or through the lining of the tank, the body of water as a whole should have been contaminated inside the tanks and inside the well and shaft.

396. The explanation is probably as follows. When the tank had filled up i.e. after the rains, the watchmen were instructed to take out some times a day, so as to stimulate natural daily withdrawal. This water was to be thrown to waste until tests had been made. It seems likely that tins which had been used for gammexane must have been used for withdrawing the water, so that the samples from the well-shaft were contaminated. The analyst remarked in the report that the water in the samples had a peculiar odour.

397. Although catchment tanks in the Experimental Yard in El Obeid have survived several years without insecticide protection and without evidence of deterioration, a positive protection is preferable, and there is a little reason to doubt that experience will enable insecticides to be used without any greater risk than is always present, inescapably, whenever insecticides are handled and used.

Further Research and Development

398. Neither the potentialities nor the problems have been fully explored or answered by the Project studies. It is to be expected and hoped that experience and continuous research will lead to better methods and better materials and better designs and will reduce still further the hazards which undoubtedly still exist.

399. What does seem certain, however, is that there are big and important parts of the country where a catchment tank is the only solution if the problems of supply are to be removed and if the farmers are to be relieved of the heavy burden and cost of transporting water. Furthermore, it seems that membranes made of the modern materials provide by far the best means of providing the solutions. Different forms of membrane will no doubt be used; for example, where speed and simplicity are needed it may well be that butyl artificial rubber will serve better than the polythene "sandwich".

400. The position is that if there is to be a real advance and a real, progressive up-grading of the peasant agriculture, a solution for the supply of water on the lines of the catchment tank, in addition to all the customary methods, is a necessity.

401. The work of the Project has produced certain designs and specifications and has carried them far enough to prove that the catchment tank solution is a practical proposition, at acceptable cost. However, this does not mean that these particular designs and specifications are necessarily the best, and indeed it would be surprising and disappointing if further experience and experiment did not lead to many improvements.

HAFIRS

402. The maps and other data given earlier have shown that most of the particular terrain of the Project Area - and especially the goz land - does not favour the traditional type of hafir.

403. Investigations at the hafirs at Jebel Abu Sinun and Mazroub over two years have given measurements of losses from evaporation and seepage compared with capacity, and costings have been made.

404. Seepage could be prevented, by means of impervious linings. There are several possible methods. Evaporation losses, however, are far more difficult to deal with. The depth and size of a hafir make it impracticable to consider any form of rigid roof at reasonable cost.

405. Monomolecular film was investigated, but its use required continuous attention, with continuous supplies of material, a degree of skill which cannot be expected of a hafir watchman, and so a closeness of supervision which is beyond practical possibility for a large number of hafirs.

406. Some form of floating cover or raft was considered - the technicalities were discussed in the Interim Report on the Drinking Water Problem (DOX-OA 23). A solution on these lines could probably be found, but it would involve effort and expense in research and development which lay beyond the resources of the project. Since the terrain of most of the Project Area does not favour the hafir anyway, a solution to this particular problem is of comparatively little importance for this Project. But it is much bigger importance in the areas where hafirs provide the best solution.

407. So far as concerns the Project Area, the catchment is a difficulty for hafirs. The sandy goz area - where the peasant farming is located - has virtually no surface run-off. The actual hafirs in the goz country are associated with the lacustrine depressions which lie, usually, to the south of the jebels and with longitudinal dunes: Jebel Abu Sinun, Jebel Taloshi and Mazroub are the three outstanding examples associated with jebels. The project investigations on Abu Sinun show well the problem of this kind of catchment, where there is no flowing Khor or Wadi in the ordinary sense, but a drift of water down-slope which may be collected.

408. The Jebel Abu Sinun hafir is illustrated in Plate 15 and Fig. 64. Collector channels are run round the contours at pediments of the rock outcrop to catch the sheet run-off. These collectors deliver into a feeder, which picks up a fula and runs into the hafir. A second pair of collectors gathers drift-water in the bed of the depression.

409. The run-off ratio is extremely small because the slopes leading up to the Jebel are covered with thick grass and are also rather permeable. The hafir does not always fill up properly.

410. The studies show clearly that if more large hafirs are to be built in the goz country - which means mainly in those few localities where there are lacustrine depressions - an artificial catchment will be advisable if a reasonable reliability in filling the hafir is to be attained.

411. If this is done, however, the result is more and more like a very large "catchment tank" - but without a roof to control evaporation. And then this question must arise: is it good to build very large "catchment tanks" - i. e. hafirs - which can serve half a dozen or more villages, all of which have to carry their water several kilometres from the hafir to the village, when a number of smaller catchment tanks can be built at the villages themselves, thus eliminating the costs of transport? The answer is in terms of comparative costs, which are discussed later.

BOREHOLES

412. A borehole is usually considered the preferred choice of water source. Unfortunately, as the maps and other data in Chapter 4 have shown, there are big areas where no success has yet been found from boreholes, although drilling by Government agencies, for exploration as well as production, has been going on for a quarter of a century and more.

413. Generally speaking, there are fair hopes for boreholes in the areas over the Umm Ruaba Series and the Nubian Series, as shown by the accumulation of experience over many years.

414. The Umm Ruaba Series areas fall into two broad categories. The first coincides with Land Use Zones A_1, A_2, and D (see Fig. 43) where, as already explained, there is something like a general water table, and where there are no obvious indications which are visible on the ground surface, such as vegetation, contours, soil types. The second corresponds with Land Use Zone A_4, which is the Zone of longitudinal dunes. In this Zone the boreholes (as also the dug wells) are in the inter-dune hollows. Possibly - or even probably - there is little significance in this because if there were a general water-table the shortest and cheapest way of reaching it would be to drill or dig in the hollows.

415. The characteristics in the Nubian Series Zone - Land Use Zone B, Fig. 43 - are significantly different. It is a statement of fact that all the active, producing boreholes in Land Use Zone B are geographically associated with the serpentine lacustrine deposits. From this it is tempting to deduce cause and effect; that is, to conclude that the boreholes succeed in these places because the depressions act as collectors of surface water which then percolate down into the aquifers of the Nubian Series.

416. The historical sequence permits - or encourages - a quite different interpretation. There were villages in these serpentine depressions before there were boreholes. The villages were established by making storage tanks in tebeldi trees. Population grew and water ran short. So boreholes were drilled. The borehole sites were chosen because that was where water was needed, not because that was where the chances of finding water were brightest. On this interpretation the co-existence of boreholes and the fluvio-lacustrine depressions has no necessary hydro-geological significance.

417. What then are the prospects of finding water by drilling in these big stretches of Land Use Zone B which are at present empty, or virtually empty?

418. The Nubian Series is proved, already, to be favourable as an aquifer. The sandy pediplain which was formed in situ over the Nubian Series is extremely permeable - there is virtually no run-off so that the proportion which soaks in is relatively high. The trees which are characteristic of this zone do not, for the most part, send down very deep tap roots (as does the gum acacia) so that water which percolates down below the comparatively shallow root zone must presumably join the Nubian aquifers.

419. All in all, the prospects must be regarded as fair, but nonetheless, the only way of finding out for certain, in any particular place where water is needed, is to drill an actual hole.

420. During the course of the Project, some periodic records of the water level in the existing boreholes were collected. The data are few, because measurements are only physically possible at the single season in the year when the pumping machinery is withdrawn for annual maintenance. The records do not show evidence of any general downward trend in the water levels. Since observations are only taken during one short season in the year, they do not give any indication as to whether there are, or are not, seasonal variations correlated with the rainfall.

DUG WELLS

421. Unfortunately, the Project Area is not one of those regions where extensive water-tables are found, which when surveyed can be tapped almost everywhere. Only Zones A_1, A_2 and A_6 are conditions of this kind found, and so these zones are already well supplied with water from dug wells. (Fig. 43).

422. The surveys and investigations have made it possible to diagnose, with considerable confidence, the general circumstances of the several groupings of dug wells.

423. In Zone A_1 and A_2, almost every village has its well. Seasonal variations in level are definite but small. Seasonal response to the season's rain shows no identifiable time-lag, which suggests, with fair certainty, that the annual re-charge is by direct infiltration of the rainfall over the area itself.

424. In Zones C_1 and C_2, which contain the surface drainage basins, dug wells are associated with the surface flow. Characteristically, the tributaries change slope at a certain point, from a higher slope to a lower slope. From this point, the typical ribbon-like flood-plain begins, covered with trees, with dark clayey alluvium. Most of the well-fields are situated near the junction of the two slopes. The seasonal variation in level is much greater than in Zones A_1 and A_2. This is to be expected since the evidence is that the Zone C aquifers are confined within their valley while the A_1 and A_2 aquifers are continuous. The Zone C seasonal response to the season's rain shows no identifiable time lag.

425. In Zone A_3 there are a very few wells associated with the lacustrine depressions which lie to the south of the jebels. The most notable case is Mazroub.

426. Two places call for special mention, i. e. the well-fields at Bara (in Zone A_1) and Bangadeed (Zone C_1), both supporting small but important irrigation. These were both put under intensive study, and a mass of statistical data is referred to under Volume IV. The programme of field data was prepared in the expectation that comprehensive technical analysis would be needed. In the event, however, it only required a comparatively simple analysis to provide a practical conclusion for the proper purposes of the Project: i. e. a conclusion in terms of the policy to be adopted and the action to be taken. For both Bara and Bangadeed, no proposals are made for Government investment in development because at Bara the existing private-enterprise exploitation is judged to be near the practical limit, while at Bangadeed the delicate balance of water-levels could too easily be upset, leading to water-logging, if attempts were made to enlarge the capacity. For both places, however, regular observations should continue so that any secular changes can be diagnosed, for which purpose the time-space of the Project was naturally too small.

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427. Wherever there are actual dug wells, there is some definable explanation, some indication (on maps or in the data collected) as to why the well is there. Where the indicators are absent, no wells have been observed.

428. It is clear that the peasants of the region have accumulated a vast body of practical experience, telling them where water is likely to be found and where it is not. The proof is that if there were no dug wells at all, and if the present survey had been made, with sufficient trial wells dug according to the indications of the surveys, the areas which would have been recommended for exploration would have been those where the peasants have in fact found water.

429. No evidence suggests that there are still to be found any important groundwaters capable of being exploited by dug wells. Even if there are, there is no sure way of proving them except by actually digging shafts in all the places where there are favourable indicators, and this was far beyond the resources or the function of the Project.

430. From this point of view of land use planning the difficulty is the same as with boreholes. The essential point of planning is to guide economic investment; its purpose is nullified if the major item of investment has to be carried out in order to get the knowledge about water supplies which is the essential starting-point for making the plan.

RAHAD TURDA (NATURAL LAKE)

431. The situation of the lake at Rahad, and its general place in the hydrology of the Khor Abu Habl basin, have already been described.

432. At the end of the second World War two flood-irrigation systems were built; one near Rahad, one near Semeih. In 1961 the system near Rahad, which had fallen into disuse, was converted into a feeder, to take water from Khor Abu Habl and put it into the lake. Whereas formerly the Lake used to dry out, as often as not, it now becomes a permanency.

433. The Project Studies, described in Volume VIII, aimed at improving the diversion works enlarging the storage capacity, and providing for the beneficial use of the stored water.

434. A "first-stage" project has been prepared in outline. It would provide for a total useful annual supply of water of 17.0 million cubic metres. The assumption is made that the existing irrigation system at Semeih would be given an assured controlled supply, accounting for 610 million cubic metres per annum. The sketches in Figs. 65 and 66 illustrate the general plan.

435. The remaining 11.0 million cubic metres could be allocated in several directions:

a. Water could be run down-slope in the general direction of the Khor Abu Habl Valley, supplying towns and villages on the way, even as far as Tendelti, 150 km. The water would run by gravity in a substantial sized conduit. Some of the water could be used for small-scale intensive irrigation, for vegetables and fruit, for local village consumption.

b. From this main conduit, branches could be added later, so as to spread the area served. The general contours, as shown on the maps, indicate the technical feasibility, but more detailed survey is needed before specific plans and estimates can be worked out.

c. Water could be sent in other directions, all of which would require pumping since (a) above is the only down-hill line. For example, water could be pumped north-westwards via Rahad and into El Ain reservoir which serves El Obeid. The pipeline would serve a substantial belt of territory, mainly in the gardud soil, which is suitable for mechanised development. This pipeline could be installed in stages, assuming that additional supply to El Obeid is not an early need.

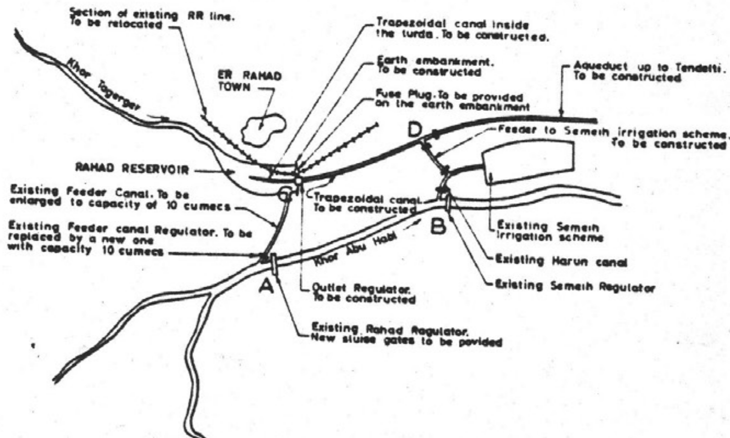
436. It is useful to put the quantities involved into perspective. If all the 17 million cubic metres per annum were distributed for drinking water on the lines of (a) above, it would suffice liberally for a million people and their livestock, or more. In addition, the capacity of the reservoir can be substantially increased.

437. The estimated capital cost is L. S. 1,450,000. The estimated annual cost is L. S. 125,000 of which L. S. 105,000 represents interest on capital.

438. If the annual cost is spread over the whole output of 17 million cubic metres the cost of the water is 7.4 mils per cubic metre. The actual selling price of water from the government boreholes is 110 mils per cubic metre.

SCHEMATIC LAYOUT OF FUNCTION

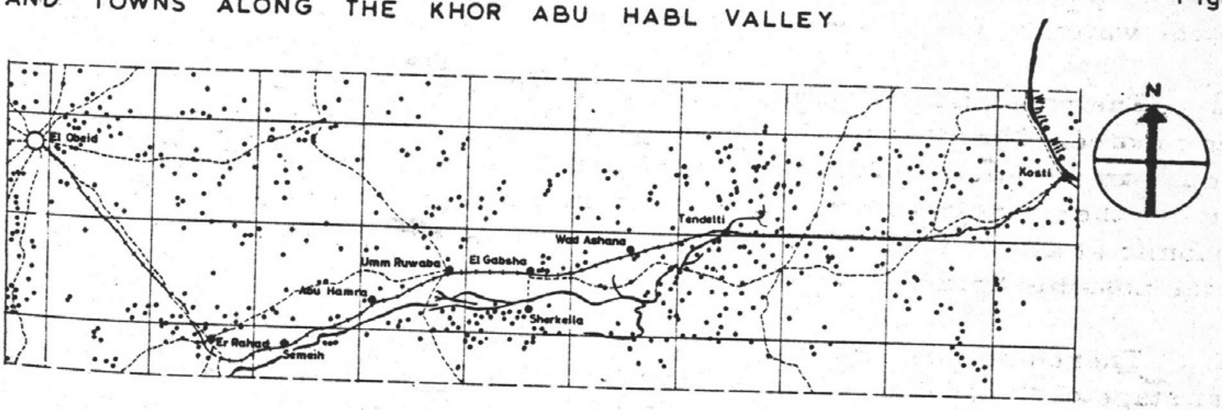
Fig. 65



The Cross-Regulator A diverts flood-waters into the Turda (Lake) The outlet Regulator C controls the output. At D, a cross-regulator controls the feeder to the existing Semeih irrigation scheme, and from D, onwards, the acqueduct or conduit carries the water down the valley See Fig. 66 below.

EKISTIC MAP SHOWING THE VILLAGES AND TOWNS ALONG THE KHOR ABU HABL VALLEY

Fig. 66



This shows the general disposition of the Khor Abu Habl Valley and the towns and villages. The alignment of the conduit requires a detailed contour survey, and policy decisions about the areas to be served.

Scale 1:2.000.000 0 10 20 30 40 Km

39. This very favourable cost is largely due to the fact that the lake is a atural phenomenon of very big volume, requiring no dam, but only a small mbankment to enable the level to be raised a metre or so. In addition, he gravity conduit would be cheap per unit of water because its capacity s large. Naturally, unit costs of water delivered will go up when branching ipelines are added, so as to enable the water to be spread over a bigger rea and to solve the water supply problem in more villages and towns. Estimates cannot be made until detailed contour maps are available.

440. The first stage can be judged economically from the following considerations. Water is sold at 110 mils per tin from government boreholes and El Obeid waterworks: the estimated cost of the Rahad Project water (first stage, i. e. as in (a) above) is 7 1/2 mils per cubic metre. Water for irrigating high-cost intensive market gardens in Bara and Bangadeed is generally reckoned to cost 6 mils per cubic metre, commercially. It would seem economically reasonable to provide water at 7 1/2 mils per cubic metre, for market garden irrigation alone, even if there were no need for drinking water along the valley. A very great benefit would accrue if a series of small pockets of irrigated vegetables and fruits were to be created at intervals along the Khor Abu Habl Valley, putting fresh produce into the markets all the year round, for people who, mostly, never see such things.

PIPED SUPPLIES

441. The studies of Rahad Turda, indicating the possibility of cheap supplies down the Abu Habl Valley through a conduit, opens this question: Why not provide water by pipe everywhere?

442. The possibility of pumping domestic supplies from the Nile has often been mooted. Now that the Rahad potentialities are known the answer to the Nile is simple. Rahad lake is nearer, and at much higher elevation than the Nile and therefore cheaper. If piping from a bulk source is practical and economic at all, it would be from Rahad, which could be developed to supply all the possible drinking water needs of the Project Area.

443. There are three reasons why the water is so cheap in the proposed first stage of Rahad Lake Project. First, the storage reservoir is a natural phenomenon and the unit cost of developing it is very small. Second, the proposed conduit runs down hill by gravity. Third, the capacity of the conduit is big so that the cost per unit of water delivered is low.

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444. If Rahad Lake waters are to be delivered to any other part of the Project Area than the Abu Habl Valley it will have to be pumped. The test case is the possible pumping main running northwest from Rahad Lake towards El Ain Reservoir. If this turns out to be economically practicable, further similar developments can be examined. Until then, the only possible assumption is that although piped supplies to peasant villages may be the right solution in particular cases where conditions are favourable, no general solution can be expected in this way.

445. There are also possibilities of distributing water by pipeline from boreholes or from hafirs. Indeed, there is no purely technical difficulty in doing so, within the limits of capacity of the source concerned. The question has to be resolved for each particular case, mainly on the issue of costs.

COMPARISON OF COSTS

446. Wherever catchment tanks are under consideration, cost comparison is needed. The cost that matters to the villagers is the cost of water delivered into his home. This is made up of two chief elements; first, the cost of the water at the source, and second, the cost of transporting it from the source to the home.

447. Water from government boreholes and the El Obeid waterworks is sold at 2 milliemes per 4-gallon tin. (1,000 milliemes = 1 Sudanese Pound = 1 Pound Sterling = 2.8 U.S. Dollars). It is generally supposed that this is less than the cost of production.

448. The Project investigations on the hafirs at Jebel Abu Sinun and Mazroub show that, taking all losses by evaporation and seepage into account, the cost per cubic metre delivered to the consumer at the hafir site itself is about 30 piastres. That is, 5 1/2 mils, per four-gallon tin.

449. Next, equivalent costings for the catchment tanks are needed. To do this the actual data for the actual prototypes built in the experiment yard in El Obeid in 1964 have been used. All experience shows that costs for experimental prototypes are higher than they should be when a "production line" is established but it is preferable to use the recorded facts and make allowances later, if necessary, rather than import unsubstantial estimates at the outset.

450. To convert from construction costs to cost per tin yielded to consumer, a stringent standard has been used. It has been assumed that the capital cost must be amortised in 10 years, and that the outstanding belance un-amortised must bear interest at 6%.

451. On this basis the cost per tin of four gallons, reckoned at the source itself, (i. e. without adding the cost of transport from source to consumer's home) is:

"Beehive" Tank, double filtered, "First Quality" water, for drinking	:	14	mils per tin.
"Pillared Roof" Tank, no filtration, "Second Quality" water	:	6 1/2	mils per tin.

Comparison can now be made:

Beehive	:	14	mils per tin (cost)
Pillared Roof	:	6 1/2	mils per tin (cost)
Hafir	:	5 1/2	mils per tin (cost)
Borehole (Govt.)	:	2	mils per tin (selling price)

452. The Pillared Roof and the Hafir are comparable. This is not very surprising. A Pillared Roof is really a small hafir, plus lining and a roof. The hafir is cheaper to build, per unit of capacity, but losses were more than half through seepage and evaporation; the Pillared Roof tank is more expensive to build but loses comparatively little from seepage and evaporation.

453. The Beehive is much more expensive, but the water is of much higher quality, double filtered, - on the way in and on the way out - so that while it is "in store", it is protected after being filtered.

454. On a straight comparison, it emerges that if plain tankage suffices (for animals, cooking, washing) a catchment tank is competitive with the big hafir. A borehole, on the other hand, wins handsomely - assuming that the selling price of 2 mils per tin is not too much less than actual cost.

455. These comparisons, however, relate to costs at the source itself. They take no account of the cost of transport, and as has been shown in Chapter 4, apart from a fortunate minority most villages are some kilometres away from the nearest all-season source.

456. Costs of transport have been established. For lorry transport there is a regular market price, according to distance, running from 15 mils up to 80 mils per tin. In the "lorry transport" zone shown in Fig. 41, the average cash price is about 40 mils per tin.

457. Costings for animal transport were calculated on the basis of 200 mils daily wage for a man, 50 mils for a boy and 40 mils for a donkey. The yardstick was based on a boy with two donkeys, which showed the lowest of several different calculations. A distance of 5 km. is a characteristic distance, governed by the area occupied by the lands of a village and the resulting spacing of villages.

458. At this distance the equivalent cost of animal transport is 15 mils per tin. This tallies on a rough cross-check with the lorry price. Where the lorry-transported price is in its lowest range, animal transport and lorry transport co-exists, which suggests that the "market" puts them at about the same level of cost.

459. The cost comparisons for a village which is 5 km. from a bulk source is as follows:

Source : Borehole	Mils per tin
Price at Borehole	2
Cost of transport	15
Total cost, delivered at consumer's household :	17 mils per tin

Source : Hafir	
Cost at Hafir	5 1/2
Cost of transport	15
Total cost, delivered at consumer's household :	20 1/2 mils per tin

Source : Beehive	
Catchment Tank	
Cost at tank	14
Transport	0
Allow 20% for unavoidable losses in storage and handling	3
Total cost, delivered at consumer's household :	17 mils per tin

Source : Pillared Roof	
Catchment Tank	
Cost at tank	6 1/2
Cost of transport	0
Allow 20% for unavoidable losses in storage and transport	1 1/2
Total cost, delivered at consumer's household :	8 mils per tin

460. If the cost of human or animal labour is omitted, on the grounds that it costs the peasant nothing then the cost of transport by donkey becomes zero. The cost per tin from the catchment tanks is reduced, according to the data in Table 8, and they become:

Beehive Tank (double filtered)	7 mils per tin
Pillared Roof Tank (outlet filter)	3 mils per tin

461. However, the evidence shows quite clearly that the cost of peasant labour must not be omitted. There are more profitable things for him to do than spend effort in carrying water from boreholes and hafirs to the villages. The circumstances found in the "water crisis" area (Fig. 41), where water is transported by lorry and paid for by the peasants in cash, for an average of about 4 mils per tin, illustrate very well the benefits which accrue if seasonal under employment can be put to truly productive purposes.

462. It is precisely in this part of the Project Area that the farmers can and do manage a second cash crop, more profitably than anywhere else, i. e. gum, (see Fig. 52). By this means they convert their labour, during a part of the agricultural off-season into cash, and they use part of this cash to buy water.

463. If they invest some extra labour into building catchment tanks, plus some of their cash, they could make a big profit:

Actual average price paid per tin of four gallons	:	40 mils per tin
Cost per tin from a beehive tank, reckoning that the villagers invest their own labour for their own water and buy their materials for cash	:	7 mils per tin
Ditto, Pillared Roof Tank	:	3 mils per tin

464. For the other parts of the Project Area, (see Fig. 41), where most people get water by sending donkeys to the nearest all-season source the effect of having catchment tanks at the villages would be to save labour, i. e. of people and donkeys who now have to transport the water.

TABLE 8

CAPITAL COST OF CATCHMENT TANKS

Type	Capacity in m^3	Cost in Sudanese Pounds			Cost per cubic metre Sudanese Pounds		
		Materials	Labour	Total	Materials	Labour	Total gross
Beehive	100	200	300	500	2.0	3.0	5.0
Pillared Roof	230	110	223	333	0.5	0.9	1.4

N.B.:

- 1 Sudanese Pound = 1 Pound Sterling = 2.8 U.S. Dollars
- Capacity is the water-holding capacity of the completed tank.
- These costs are based on the actual costs incurred in building full-size experimental prototypes in the Experiment Yard in El Obeid in 1964, with some slight adjustments. These costs are high, as is always the case with experimental work. There is no adequate basis for assessing costs under market conditions except to some extent, for the polythene elements which have been adjusted. See DOX-SUD-A 42.

465. What would they gain if this labour could be saved? There are two immediate gains. First, because there is a critical period, just before the rains, when the water supply is at its worst and when, also, the demands on labour for clearing the fields and getting ready to sow are greatest. Secondly, there is the donkey which spends its days carrying water; he has to eat and drink and there are other animals which would be more profitable.

466. In addition, however, there is plenty of scope for gum culture, charcoal burning and other possibilities (to be dealt with later) for more profitable activities during the agricultural off-season, if the water-carrying burden can be relieved. At present it is only in the densest (and therefore most profitable) parts of the gum belt that the second cash crop gives the peasants financial prosperity to buy water at high prices and to buy lorry transport. The cash-cropping capacity of the other villages might be markedly increased if they could devote all their labour and attention to it.

467. One very significant fact must be noted. The farmers in these lands cry out for water, and they switch more and more to cash cropping but they do not leave their lands. They make demands on Government for more water, but they do not demand to be resettled somewhere else. The significance is that the capabilities of the land are enough to support a farming system profitable enough, in cash, to make it worth while buying domestic water at a cash price which would be regarded as intolerable in any city in the world; and secondly, that the local farmers have had the initiative and enterprise to make their farming pay, despite this heavy burden of water costs.

GENERAL CONCLUSIONS

Catchment Tanks

468. Water storage tanks "Catchment Tanks") of sizes suitable for villages, farms, or individual families, can now be made at acceptable cost, using modern materials and methods, to be filled during the wet season by water collected from the rain on small artificial catchment aprons. Prototype models have been built and tested.

469. Wherever in the Project Area there is enough rain to raise crops, water to drink can be assured, because catchment tanks can always provide a practical solution if there is no other preferable way. The ultimate principle is the same, however whether it be borehole, hafir or catchment tank, as Fig. 67 shows.

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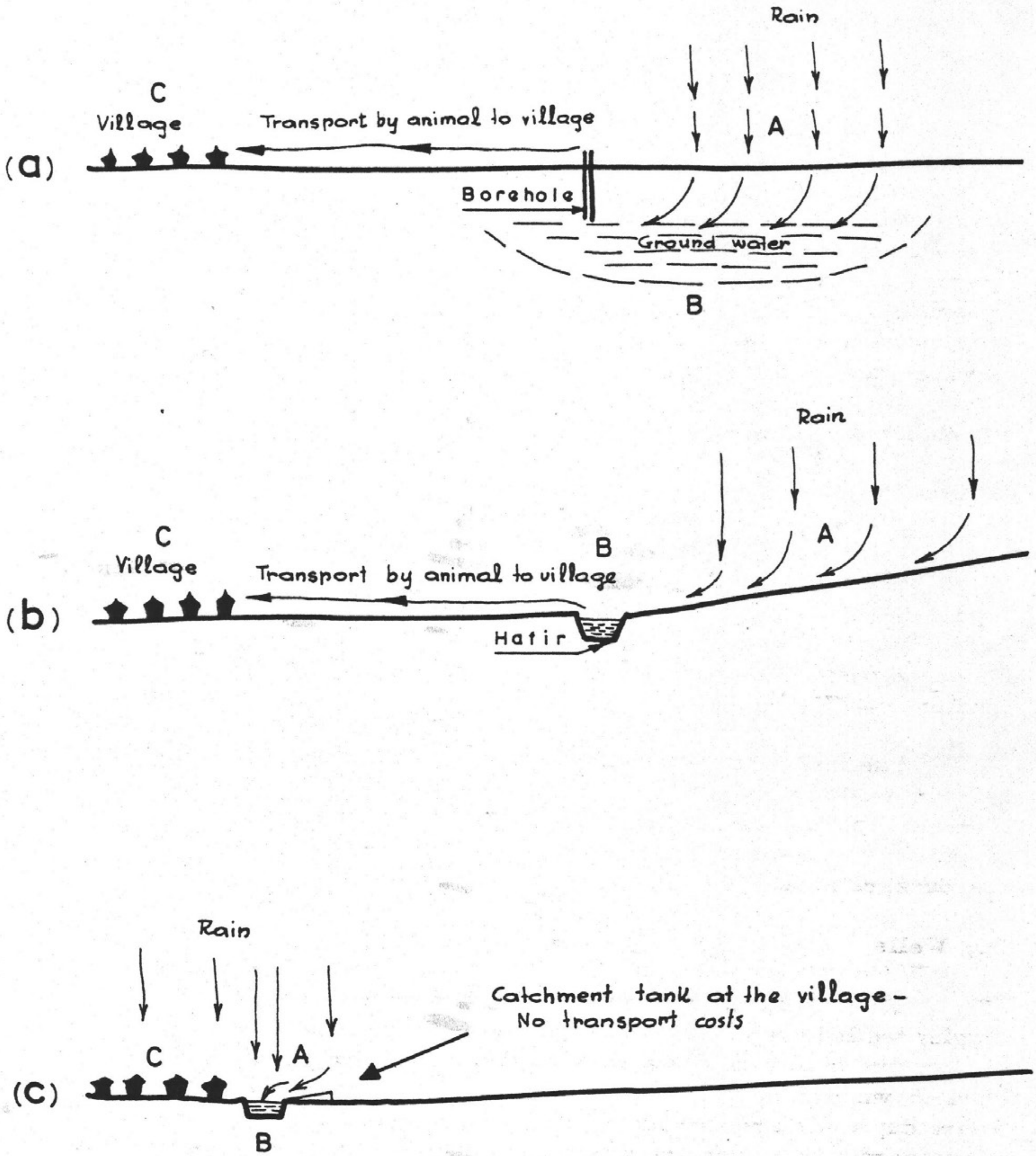
SCHEMATICS SHOWING THE WORKING PRINCIPLE OF BOREHOLES HAFIRS AND CATCHMENT TANKS.

Fig. 67



Whether it is a Borehole, a Hafir or a Catchment tank, the ultimate principle is the same. The rain falls on a Catchment A; it goes into a storage space B; and it is delivered at the destination required, i.e. the village C. With Borehole and Hafir A, B and C are widely separated. With the Catchment tank they are all in one place.

Hafirs

470. The possibilities for hafirs of the traditional type in Land Use Zone A and B and sub-divisions (goz country), are limited to the few places where there are lacustrine depressions in the down-wind side of jebels, and even in these places the catchment areas are unfavourable for run-off. As regards the Land Use Zone B (gardud country) the presence of surface drainage waters in the rainy season provides source-water for hafirs, and the potentialities depend on the selection of water-tight sites.

Boreholes

471. The investigations have not revealed any evidence to alter the general assessment already established by many years of drilling, i. e. that the Umm Ruaba Series and the Nubian Series (Land Use Zones A_1, A_2, A_4, A_5, A_6, D and B, Fig. 43) yield water although there is no certainty for any particular site and no practical way of securing certainty, except by drilling actual boreholes at the site where water is needed. Evidence of water levels does not suggest progressive depletion of the aquifers.

472. The investigations have not yielded any hopeful evidence in relation to the areas overlying the Basement Complex (Land Use Zones A_3 and C). On the contrary, the accumulation of data goes far to explain why ground water is not found in these areas and by so doing, discourages hope.

Dug Wells

473. The results suggest that the areas where water is accessible by digging wells have already been disclosed, by generations of peasant exploration in search of water, followed by governmental digging. Further water from dug wells can be looked for within the envelopes where dug wells are already mapped, but outside this envelope the chances in any particular place are minimal and there is no prospect of a comprehensive solution through dug wells.

Rahad Turda (Lake) Development

474. There are important potentialities, by a new development project, to serve water for drinking and for some irrigation over a big region. Estimated cost is L. S. 1, 750, 000 for a first stage of development which would dispose of 17 million cubic metres of water per annum.