TIME-COST SCHEDULE FOR WATER DEVELOPMENT IN LIBYA

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AGRICULTURAL REPORT NO. 10

TIME-COST SCHEDULE

FOR WATER DEVELOPMENT

IN

LIBYA

by

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Letter of Transmittal

Minister of Agriculture
Kingdom of Libya
Tripoli, Libya

Excellency:

This time-cost schedule of water development has been prepared pursuant to requests by Ministry of Agriculture staff under the Libyan-American Joint Project 670-11-190-089 Assistance to the Ministry of Agriculture. The report is bound under a cover as a service to you for ready reference and for use over a long period of time.

The plan is based on facts supplied by the Libyans and Americans who were assigned to this activity. However, the recommendations represent individual views of the American advisors and do not necessarily reflect American or Libyan government policy objectives. They are furnished to the Ministry of Agriculture under the Joint Libyan-American project, "Assistance to the Minister of Agriculture". We hope that you will find this plan of water development useful to your own important work and that of such other Libyan officials as may profit from its content.

Lindsey A. Brown
Chief Agriculture Advisor
USAID

FOREWORD

TIME-COST SCHEDULE FOR WATER DEVELOPMENT IN LIBYA

Since 1953, the United States Agency for International Development has been conducting activities in Libya in the water resource development fields. Many reports and summaries of these activities have been prepared. These very excellent background materials and reports have been freely drawn upon as source material for the following report. An attempt is made to bring this material together into a unified whole and relate the water resource development activities to a time-cost schedule.

This report was prepared by the Ministry of Agriculture, Studies and Research Section in response to a request of the Under Secretary of Agriculture. It must be recognized that such operations scheduling is a series of compromises and judgements. As additional information and data becomes available the time and cost figures can be revised.

We believe that the time-cost schedule as presented will be useful to people that are programming and planning Libya's water resources development.

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SUMMARY

General

Briefly set forth herein is a summary of the time-cost factors included in a development plan for Libya's water resources. The plan includes the entire area of Libya where it may be possible to develop water and soil for productive agricultural use. The information is based on long-range estimates and from generalized reconnaissance data. It may serve as a basis for starting detailed investigations and planning.

A summary of the projects of the plan is presented in the attached Table A. A condensed summary shows the following:

Summary of Plan

Cost

Total Cost of Plan in 35 years	£ 48,777,560
One-Year Cost	£ 1,393,700
Five-Years Cost	£ 6,968,000

Economic Factors

Average Annual Net Return	£	198,180
Return on Investment		14%
Gross National Annual Return	£	614,364

Benefit-Cost Ratio

Range from 1.26:1 to 3.22:1; therefore, all projects are economically feasible.

Families Benefitted

Total Benefited		40,182
Settled on New Farms		11,652
Annually Benefited		1,146
Annually Settled on New Lands		332
Initial Cost Per Family on New Land	£	4,200/per 10 ha.farm
Gross Return per 10 Ha. Farm	£	2,100

This water development plan will do much to put new life-blood into the agricultural economical system of Libya. The increased wealth accruing to the agriculture workers will be reflected immediately in increased business for merchants and tradesmen. This new agricultural wealth will appear wuickly and will furnish increased revenues to both farm people and the Government. Also this type of agricultural development will stabilize agriculture and prevent future occurrences of devastating losses from droughts which occur at frequent intervals at present.

Much of the newly-found oil wealth could well be invested in this plan, as the benefits of the plan exceed the costs. This plan, if implemented, will provide an incentive for the farmers to remain on and continue to cultivate their land. The new irrigation lands proposed for development will provide farms for settlement of farm families and landless peoples so they can participate in a stabilized livelihood from the land.

To assure success of plan, incentives to produce by guaranteeing a fair return to the farmer are of first importance. The price stabilization programs for cereals and oils, and also for perishables, which are being considered by the Minister of Agriculture will provide the assurance to all farmers for sale of their products at a good price and will thus assure success of the water and land development program.

Economic Factors

The development period is estimated to be about 35 years. The attached Table Z shows that the total cost of the plan is about £48,777,560. The expenditures during the period of the plan implementation are assumed to be average for the period or an equal amount of money would be invested in the plan during each year of development. This results in a program costing about £1,393,700 per year or for a five-year period is £6,968,000. This is about the size of water development program that the Ministry of Agriculture could properly undertake. It is suggested that a balanced program be maintained among the listed projects, with the annual expenditures to be about as that shown in Table A.

An average annual investment of £1,393,600 will yield an average annual net return after production costs of about £198,188. This is 14% return on a capital investment of £1,393,700, which is a reasonable return. The gross national

annual return from the plan would be £614,364 which is about 44% of the annual capital investment. These figures are contingent and depend upon full development of the projects of the plan. In the beginning, during development phases, certain projects of the plan will not produce any net income. The farmers may need assistance to develop their productivity along with an assured market at a fair profitable price for their products.

Benefit-Cost Ratio

The benefit-cost ratios shown in Table A were computed on the basis of all costs and net returns of development being included. In addition, the capital improvements were amortized at 4% interest over a 35-year development period. A sinking fund for replacement of capital works was also included in the calculations so that capital works could be replaced as they are worn out.

The benefit-cost ratios for the listed projects of the plan range from a value of 1.26:1 to 3.22:1. This indicates that the water development projects in the plan are feasible. The higher ratio of benefit-to-cost indicates the more economically-feasible projects.

The most economically-feasible projects are those where development takes place on already-cultivated and irrigated land. The cistern development project is next in order. The new-lands irrigation development project is next in order and is entirely economically feasible and practical.

Families Benefited

The plan, when completed at the end of the 35-year development period, would benefit wholly or partly a total of about 40,182 families. Of these, about 11,652 families would be settled on new additional irrigation land. This amounts to a total of 1,146 families benefited annually with 332 families that could be settled annually on newly-irrigated lands.

The capital cost of development of newly-irrigated areas averages £4,200 per family for a 10-hectare farm; the gross return per year averages £2,100 per family unit. This compares with a capital cost for cisterns of £230 per family with a gross annual return of about £76 per family.

TABLE A — SUMMARY OF TIME COST ELEMENTS OF THE WATER DEVELOPMENT PROGRAM —

	Area Benefited		Development Cost			Average Annual Factors			Benefit Cost Analysis (35-Yr. Period)			Families Benefited			Development Cost Per Family ***	Ann. Gross Output Per Family
	Total	5-Yr. Program	Total	Annual	5-Yr. Program	Gross Output	Cost of Production	Net Benefits	Net Benefits	Total Development Cost	Benefit Cost Ratio	Total	5-Yr. Program	No. Famil Benefited Ann.		
	Ha	Ha	£	£	£	£	£	£	£	£		No.	No.	No.	£	£
1. Development of new irrigation areas from wells in Tripolitania, Cyrenaica & Fezzan.	2,397	13,350	38,900,000	1,111,400	5,556,000	469,920	323,070	146,850	1,920/Ha	1,249/Ha	1.54:1	9,235	1,316	264	4,210	1,780
2. Development of new irrigation areas from springs in Tripolitania, Cyrenaica, and Fezzan.	4,370	740	1,839,770	52,600	263,000	26,048	17,908	8,140	1,920/Ha	1,249/Ha	1.54:1	437	63	12	4,383	2,171
3. Development and rehabilitation of present cultivated areas exclusive of spring development in the gebel and improved canal lining program.	3,565	620	937,600	26,800	134,000	21,824	15,004	6,820	1,920/Ha	1,053/Ha	1.82:1	357	51	10	2,680	2,18
4. Improvement of present irrigation system canal lining on farms in Tripolitania, Cyrenaica and Fezzan.	5,390	784*	1,180,000	33,700	170,000	27,632	18,997	8,635	1,920/Ha	596/Ha	3.22:1	1,623*	234*	46*	733	60
									Total Items 1 Thru 4—			11,652	1,664	332		

TABLE A — SUMMARY OF TIME-COST ELEMENTS OF THE WATER DEVELOPMENT PROGRAM — (Continued)

Item	Area Benefited		Development Cost			Average Annual Factors			Benefit Cost Analysis (35-Yr. Period)			Families Benefited			Development Cost Per Family ***	Ann. Gross Output Per Family
	Total	5-yr. Program	Total	Annual	5-yr. Program	Gross Output	Cost of Production	Net Benefits	Net Benefits	Total Development Cost	Benefit Ratio	Total	5-Yr. Program	No. Families Benefited Ann.		
	Ha	Ha	£	£	£	£	£	£	£	£		No.	No.	No.	£	£
5. Gafara water spreading program in Tripolitania.	30,000	4,286	1,000,000	28,600	143,000	43,707	34,280	9,427	385/Ha	202/Ha	1.92:1	** 8,000	1,150	228	125	192
6. Dike and terrace program in Tripolitania and Cyrenaica.	5,300	757	318,000	9,100	45,000	7,701	6,040	1,661	388/Ha	309/Ha	1.26:1	530	76	15	607	513
7. Potable domestic stock water development on the Gafara and Gebel in Tripolitania and Cyrenaica - Eastern development and rehabilitation	3,068,100 M^3 of water developed	438,300 M^3	7,602,190	131,500	657,000	17,532	877	16,655	6,650/M^3 of water	2.906/M^3 of water	2.29:1	** 20,000	2,857	571	230	76
GRAND TOTALS			48,777,560	1,393,700	6,968,000	614,364	416,176	198,188				40,182	5,747	1,146		

* Includes area at base of Gebel.
** Duplication of some family numbers.
*** These costs incurred only the first year.

TIME-COST SCHEDULE
FOR WATER DEVELOPMENT
IN
LIBYA

Need for Water Development

Dry land farming in Tripolitania region is very insecure due to the relatively low rainfall and sandy soils with low moisture-holding characteristics. In Cyrenaica region the possibilities of good dry land farming are more favorable due to a higher rainfall and more favorable soil conditions. In the desert areas of Libya lying south of the zones experiencing 50 mm or more of rainfall only oasis desert type of agriculture can be practised. To grow anything in the desert areas requires the application of water.

From the standpoint of climate and soils, it would be advantageous to increase water and irrigation development to the maximum in all areas of Libya where adequate good water and suitable soils can be found. Since more work has been done on water and irrigation development in the Tripolitania region, there is more information available on the possibilities of irrigation expansion in this area than there is in the Cyrenaica and desert regions. Additional detailed exploration for water will be required in the Cyrenaica and desert regions before any large-scale irrigation development can occur. The larger springs already in existence in the gebel area of Cyrenaica are located where there is little land that can be irrigated so that the water supply is in excess of the available land.[1)2)] No large irrigation projects can be planned on these areas. Only in connection with costly pumping and water transportation systems from the springs.

Good dry land crops cannot be expected in most of Tripolitania. It is estimated the following amounts of rainfall are required for dry land crops:

Olives	Good crop	-	300 mm.
	Fair crop	-	250 mm.
	Poor crop	-	180 mm.
	No crop	-	150 mm.
Wheat and Barley	Good crop	-	300 mm.
	Fair crop	-	250 mm.
	Poor crop	-	200 mm.
	No crop	-	Less than 200 mm.

In the desert areas a full supply of irrigation water must be applied to the crop to enable anything to grow. Thus irrigation agricultural development can occur only around springs and developed wells where good water occurs or can be found.

The average rainfall and temperatures of representative weather stations of the gefara and gebel areas of the Tripolitania and Cyrenaica regions are presented in Tables 1 and 2. Good dry land crops can be expected only in the surrounding areas of Tripoli and Garabulli under average rainfall and temperature conditions. Most of the gebel areas in the northern zones of Cyrenaica can be expected to produce good dry land crops. In an average rainfall year, fair crops can be expected in the areas of Sabratha, Bianchi, Castel Benito and Homs. The possibility of getting dry land crops are very uncertain in other parts of the gefara. The average rainfall throughout the Tripolitania and Cyrenaica regions are presented graphically in Figures 1 and 2. From a climatic point of view, better dry land crops can be expected in Cyrenaica.

The irrigated land use survey[3)] conducted by USAID revealed that there are many landless farmers in Tripolitania. In some instances as high as eight farmers are living on one hectare of land. In most instances, the Libyan farmers are entirely dependent on the dalu well to irrigate a small portion of their holdings. The average water production by means of the dalu is approximately 2.5 cubic meters per hour. Water requirements for alfalfa, one of the heavy water users, is about 800 cubic meters per hectare every 6 or 7 days during the warm season and 500 cubic meters every 20 to 25 days during the cool rainy season. Cash crops such as potatoes, tomatoes, and peanutsnrequire approximately 300 cubic meters per hectare every 7 to 10 days during the warm season. In the Arab garden areas, the farmer can only expect to irrigate his trees and a small portion of his land at one time.

TABLE 1

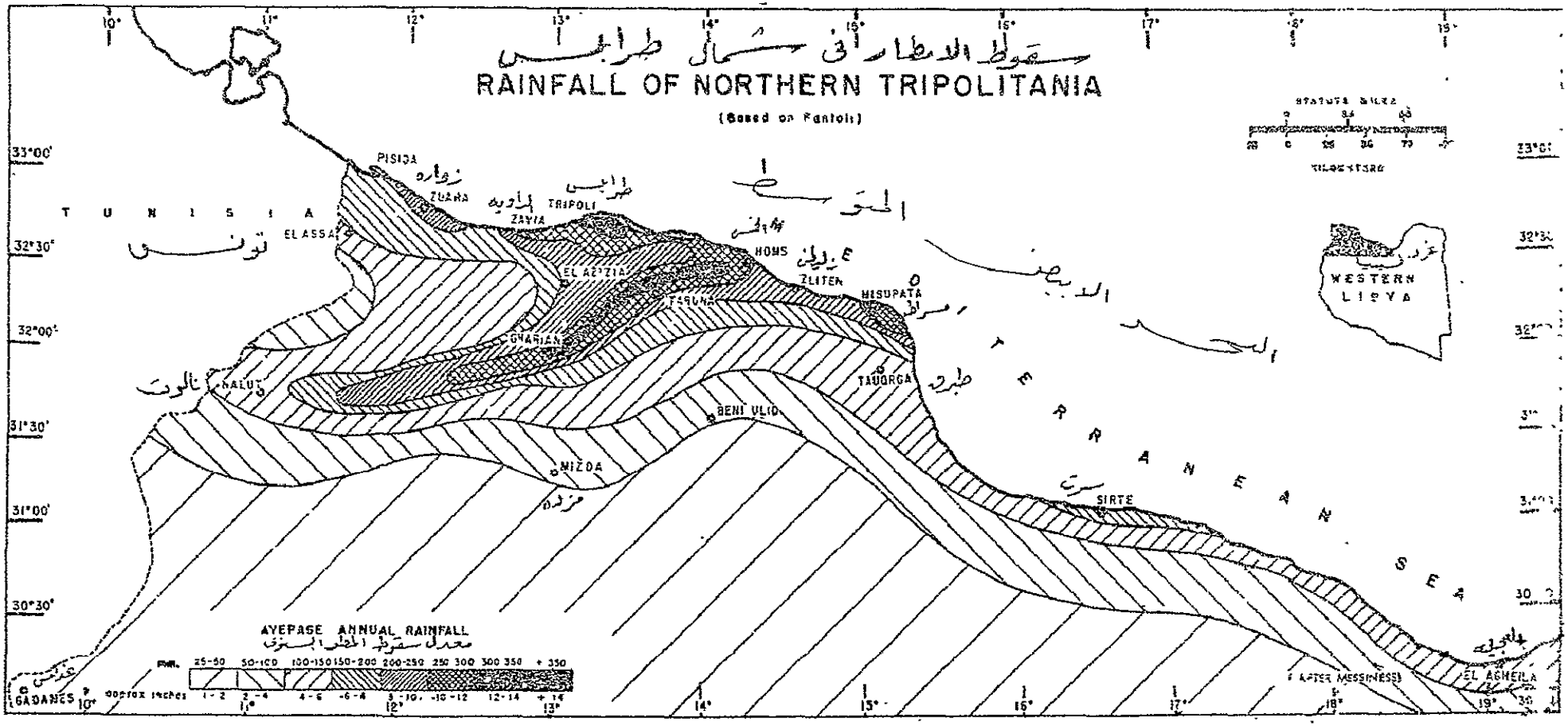
AVERAGE RAINFALL AND TEMPERATURE OF REPRESENTATIVE STATIONS OF THE GEFRA AND GEBEL AREAS OF TRIPOLITANIA

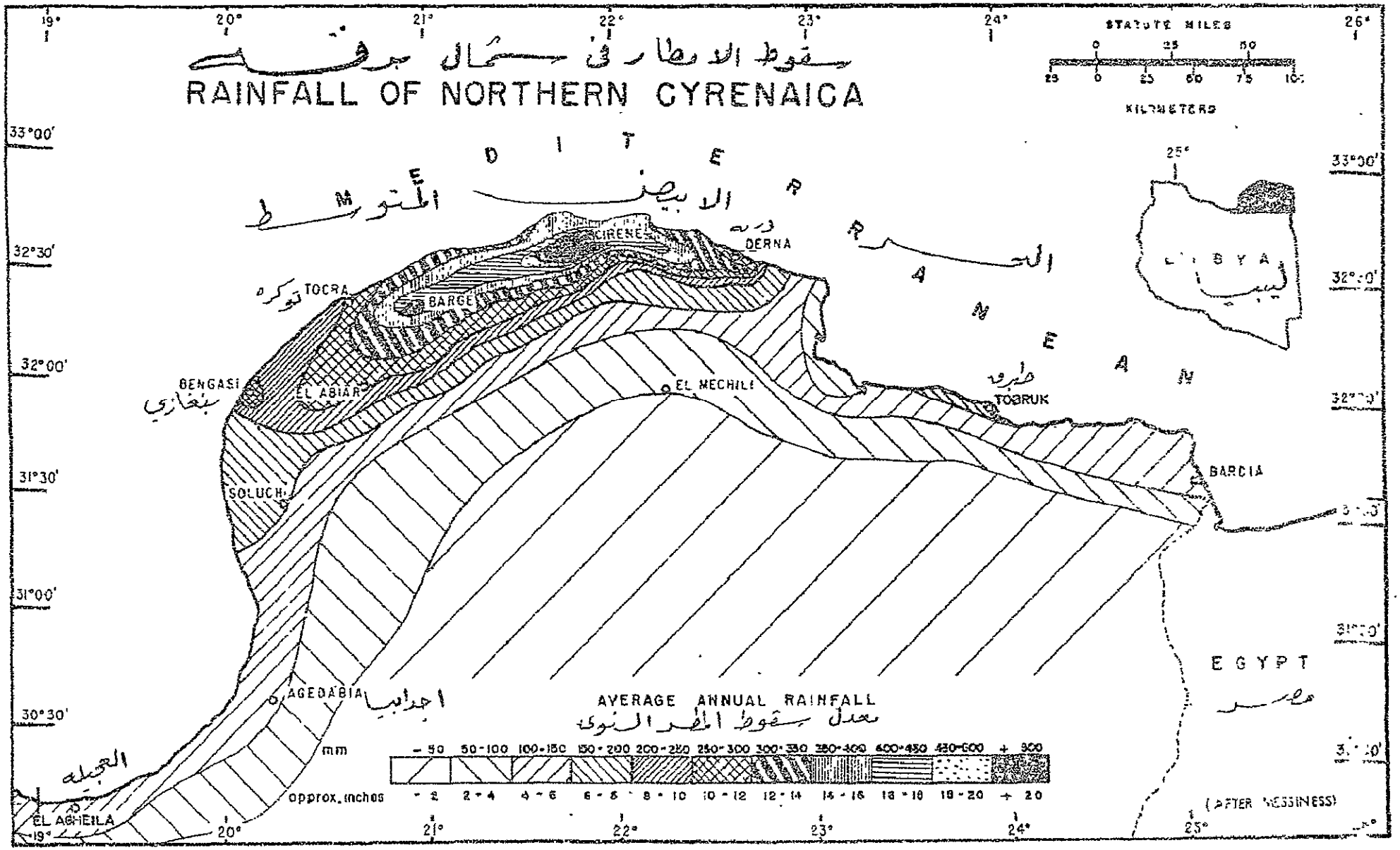
	Annual	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Tripoli Coastal Area													
Av. Rainfall	325.4	65.7	37.0	23.5	13.6	4.0	0.8	0.2	0.6	8.1	32.6	55.1	84.2
Av. Temperature	19.9	11.8	13.2	15.2	18.8	21.3	24.8	27.0	26.8	25.5	22.6	18.6	13.7
Zavia-Zanzur-Idris Area													
Av. Rainfall	267.0	54.2	36.1	19.0	11.5	3.4	0.9	0.7	0.5	2[illegible].3	7.9	41.0	67.2
Av. Temperature	20.3	12.0	13.4	15.8	19.0	21.7	25.6	27.1	27.7	26.4	23.5	18.3	13.3
Aziza-Bu Argub-Sabratha Area													
Av. Rainfall	212.2	44.4	26.7	18.8	11.5	3.8	0.9	0.0	0.2	6.7	19.8	31.0	48.4
Av. Temperature	20.0	11.5	13.1	15.5	18.6	21.3	25.0	26.9	27.4	26.2	23.0	17.8	13.2
Homs-Misurata Area													
Av. Rainfall	234.2	49.4	28.9	15.1	10.3	4.5	0.5	0.1	0.2	8.7	31.2	31.4	53.9
Av. Temperature	20.03	12.8	13.8	15.8	18.9	21.0	24.4	26.4	27.2	26.3	23.5	19.1	14.5
Kararim-Agedabia Area													
Av. Rainfall	125.6	29.9	19.0	7.5	4.1	2.8	0.2	0.0	0.0	4.6	12.1	15.3	30.1
Av. Temperature	20.4	12.6	13.9	16.4	19.6	22.6	24.9	25.8	26.5	25.4	23.1	19.5	14.6
El-Assa-Tigi-Bir el-Ghnem Area													
Av. Rainfall	120.3	23.9	16.5	18.2	9.4	2.1	1.0	0.0	0.3	3.1	7.5	16.8	21.5
Av. Temperature	21.6	12.3	13.4	16.7	20.9	24.3	29.0	30.1	29.6	27.5	23.2	18.1	13.8
Uassen-Giado Area													
Av. Rainfall	149.3	26.3	21.6	26.4	13.7	2.6	1.3	0.1	0.5	4.9	7.3	21.5	23.1
Av. Temperature	18.6	8.3	9.7	13.7	17.9	21.3	26.2	27.8	27.2	24.9	20.2	15.2	10.5
Zintan-Khiclo Area													
Av. Rainfall	218.8	48.5	34.3	31.0	17.6	4.2	2.5	0.2	0.3	5.3	11.5	23.7	39.2
Av. Temperature	19.2	8.1	9.9	14.4	18.7	22.0	27.0	28.6	28.2	25.9	21.2	15.7	10.6
Asabaa-Kusbat Area													
Av. Rainfall	266.0	59.6	39.5	28.0	19.1	6.1	1.3	0.1	0.7	7.9	20.0	26.1	57.6
Av. Temperature	18.8	9.8	11.2	14.0	17.6	21.2	25.0	26.5	26.8	24.7	21.4	16.5	11.2

TABLE 2

AVERAGE RAINFALL AND TEMPERATURE OF REPRESENTATIVE STATIONS
OF THE GEFARA AND GEBLE AREAS OF CYRENAICA

	Annual	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Kararim-Agedabia Area													
Av. Rainfall	125.6	29.9	19.0	7.5	4.1	2.8	0.2	0.0	0.0	4.6	12.1	15.3	30.1
Av. Temperature	20.4	12.6	13.9	16.4	19.6	22.6	24.9	25.8	26.5	25.4	23.1	19.5	14.6
Magrun-Soluch Ghemnes Area													
Av. Rainfall	162.5	44.1	26.4	10.9	2.4	1.4	0.1	0.1	0.0	0.9	10.2	20.0	46.0
Av. Temperature	19.8	11.7	12.5	15.1	18.7	22.8	25.6	26.2	26.2	24.7	22.2	17.8	13.8
Benghazi-El-Nania Area													
Av. Rainfall	268.0	70.4	44.5	19.6	5.4	2.2	0.4	0.1	0.1	3.3	17.7	33.4	71.5
Av. Temperature	20.1	13.6	14.1	16.1	18.7	21.4	23.7	25.2	25.9	24.5	22.8	19.7	15.4
Apollonia-Derna Area													
Av. Rainfall	341.9	80.7	55.5	31.7	8.8	5.8	0.3	0.1	0.2	5.1	32.8	38.1	82.8
Av. Temperature	19.8	13.3	14.4	15.5	17.9	20.0	23.1	25.5	25.9	24.7	22.8	19.3	15.0
Martuba-Bardia Area													
Av. Rainfall	117.6	29.1	22.0	11.8	2.1	2.9	0.0	0.0	0.0	0.5	10.4	12.0	26.6
Av. Temperature	19.7	12.8	13.6	15.5	18.3	20.8	23.6	24.8	25.4	24.5	22.7	19.4	15.1
Regina-El-Abragh Area													
Av. Rainfall	532.5	131.7	96.5	53.3	18.4	8.7	0.9	0.3	0.5	4.0	36.4	53.9	127.9
Av. Temperature	17.5	9.6	10.3	12.4	16.3	20.1	22.7	24.0	24.1	23.0	20.1	16.1	11.8
Slanta-Gubba Area													
Av. Rainfall	374.4	100.4	72.8	36.3	12.5	5.4	0.8	0.0	0.0	1.7	25.7	34.5	84.3
Av. Temperature	16.7	8.9	9.3	11.9	15.3	19.4	22.1	23.0	23.3	21.8	19.2	15.1	11.3


سقوط الامطار في شمال طرابلس
RAINFALL OF NORTHERN TRIPOLITANIA
(Based on Fantoli)
STATUTE MILES
KILOMETERS
TUNISIA
تونس
ELASSAS
PISIDA
زوارة
ZUARA
الزاوية
ZAYIA
طرابلس
TRIPOLI
EL AZIZIA
FASUNA
GHARIAN
HOMS
الخمس
ZLITEN
زليتن
MISURATA
مصراتة
TAUORGA
طورغة
NALUT
نالوت
BENI ULID
MIZDA
مزدة
SIRTE
سرت
MEDITERRANEAN SEA
البحر الابيض المتوسط
WESTERN LIBYA
غرب ليبيا
GADANES
غدامس
EL AGHEILA
AVERAGE ANNUAL RAINFALL
معدل سقوط المطر السنوي
25-50 50-100 100-150 150-200 200-250 250 300 300 350 + 350
1-2 2-4 4-6 6-8 8-10 10-12 12-14 + 14
(AFTER MESSINESSI)


سقوط الامطار في شمال برقة
RAINFALL OF NORTHERN CYRENAICA
STATUTE MILES
KILOMETERS
MEDITERRANEAN
البحر الابيض المتوسط
CIRENE
DERNA
TOCRA
BARGE
BENGASI
بنغازي
EL ABIAR
EL MECHILI
TOBRUK
طبرق
BARCIA
SOLUCH
AGEDABIA
اجدابيا
العجيلة
EL AGHEILA
LIBYA
ليبيا
EGYPT
مصر
AVERAGE ANNUAL RAINFALL
معدل سقوط المطر السنوي
mm
approx. inches
(AFTER MESSINESS)

Only a small portion of the available ground water in many areas is being used.

Water, soils, and irrigated land use studies conducted by USAID[3] indicate that large tracts of new land are available for irrigation development and that considerable development can be accomplished in the areas which are presently under cultivation.

New Development Areas

The areas outlined in Figure 3 are the general sites where irrigation development could be conducted. These areas are predicated on the basis that adequate water is available to supply irrigation development. The general ground water supplies in these areas are of adequate quantity and quality (see Appendix 2) to justify additional investigations for development of irrigation agriculture. Detailed soils, water, and agriculture economic studies will be required to define the areas for development. The principle areas that can be developed are shown. A more intensive study of the regions may show limited additional areas.

In the plan it is estimated that a total of 96,767 hectares of new land can be brought under irrigation in the areas listed in Table 3. This amount of land takes into consideration crops that only require supplemental irrigation as well as those requiring full irrigation. For example, a good crop of olives can be produced with about 5,000 cubic meters of water per hectare per year, while alfalfa will require around 16,000 cubic meters per hectare per year. Good crops of grain can be obtained with supplemental irrigation.

Cultivated Areas

The irrigated land use survey[3] of the gefara area indicates that less than 1% of the cultivated area from Misurata west to the Tunisian border south to the gebel was under full irrigation. Supplemental irrigation is practised over a larger area. Although the Italian and some Libyans developed some good wells, few are operating at their full capacity. Pumping tests indicate that even at the Sidi Mesri Experiment Station, only about half of the capacity of the well is being utilized. Electric and diesel driven-pumps in many cases are too small. Water production in the shallow acquifer areas is limited because of means of lifting the water. Only a small area can be irrigated by means of the dalu well. The amount of water available for

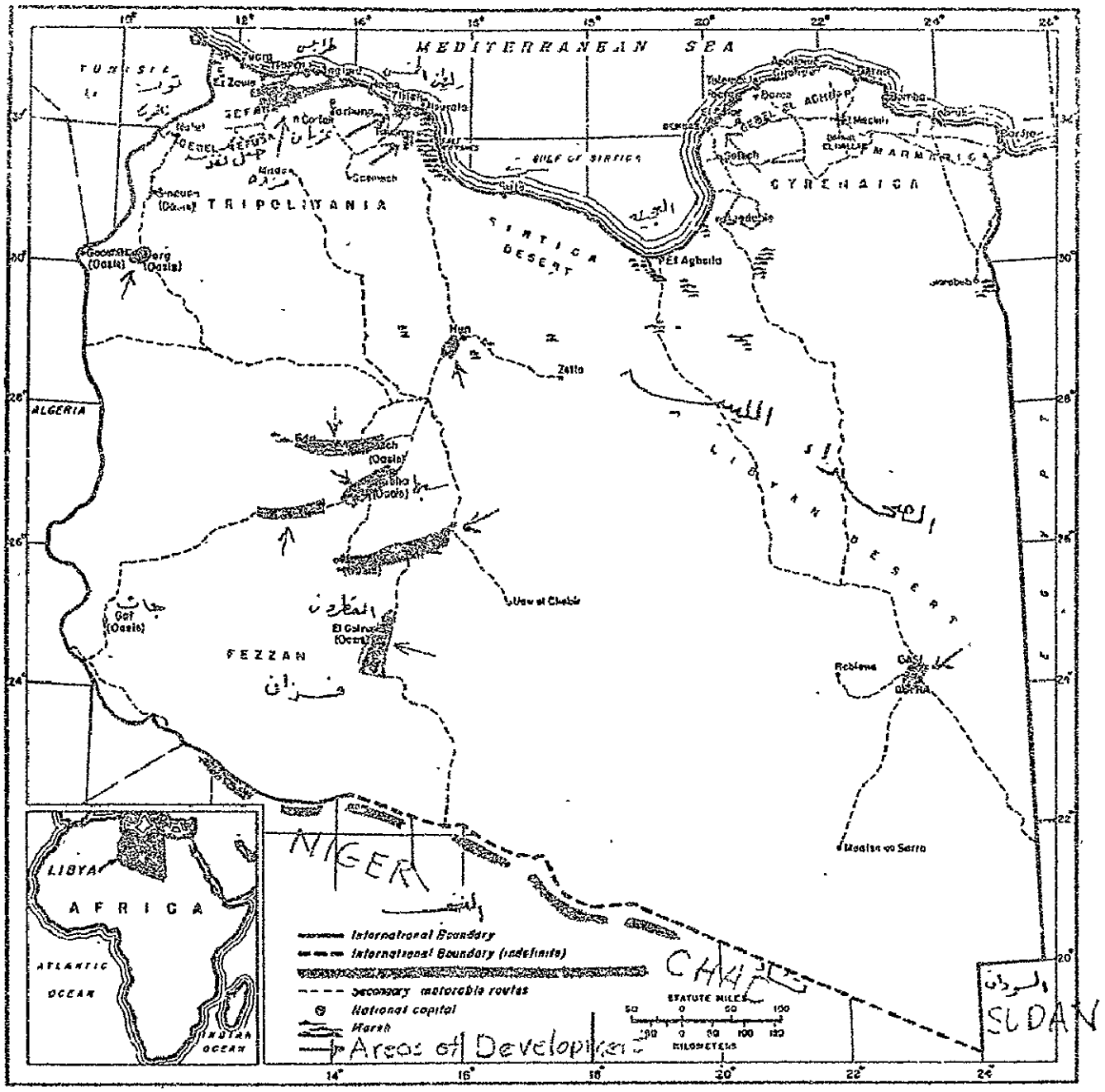

MEDITERRANEAN SEA
TUNISIA
TRIPOLITANIA
CYRENAICA
SIRTICA DESERT
GULF OF SIRTICA
ALGERIA
FEZZAN
LIBYAN DESERT
NIGER
CHAD
SUDAN
LIBYA
AFRICA
ATLANTIC OCEAN
INDIAN OCEAN
International Boundary
International Boundary (indefinite)
Secondary motorable routes
National capital
Marsh
Areas of Development
STATUTE MILES
KILOMETERS

TABLE 3

IRRIGATION DEVELOPMENT AREAS

1) From Wells in New Areas

The following areas appear to have enough water to support slow carefully controlled further irrigation development:

Irrigation Project	Estimated arable area Ha.	Recommended wells - Five Year Program No.	Five Year estimate irrigation area Ha.
1- West and South of Bir-el-Ghnem Project Area	29,549	440	4,400
2- Bir-el-Ghnem	28,400	400	4,00
3- Areas southeast, south. southwest and west of Azizia	20,898	298	2,980
4- Fondug Nagazza	200	3	30
5- Fondug Allush	200	3	30
6- Area to West of developed area at El Guea	90	2	20
7- Area to East of developed area at Ain Zara	90	2	20
8- Gasr Chiar	1,090	10	160
9- Gasr el Garabulli	80	2	20
10- El Guea	120	4	40
11- South of Zliten	7,000	143	1,000
12- Nahima	800	10	100
13- Wadi Ajal	300	4	40
14- Vicinity Serdeles	100	3	30
15- Wadi Chatti (Soil studies critical)	400	6	60
16- Kufra Oasis	80	2	20
17- Sahel Benghazi-Tocra (Pumping rates limited) to $4M^3$/Hr.)	3,000	40	400
	92,397	1,372	13,350

TABLE 3 (Cont'd)

2) From Springs in New Areas

	Estimated arable area	Estimated total flow	Flow utilizd	Five Year estimate irrigation area
	Ha.	M/Hr.	Lit/Se	Ha.
Tauorga Spring	2,000	2,040	496	400
Springs in Gebel Cyrene	1,3[illegible]0	1,900		200
Susa-Derna	1,000			140
Total	4,370			740

3) Development and Rehabilitation of Present Cultivated Areas Exclusive of Spring Development in the Gebel

	Estimated arable area	Wells	Five Year estimate irrigation area
	Ha.	No.	Ha.
New Wells	1,875	30	270
Rehabilitation of Old Wells	1,250	20	200
Unused Flowing Wells	440	15	150
Total	3,565		620

4) Improvement of Old Irrigation Systems

	Irregation area	Total increase due to improvement	Five Year estimate irrigation area
	Ha.	Ha.	Ha.
Irrigation System Improvement Tripolitania Region	14,600	4,880	700
Irrigation System Improvement Cyrenaica Region	1,530	510	70
Total	16,130	5,390	770
Estimated area from improvement of springs at the base of the Gebel	100		14

* Estimated development in three years.
** Total area possible to irrigate.

irrigation in the better shallow ater areas could be increased by the use of more efficient means of water lifting. The cow or camel used to operate the dalu well consumes a large portion of the crop produced. In spite of the fact that the water levels are declining in the vicinity of Tripoli, additional amounts of ground water can be safely developed.

The areas of Tagiura, Zavia, and Ber El Ghnen still have good ground-water supplies.

There are about fifteen unused, flowing wells in the area that could be developed for the irrigation of some crops. Most of these wells could be used for the growing of medium and salt tolerant crops. Some of the better ones can be used on any crops. Due to the high permeability of the soils and the high gypsum content of the soil, even some citrus are being grown with poor irrigation water. There are a few other flowing wells that are too salty for irrigation purposes.

Presently Irrigated Land

Irrigation system improvements on existing farms would significantly increase the irrigated areas.[4] In the Tripolitania region about 7,118 irrigation systems need improvement. This includes about 14,000 hectares of land. It is conservatively estimated that if one-third of the irrigation water being applied on this area were saved from seepage loss, one-third more area or 4,880 hectares of additional land could be irrigated without withdrawing additional water from scarce ground water supplies. Most Libyan farmers with their small land area irrigate only about one-half of their farm; therefore, adequate area already exists for expansion of irrigated land without developing new lands. Water thus saved by installation of irrigation system improvements in the form of canal linings or sprinkler systems and used on the present farm areas will not withdraw additional ground water. This would conserve and better utilize the scarce underground water resources.

In Cyrenaica it is similarly estimated that 746 farms could benefit from improved irrigation systems.[5] This would increase the amount of irrigated land about 510 hectares in those areas already irrigated. This would not withdraw additional ground water and conserve and better utilize scarce underground water resources.

Areas for Irrigation Development

Considering the development of wells in new areas, the Tauorga Spring,[6] improvement of irrigation systems, well development and rehabilitation, and the development of the springs at the base of the Gebel, a total of about 105,722 hectares of land is available for development.

In the gebel area of Cyrenaica the total daily water supply from 100 listed springs amounts to about 45,713 m^3 per day.[1] This water supply is capable of irrigating about 1,371 hectares. This represents the maximum of land that can possibly be put into irrigated vegetable or truck crops. Some increase in land area is possible, however, for fruit production.

With the exception of the coastal plan, land which lies between Tocra and Benghazi, the only other area suited to irrigation in Cyrenaica consits of a narrow strip along the coast from Susa to Derna. This latter area is estimated to be 1,000 hectares.

Springs are the sole source of irrigation water in the gebel area; renovating them, thereby increasing the water supply and reducing losses, is of the utmost importance. Most gebel springs are jointly owned and their development results in benefits to many families. The construction of storage reservoirs at the spring site would conserve for irrigation water which is now lost. This increased water supply would make it possible to increase land area and farm income, the latter would be an incentive for stabilization of the farm population.

Farm Families Benefited

Little work has been done on the determination of the size of family units. An intensive agricultural-economic study of the Bir-El-Ghnem area was conducted by a consultant.[7] In this study, eight farm types, varying in size from 4 to 100 hectares, and also in cropping pattern, were examined, particularly in regard to labor self sufficiency, total water requirements, well and pump capacity, and the income to be earned when full production is attained. Holdings of up to 10 hectares are self sufficient in labor if the operator and his family represent a labor force of three units. At 10 hectares some outside aid is required, particularly during the tomato, ground nut and olive harvest. Holdings of 15 hectares and over would find difficulty in obtaining sufficient labor during the peak growing

period. Holdings of 15 hectares are also considered the maximum based on one well installation. All holdings are uneconomic in the early years but have adequate incomes under full production. Therefore, any development along the lines indicated would require substantial financial aid until full production was attained. It was concluded that 10 hectares are the optimum size of a farm holding. It will be assumed that an average 10 hectare farm is an average sized family unit, Libya wide. It is recognized that exceptions to this size may make other size farms more desirable. It is believed that for the majority of the potential irrigable areas that a 10 hectare irrigated unit is the ideal size. On this basis, Table 4 presents the numbers of families that could be settled on certain areas if developed for irrigation.

There is enough potential irrigated land area to settle about 4,572 families with an average 10 hectare irrigated farm each. It is estimated that under a normal rate of development of irrigated land that 1664 families could be settled or benefited in five years.

Increased Crop Production

Although different crops are grown, it is considered for the broad purposes of this analysis that the gross and net value of crops grown on irrigated lands in Tripolitania, Cyrenaica, and the desert oasises regions of Libya will be about the same. A more exact analysis of specific areas may show small difference from the results of the broad analysis of this study. It is estimated the agricultural returns will be about the same for all proposed development areas. Land development costs will be different, and these will be discussed in a later part of the report.

The average yields, prices, farm costs, and net returns for different crops commonly grown in Libya are presented in Table 5.

It can be observed that for maximum gross returns, a holding comprising citrus only would be the most profitable cropping pattern. But such a type of holding could not be recommended because the cost of supporting the settlers in the earlier stages would be very high, if they do not have some intersource annual cash and food crops, and also because of the hazards of placing too much reliance on a single crop.

TABLE 4

FAMILIES SETTLED OR BENEFITTED

	Total No.	Five Year Estimate No.
1) New Areas		
1- West and South of Bir-el-Ghnem Project Area	2,950	421
2- Bir-el-Ghnem	2,840	406
3- Areas southeast, south. southwest and west of Azizia	2,090	297
4- Fondug Nagazza	20	3
5- Fondug Allush	20	3
6- Area to West of developed area at El Guea	9	1
		1
7- Area to East of developed area at Ain Zara	9	1
8- Gasr Chiar	109	16
9- Gasr el Garabulli	8	1
10- El Guea	12	2
11- South of Zliten	700	100
12- Nahima	80	11
13- Wadi Ajal	30	4
14- Vicinity Serdeles	10	1
15- Wadi Chatti	40	6
(Soil studies critical)		1
16- Kufra Oasis	8	42
17- Sahel Benghazi-Tocra (Pumping rates limited) to $4M^3/Hr.$)	300	
Total	9,235	1,316
2) From Springs in New Areas		
Tauorga Sprong	200	30
Spring in Gebel Cyrenaica	137	20
Susa-Derna	100	13
Total	437	63
3) Proposed Development and Rehabilitation of Present Cultivated Areas Exclusive of Spring Development in the Gebel		
New Wells	188	27
Rehabilitation of Old Wells	125	18
Unused Flowing Wells	44	6
Total	357	51
4) Improvement of Old Irrigation Systems		
Irrigation System Improvement Tripolitania Region	1,460	210

	Total No.	Five Year Estimate No.
Irrigation System Improvement Cyrenaica Region	153	22
Total	1,613	232
Improvement of Wells at Base of Gebel	10	2
Total	1,623	234
Grand Total	11,652	1,664

TABLE 5

YIELD, PRICE, COST VALUES AND NET RETURNS FOR IRRIGATION DEVELOPMENT AREAS

	Yield (Qtls/ha)	Price (ŁLQtl)	Gross Return (ŁL/ha)	Farm Costs (ŁL/ha)	Net Return
Citrus (280 trees)	100	3.0	300	129.7	170.3
Olives (33 trees)	14	4.0	56	46.7	9.3
Groundnuts (in shells)	18	7.5	135) 147	86.3	60.7
(haulms)	15	0.8	12)		
Barley (grain)	18	2.0	36) 51	39.9	11.1
(straw)	15	1.0	15)		
Tomato	150	1.4	210	163.4	46.6
Potato	150	1.5	225	172.5	52.5
White Beans	15	7.0	105) 114.6	56.3	58.3
(straw)	12	0.8	9.6		
Lucerne	600	0.4	240	127.9	112.1

Two idealized 10 hectare farms with different areas of crops is presented in Table 6. The annual crops shown in Table 7 can be suitably rotated and resting periods under follow. The sizes of tomato or potato fields are such that the same land need not be under those crops more than are on 6-8 years so that the danger of nematode infestation can be minimized. While the cropping patterns try to provide the maximum area under restorative crops such as ground nuts, white beans and lucerne, barley also forms an important feature of the pattern. Under normal circumstances, barley would not be economically justified as an irrigated crop, but is included in the cropping patterns because it is a stable food crop of the region; and being grown as an intercrop between olives saves of the cost of irrigation, and fertilizers would in fact be shared by the olive crop.

Other factors must be taken into consideration in planning cropping programs. The net irrigation requirements for the common crops which have been calculated by an empirical formula and are presented in Table 7.

Table 7

ANNUAL (SEASONAL) CROP WATER REQUIREMENTS

Crop	Net requirement per hectare Cubic Meters
Olives	5,000
Citrus	11,000
Ground nuts	8,500
Barley	3,000
Tomato	7,900
Lucerne	16,000
Potato	4,400

Gefara Water-Spreading Program

Good opportunities occur for a range water-spreading program near the seaward base of the gebel from Nalut to Homs and in the gebel area of the Wadi Gattara in Cyrenaica. Run-off water from storms flows off the steep slopes of the jebel and out into the flat plain of the Gefara below.[8)12)] Some of this water spread naturally, but much of it sinks into the wadi bed or runs to the sand dune area and is lost, or spreads on areas of poor soil where it does little good. This run-off water should be diverted from the wadi channels and led to areas of

TABLE 6

CROPPING PATTERNS FOR A TYPICAL 10 HECTARE HOLDING FOR ALL AREAS

Crop	Area (10 Ha Total) Plan A Ha	Plan B Ha
Citrus	2.0	4.0
Olives	7.5	5.5
Groundnuts	3.0	2.0
Barley	2.0	2.0
Tomato	0.5	0.5
Potato	—	—
White Beans	1.0	1.0
Lucerne	1.0	1.0
Almonds	—	—
Melons	—	—

good soil, and there spread uniformly and efficiently by means of earth dikes designed to regulate the flow of water both as to direction and speed of flow.

The gebel escarpment where the run-off originates lies in a rainfall zone of approximately 175 to 300 milimeters. One or more runs of water can be depended upon in most years. The improved spreading grounds can be utilized both for increased barley production and for production of badly-needed hay reserves and supplement pasture. The hay and pasture supplies are needed to improve the condition of the livestock and to guild up feed and fodder reserves for drought years. Part of this increased yield on the gefara could be used for relieving the grazing pressure on the already-overstocked rangelands of the area.

Another purpose of this program is to recharge the underground water supply at a point not far from the base of the Gebel with the expectancy that this will improve ground-water supplies.

One hundred wadies along the gebel front should be treated for water-spreading purposes. The nature of the work would vary from simple structures on small wadies to large schemes approaching those on the Wadi Megenin in size.

Benefit-cost items are summarized below:

Total cost of treating 100 wadies with water-spreading systems, £800,000.

Area brought under improved water-spreading practices, 40,000 hectares.

Number of families benefited, 20,000.

Dike and Terrace Program in Tripolitania and Cyrenaica

During the Roman era in Libya, many dikes were constructed in the former provincial areas of Cyrenaica and Tripolitania. The purposes of these dikes were to cause deposition of soil carried by surface water and to cause infiltration of surface water into the soil. The areas behind these dikes, if beneficially affected, then were capable of increased production of crops. The dikes, to be of benefit, had to meet the following conditions:[8)]

(a) Soil depositions must have been of a tillable and productive nature.

(b) Enough soil must have existed or have been deposited to furnish an adequate soil moisture reservoir.

(c) Flowing surface water must have been controllable within the limits of the system.

(d) The dike must have performed a function of direct economic benefit which could economically support the maintenance of the dike.

Many dikes constructed by the Romans in Tripolitania met these conditions. Favorable topography and deep sandy soils made possible construction of good dikes. In Cyrenaica many dikes constructed did not meet these conditions because of unfavourable topography and shallow fine silt and clay soils.

USAID's participation in dike construction started in Tripolitania in November, 1954 with the construction over 1,700 kilometers of water-spreading dikes affecting over 1,500 hectares of land by July 1956. The successful completion of this work motivated plans for expansion of work of this nature in Tripolitania and starting of work in Cyrenaica.

By May 1961, additional work in Tripolitania brought the total area of land benefited by dikes to 2,800 hectares. Work started in Cyrenaica on dikes in July 1957. By October 1958, 290 major dikes had been built to benefit 2,140 hectares of land. In addition, from July 1957 to August 1960, 210,800 meters of small terrace dikes were constructed to benefit 2,500 hectares of land. Because the conditions in Cyrenaica were vastly different than Tripolitania, few of the major dikes constructed in Cyrenaica are of any appreciable value. On the 210,800 meters of small terrace dikes built, perhaps 20% are performing a function which justifies their construction. These desirable terraces can be found on fenced land in use as orchards or vineyards where enough soil is available to provide a moisture reservoir for plant growth.

Since the cost of dike and terrace construction is relatively high compared to the area of land benefited, careful economic feasibility studies should precede any additional work.

An appraisal study should be made of the dike and terrace failures to determine what corrective action should be taken in future construction.

Potable Domestic and Stock Water Development on the Gefara and Gebel

The scarcity of good drinking water throughout the area within the plan, with the exception of some of the towns and near irrigation developments, hinders economic and social improvements planned for the dry-land and range areas. Improvement of sanitation conditions for the rural people and providing of ample supplies of water for people and livestock call for a big probram. This program consists of cistern repair and improvement, drilling of wells for drinking water, and impounding of surface run-off water in small reservoirs.

In much of the range country in both Tripolitania and Cyrenaica, cisterns are the only practical water supply. During Roman times, thousands of these cisterns were dug on small drainages. Except for a fringe area 20-30 kilometers deep from the gebel face, many of these cisterns have been lost to present-day use. They are full of sand and debris, and are marked only by the original excavation mounds. In most instances, grass in these back areas is good.

In twenty-five years, livestock numbers in the former Provinces of Cyrenaica and Tripolitania fluctuated between 1,280,000 and 2,950,000. This was primarily due to fluctuating supplies of available livestock feed and water caused by variations in rainfall. In these provinces, forty-five percent of the people are nomads dependent upon livestock husbandry for the basic necessities of life. Another thirty-five percent are semi-settle farmer-herdsmen who depend on livestock to furnish a significant part of their livelihood. The cistern renovation activity was designed to help this eighty percent of the population achieve a more stable production of livestock by increasing quality and quantity of livestock water sources in the principal range areas. USAID participation in this activity was planned to demonstrate economical methods of renovating and building cisterns. It was also planned to develop private and governmental personnel and material resources for continuing cistern development.

During the Greco-Roman period, a large number of underground water storage cisterns were constructed. Their numbers are in excess of what present soil and vegetative resources could support in many areas. Present conditions of these cisterns vary considerably. Many are completoly buried or silted full, many are unrepairable due to structural failure, and an unknown number are in use.

During the Italian occupation of Libya, a small number of these Greco-Roman cisterns were renovated and put back into use as public livestock cisters.

USAID's participation in the cistern activity[10) 11)] started in Tripolitania in 1955 and in Cyrenaica, August 1957. The broad objective of the cistern program was "to conserve water".

USAID advisors estimate that twenty-five percent of the cistern needs of Cyrenaica and thirty-five percent of the cistern needs of Tripolitania have been met by this activity's development of 1,254 cisterns in Cyrenaica with a storage capacity of 426,500 cubic meters of water, and 7,127 cisterns in Tripolitania with a storage capacity of 579,000 cubic meters. They estimate that the above accomplishments cost £1,364,984, contributed as follows: £765,581 from USAID, £L106,187 from the GOL and L£493,216 in from cistern owners. In addition, USAID furnished technical assistance and the GOL furnished administrative and building facility support.

It is conservatively estimated by USAID advisors that cisterns developed by this activity have an annual worth of at least L£290,000 and that cistern owners will realize benefits equal to the total cost of the program over a period of five years.

Although this activity progressed under similar program in both former provinces, the programs progressed independently of each other and are dissimilar in important respects. The Cyrenaican activity limited itself to renovating old Greco-Roman cisterns, while in Tripolitania the activity was engaged primarily in building new cisterns. The average capacity of Cyrenaican cisterns was 350 cubic meters while those in Tripolitania average 80 cubic meters capacity. Both programs subscribed in theory to the principles of self-help. The Tripolitania program achieved an estimated sixty percent of the total cost as contributions from cistern owners, while in Cyrenaica, owners contributed approximately eight percent of the total cost of the program. Activity contributions in Tripolitania were limited to providing cement, ahnd tools and technical assistance. In Cyrenaica, the activity provided all building material, i.e., cement, sand, gravel, stone, all transportation of this material, all skilled labor, hand tools and technical assistance.

The programs were similar in one respect. Application by the owner for assistance was submitted to the Mudir who transmitted it to the Mudisariff or District Commissioner for approval. Upon receipt of approval by the Mudisariff, the application was given to the activity for implementation. If it met program criteria, it received final approval and aid was implemented through local cistern program conservation aids or supervisors.

It is recommended that technical and economic range and cistern studies should be conducted in range areas before additional cisterns are constructed.

Type of Well Needed

It is estimated that a flow of 1.247 lit/sec will supply enough water to irrigate a hectare of land. On this basis, a 10 hectare farm would be supplied by a well producing about 45 m^3/hr. In this study, it is estimated that a well of about 60 m^3/hr. can be constructed and will irrigate about 10 hectares of land.

Preliminary studies indicate that a gravel-packed well in most potential irrigable areas of Libya will be the best and yield the most dependable water supply. The cost of digging a well of the avampozzo type at the present time is about £9.000 per meter. The cost of a properly gravel-packed and screened is estimated to be £24.000 per meter. With expansion of a well-drilling program, this cost of properly-constructed wells may be reduced. Despite this great increase in cost, it is felt that the benefits received from using a properly-designed well would be worth while, particularly the benefit of being able to increase the discharge whem required. as in the month of July when irrigation needs are great, without fear of losing the well.

In this study, it is estimated that the average well would be about 50 meters deep, thus costing an average of £1,200.000. In Cyrenaica and some other areas outside Tripoli Gefara, gravel packing and special screen may not be needed; but other wells may be deeper and other costs will be compensating.

Cost of Irrigation Development Program

It is estimated that a well producing 60 m^3/h would supply enough water to irrigate 10 hectares. For convenience the same size farm unit of 10 hectares will be used as the economic unit for all of Libya. Due to the extreme scarcity of water and the roughness of land, particularly in the Tripoli Gefara, it will be assumed that a sprinkler system of irrigation will be utilized in the newly-prepared irrigation areas. The basic data used, with the exception of the cost of the wells, are applicable, to most areas to be developed. Most irrigation developments will be confined to areas of fair to good topography. The estimated cost per hectare for the coastal areas and the area south of Zliten should run about the same as Bur El Ghnem. The estimated average cost per hectare for the Bir El Ghnem project is presented in Table 8.

TABLE 3

CAPITAL COSTS AND SERVICING CHARGES

	I	II
Systems		
Capital Costs		
1 Land at £10/Ha	100	100
2 Buildings	1 000	1 000
3 Drilling casing and screens (share)	1 200	1 200*
4 Submersible pumps (share)	350	350*
5 Sprinkler system	620	620*
6 Farm implements	80	80
7 Livestock		
Horses	30	30
Cows	120	120
Calves	100	100
8 Nursery plants		
280 x citrus x £0.2	112	224*
33 x olives x £0 2	50	36*
9 Land preparation	50	50
10 Transmission line	200	200
11. Roads	100	100*
Total	4,112	4,210
Amortization		
at 4% over 25 years (= x 0.064)	263	269
Replacement Fund		
Well over 25 years	48	48
Pump over 10 years	35	35
Sprinkler over 10 years	62	62
Farm implements over 5 years	16	16
	161	161

* Values used to rehabilitate old farms.

On many of the new inland areas shown on the map, the water will have to be pumped. Flowing wells will be developed in some of the inland coastal areas. More pumps will be required on the inland projects. Flowing wells will be deeper, consequently will cost more money, while pumped wells will require the expense of the installation of a pumping system.

Since no definite plan has been developed for the spring at Tauorga,[6] the cost of development, used at Bir-El Ghnem will be a fair estimate. Although there are no wells involved, the expense of lifting and channeling the water to suitable land should off-set the cost of well development.

New wells in the areas already developed will consist of few flowing wells but mostly wells averaging about 40 meters depth. The expense of well development and cost of storage reservoirs will be less than pumped wells of the outlying areas. Their criteria will apply specifically to coastal areas of Cyrenaica.

In areas already irrigated the cost of new wells will be the same as that estimated for wells in prepared irrigation areas. The cost of rehabilitation of old wells usually envolves other costs not incurred in construction of new wells. Since old wells usually need to be deepened, (in some instances a new well is required, and other costs are required), it is estimated that well rehabilitation will cost about the same as new well construction.

In many irrigated farms in Libya it will be desirable only to improve the present surface irrigation system without necessarily improving their water supply. About 5,390 hectares of additional new land could be irrigated by the water saved through installing waterproof canal linings[4] in the existing irrigated forms. These newly-irrigated areas will cost about £219.000 per hectare. Most Libyan farmers with their relatively small land area irrigate only about one-half of their farm; therefore, adequate developed area already exists for expansion of irrigated land without developing new lands. Water saved by installation of canal linings and used on present form areas will not withdraw additional ground water. This conserves and better utilizes the scarce underground water resources. The addition of irrigation land area to the present holdings will not necessarily increase the number of families that could be settled, but this will increase the economic base of the families already depending for their income from such land. For purposes of this study, it will be assumed that for each additional 10 hectares thus developed that the equivalent of one family unit could be supported. By the same analysis each additional 10 hectares thus benefited from spring improvement in the Gebel areas will likewise benefit.

Benefit-Cost Analysis

The benefit-cost ratios for the projects of the water development plan were calculated and detailed calculations are presented in Appendix A. A summary of the benefit-cost analysis are presented in Table 9.

The benefit-cost ratios were computed on the basis of costs and net return of the development. In addition, the capital improvements were amortized at 4% interest over a 35-year assumed development period. A sinking fund for replacement of capital works was also included in the calculations so that capital works could be replaced as they are worn out.

The benefit-cost ratios for the listed projects of the plan range from a value of 1.25:1 to 3.22:1. This indicates that all the water development projects in the plan are economically feasible.

The higher ratio of benefit-to-cost indicates the more economically feasible projects. The most economically feasible projects are those where development takes place on cultivated and irrigated land. For example, development of canal lining on presently irrigated land indicated that this development would have a benefit-to-cost ratio of 3.22:1. This indicates that this development is a good investment and is economically feasible. The benefit-to-cost ratio of developing new lands for irrigation is 1.54:1. This indicates that new lands development is not as economically feasible as the canal lining program, but it indicates that new irrigation lands development is economically feasible and a worth while investment.

The benefit-to-cost ratios mainly indicate which projects are the most economically feasible. The higher value of ratio indicate the higher return per unit of investment. These ratios of benefit-to-cost will assist to determine which activities and projects should be assigned higher priorities on the basis of return on investment.

TABLE 9

BENEFIT-COST ANALYSIS FOR PHASES OF IRRIGATION DEVELOPMENTS

		Benefit-Cost Ratio
(1) (2)	New Areas.	1.54:1
(3)	Present Cultivated Areas Exclusive of Spring Development in Gebel.	1.82:1
(4)	Improved Canal Lining.	3.22:1
(5)	Gefara Water Spreading Program	1.91:1
(6)	Dike and Terrace Program in Tripolitania and Cyrenaica.	1.25:1
(7)	Rehabilitation of Roman Cisterns	2.29:1

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APPENDIX A

BENEFIT COST ANALYSIS FOR WATER & DEVELOPMENT PROJECTS

1) 2) New Areas

Cost factors calculated on the basis of one hectare

			£	£
1)	Value of output under full irrigation (35 yrs) (176)	=	6 150	
2)	Cost of production under full irrigation (35 yrs) (121)	=	4 230	
3)	Net benefits of additional output from new areas		1 920	1 920
4)	Development costs			
	a) Amortization @ 4% over next 35 years on £421/Hc capital costs			
	(421) (0.0536) (35)	=	789	
	b) Replacement fund			
	(35) (16)	=	560	
5)	Total development costs	=	1 249	1 249
6)	Benefit Cost Ratio £1 920 : £1 249			1 54:1

3) Present Cultivated Areas Exclusive of Spring Development in the Gebel

Cost factors calculated on the basis of one hectare

1)	Value of output under full irrigation (35 yrs) (176)	=	6 150	
2)	Cost of production under full irrigation (35 yrs) (121)	=	4 230	
3)	Net benefits of additional output from rehabilitated areas		1 920	1 920
4)	Development costs			
	a) Amortization @ 4% over next 35 years on £263/Hc			
	(263) (0 0536) (35)	=	493	

		£	£
	b) Replacement fund		
	(35) (16)	= 560	
5)	Total development costs	1 053	1 053
6)	Benefit Cost Ratio £1 920 : £1 053		1 32:1

4) Improved Canal Lining

Cost factors calculated on the basis of one hectare

		£	£
1)	Value of output under full irrigation (35 yrs) (176)	= 6 160	
2)	Cost of production under full irrigation (35 yrs) (121)	= 4 230	
3)	Net benefits of additional output from canal lining development	1 920	1 920
4)	Development costs		
	a) Amortization @ 4% over next 35 years pm £219/Ha capital costs		
	(219) (0.0536) (35)	= 411	
	b) Replacement fund		
	(35) (5)	185	
5)	Total development costs	596	596
6)	Benefit Cost Ratio £1 920: £596		3 22:1

5) Gefara Water Spreading Program

Cost factors caldulated on the basis of one hectare

		£	£
1)	Value of output underwater spreading each year withenough water to grow a good barley crop (35 yrs) (£51)	= 1,785	
2)	Cost of production under full water spreading (35 yrs) (£40)	= 1,400	
3)	Net benefits of additional output from water spreading	385	385
4)	Development costs		
	a) Amortization @ 4% over next 35 years on £33/Hc capital costs		
	(33)(0.0536)(35)	= 62	
	b) Replacement fund		
	(35)(4)	= 140	
5)	Total development costs	202	202
6)	Benefit Cost Ratio £385 : £202		1.91:1

6) Dike and Terrace Program in Tripolitania and Cyrenaica

Cost factors calculated on the basis of one hectare

1)	Value of output under dike and terrace program (35 yrs) (£51)	= 1,785	
2)	Cost of production under full water sprading (35 yrs) (£40)	= 1,400	
3)	Net benefits of additional output from water spreading	385	385
4)	Development costs		
	a) Amortization @ 4% over next 35 years on £60/Hc capital costs		
	(90)(0.0536)(35)	= 169	

		£	£
b)	Replacement fund		
	(35) (4)	= 140	
5)	Total development costs	300	300
6)	Benefit-Cost Ratio £335 : £300		1.25:1

7) Rehabilitation of Old Roman Cisterns

Cost factors calculated on the basis of one cubic meter of stored water

a) Estimate an annual worth of £0.200/m^3 of water

b) Estimate a total capital cost of £ 500/m^3 of water

		£	
1)	Value of output for 35 years (35)(0.200)	= 7.000	
2)	Cost of lifting water and selling (0.010) (35)	= 0.350	
3)	Net benefits of additional output from use of water	6.650	6.650
4)	Development costs		
	a) Amortization @ 4% over next 35 years on £1 500 total capital costs		
	(1.500) (0.0536) (35)	= 0.281	
	b. Replacement		
	(35) (0.075)	= 2.625	
4)	Total developments costs	2.906	2.906
5)	Benefit Cost Ratio £6.650 : £2.906		2.29:1

APPENDIX B

QUALITY OF WATER IN LIBYA AND IRRIGATION DEVELOPMENT

Generalized interpreted water quality data is available to indicate about where various qualities of water may be found in Libya. These data will assist water resource planners to select the most suitable areas for development in view of the quality of water.

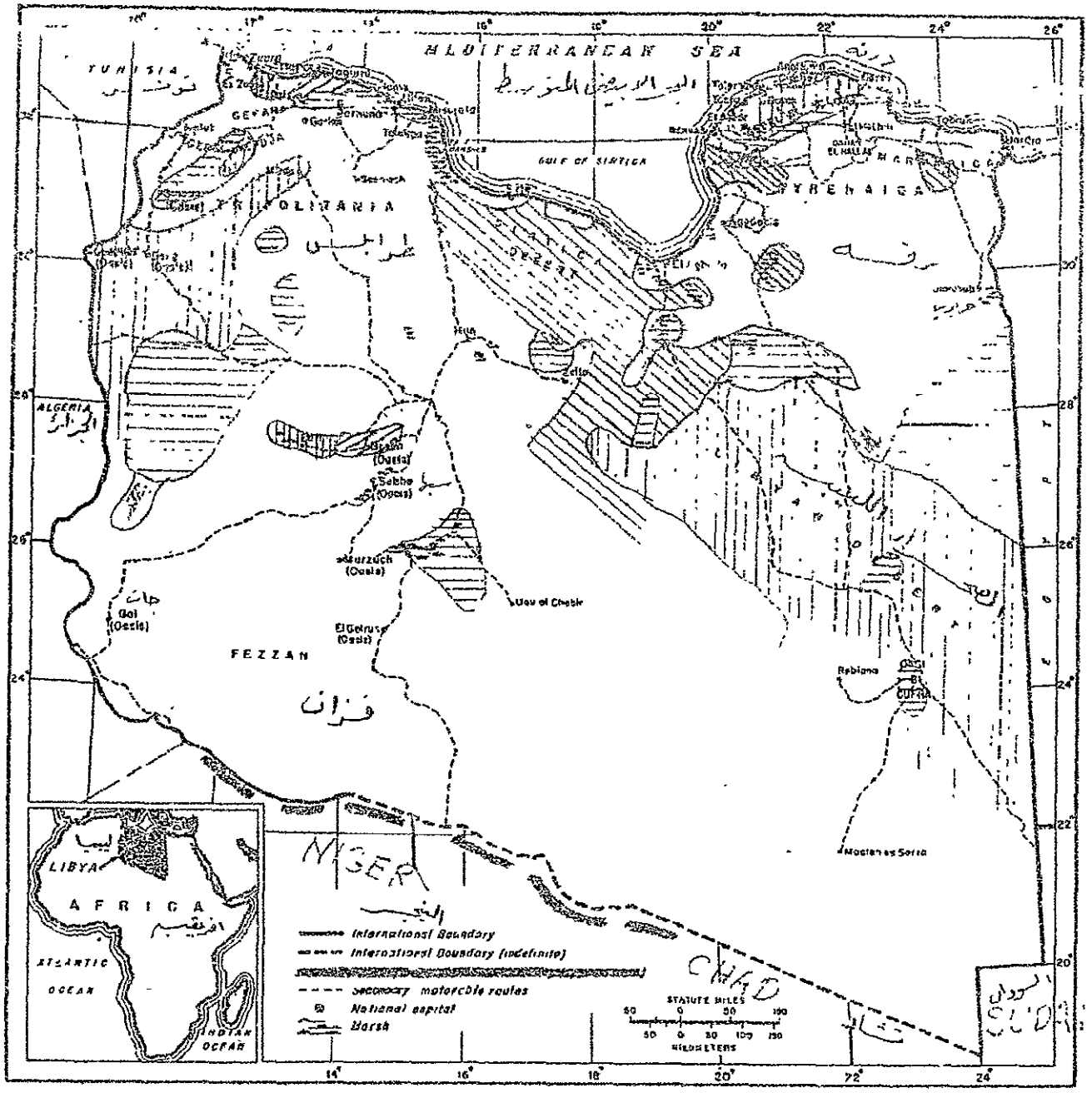
USAID technicians devoted about two years collecting water-well data, revising, and analyzing the data for ground-water conditions of Libya. Several years' collection of USAID's ground-water data, older water records, and the oil company water-well records were studied. Considerable water-well data was available in the USAID files and oil company records. It is believed that this reconnaissance evaluation of ground-water quality conditions of Libya are the best available. It is reliable enough to show approximate areas where detailed water resource development can be conducted.

One of the most important items in irrigation development is the quality of water necessary to serve the development. The attached Map A indicates areas where different qualities of ground water have been found. It must be emphasized that this map is generalized. The boundaries indicated are not as sharp or narrow as shown and cannot be sharply interpreted without additional intensive and highly-detailed ground-water investigations. The areas of water quality, as shown, are based on a very large amount of ground-water data. The quality areas are believed to be generally correct.

Briefly, the ground-water quality areas have been divided into six classifications as shown on the map.

It must first be noted that this quality water classification is also generalized. Some irrigated areas of Libya are now utilizing water of poor quality. In these instances the number of crops that can be grown and the crop production when utilizing such water is limited. Also, when utilizing irrigation water of poor quality, special irrigation techniques must be employed, which increase the cost of crop production. The water quality, as defined, is believed to give a fair indication of the ground water's suitability for irrigation purposes.

A second point of note is that the amount of ground water available is not indicated by its quality. Even though the quality of water may be good, the amount may be so limited or



Water Quality Classification

	CL 1/	SO_4 1/	Solids 2/	Spec. Con. 3/
Good	<250	<250	<1,000	<1,600
Fair	250-800	250-600	1,000-1,500	1,600-2,500
Poor	800-1,500	600-1,200	1,500-3,500	2,500-6,000
Brackish	1,500-3,500	1,200-2,500	3,500-6,000	6,000-10,000
Salty	>3,500	>2,500	>6,000	>10,000
Unknown				

1/ In parts per million
2/ Total dissolved solids, p.p.m.
3/ In micromhos at 25°C

expensive to pump that it is not practical to utilize for irrigation.

The majority of the ground-water in the northern areas of Libya are of poor quality. This correspondingly limits the possible areas for irrigation development. They are minor exceptions of perched water tables of limited supply of good water: for example, Qasr Bu Hadi near Sirte. Also, locations where deep supplies of good water have been found; for example, the newly-dug well near Socna. Other exceptions to the general pattern will be found, but only after costly and time-consuming additional ground-water investigations are conducted.

On the basis of experience irrigation development might be conducted in any of the areas where the water is not "brackish" or salty, according to water quality classification, provided the soil resources also exist and the amount of water is enough to supply irrigation development.

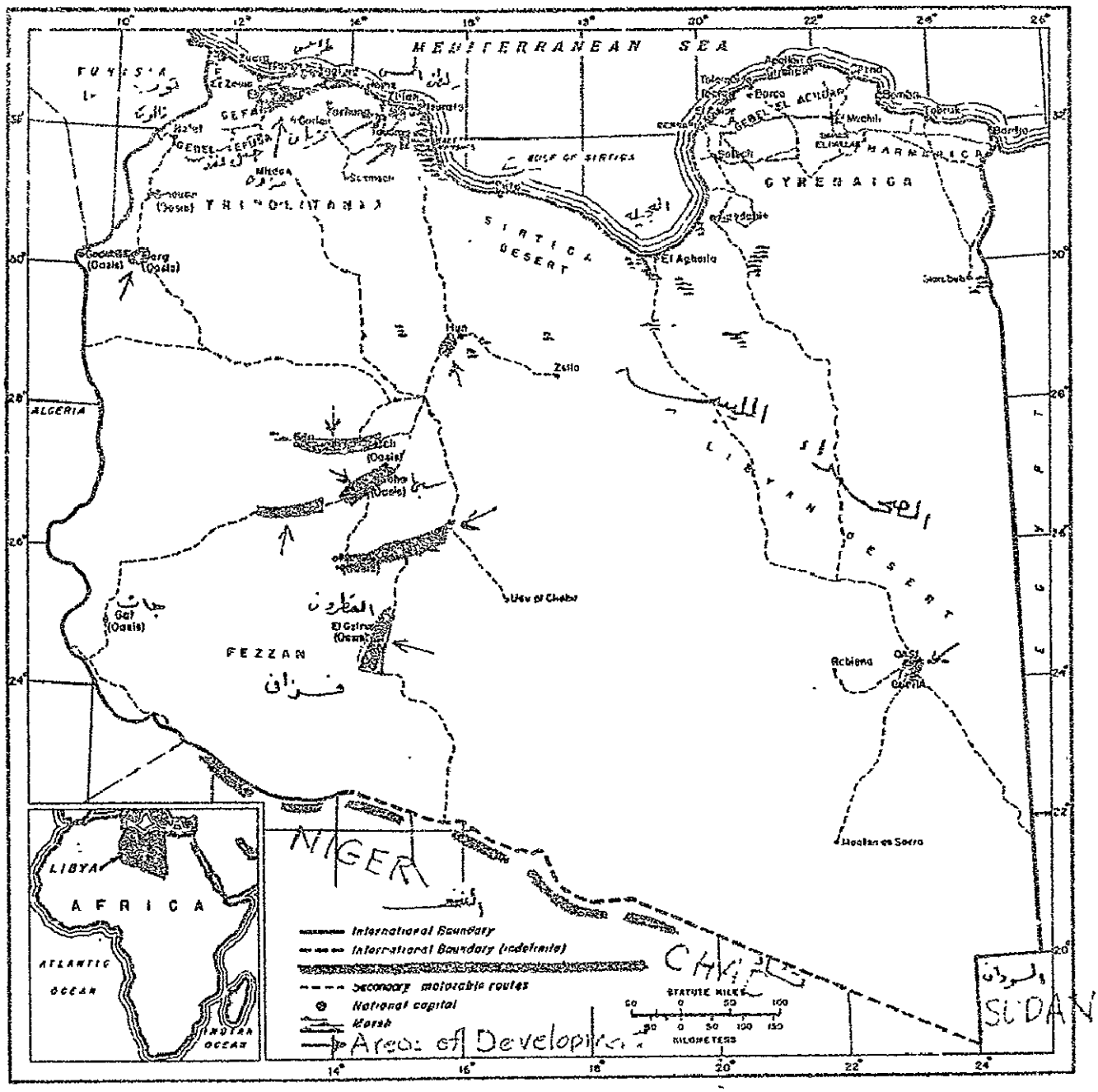
The areas which are most likely to support irrigation agriculture are those indicated by a good, fair, and pool water on the accompanying Map A. These areas indicated in the attached Map B and may be broadly defined as follows:

1. The general areas of the gefara south and both east and west of Tripoli. Additional water is available in these areas for exploitation. However, any irrigation development in these areas should be preceded by carefully-detailed, ground-water studies to estimate the effect of additional ground-water withdrawals on the existing irrigation agriculture's water supplies.

2. The larger oasis areas around Sebha, the Chatti Valley, Morzuk Basin, Wadi Ajal, and Gatrun all offer possibilities of expansion of irrigation agriculture as supplies of good ground water are known to exist in these areas.

3. An area between Zliten and Misurata known as Naimah also offers possibilities of additional irrigation development, based on the availability of good ground-water supplies.

4. The Tauorga spring is a very large known supply of water. Although the water is of poor quality, under proper irrigation management and drainage, the waters of this spring will support average crop production. The Libyan-American Joint Services recommended that these waters be used to irrigate an area of good soil lying astride the Misurata-Benghazi highway about 4 km. west of the spring.


MEDITERRANEAN SEA
TUNISIA
GEFARA
GEBEL EFUDA
Mizda
Sirtica
TRIPOLITANIA
Ghadames
Berg (Oasis)
ALGERIA
GULF OF SIRTE
Sirte
SIRTICA DESERT
El Agheila
Hun
Zella
Gat (Oasis)
Ubari (Oasis)
Sebha
Ubari (Oasis)
Gat (Oasis)
El Gizma (Oasis)
FEZZAN
Wadi el Chabir
LIBYAN DESERT
Kufra
Oasis
Uweinat
Tibesti
Ennedi
Tobruk
Bardia
Bomba
Derna
Apollonia
Cyrene
Barca
Tocra
Benghazi
Ajdabia
Jalo
Siwa
Sarobub
Kufra
Oasis
Uweinat
Tibesti
Ennedi
CYRENAICA
GEBEL EL AKHDAR
Michili
GEBEL ELMAGRUN
MARMARICA
LIBYA
AFRICA
ATLANTIC OCEAN
INDIAN OCEAN
NIGER
CHAD
SUDAN
International Boundary
International Boundary (indefinite)
Secondary motorable routes
National capital
Marsh
STATUTE MILES
KILOMETERS
Area of Development

5. Along the coast north from Benghazi to Tokra is an area in which limited irrigation agriculture could be expanded. The water and soil resources are very limited. Withdrawals from underground water sources in this area will have to be severely limited to prevent salt-water intrusions.

6. There is enough good water in a number of desert oasis areas to permit limited expansion of irrigation agriculture.

In all the sites mentioned, detailed studies as to water and soil resources need to be conducted to determine the extent to which these resources can be exploited. Also, expansion of irrigation agriculture produces more farm products which must be sold at a fair profit if the farmer is to succeed. Some of the areas suggested for irrigation development are so located that serious marketing problems exist. In all areas suggested, problems of what the farmer will grow, where he will market it, and how good will his price be should be studied and action taken toward solution at the same time the water supply is studied in detail.