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ISN 42099

# FEASIBILITY REPORT ON RICELAND RECLAMATION IN GUINEA

6150013

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KOBA PROJECT

BY THE

HARZA ENGINEERING COMPANY

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A.I.D.
Reference Center
Room 1656 NS

PREPARED FOR

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

APRIL 1964

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SUMMARY LETTER

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Table of Equivalents

HARZA ENGINEERING COMPANY
CONSULTING ENGINEERS
RIVER PROJECTS
400 WEST MADISON STREET
CHICAGO 6, ILLINOIS

CABLE ADDRESS "HARZENG CHICAGO"

TELEPHONE RANDOLPH 6-3451

April 1, 1964

Agency for International Development
State Department
Washington 25, D. C.

Subject: Koba Project
Feasibility of Riceland Reclamation

Gentlemen:

We are pleased to submit our feasibility report on the Koba Project. This report contains the results of the engineering, agronomic, and economic studies of the Koba Project which we have made in compliance with the terms of our contract AID/afe-93, dated April 3, 1963. This contract provides for feasibility studies in connection with the reclamation of a series of four project areas totaling about 17,500 hectares in the Republic of Guinea. Our reports on the Monchon and Kakossa projects were submitted on October 15, 1963, and February 15, 1964, respectively. The Koba Report is the third of the series.

Our findings indicate that a flood control and agricultural improvement project covering about 3900 hectares in the plains of Koba is economically justified and financially feasible. The project will result in an important increase in the supply of locally produced rice and thus reduce significantly dependence on foreign food sources.

## Introduction

The Republic of Guinea presently has an agricultural economy, heavily dependent upon rice. Although rice is staple food in Guinea, domestic production has been insufficient to meet the ever-increasing needs of a growing population.

The plains of Koba have long been a rice producing region, but crop yields and particularly land use have been below their potential. About 970 hectares of ricelands are currently being cultivated. In the southern portion of the plains, salt water intrusions limit very seriously the rice yields. In the remainder of the project area, severe fresh water flooding prevents the use of most of the lands. In addition, throughout the project area, the lack of supporting agricultural improvement programs has prevented the development of satisfactory rice varieties.

Outside of the project area itself, an area of about 700 hectares is in cultivation at present. This area was formerly part of the Koba Experiment Station, and its reclamation, carried out under the former Colonial Administration, was fairly successful. High yields are obtained in the better drained paddies, and fair yields in the remainder of this area. This area was investigated within the scope of our field studies because it is indicative of the potential of the Koba plains. However, rehabilitation of the drainage facilities and proper maintenance will be required to fully reclaim these lands.

## Previous Reclamation Plan

Under the direction of the Service du Genie Rural, a plan was developed in 1954-1957 for reclaiming about 4000 hectares of arable land located in the plains of Koba. The plan consisted of a system of dikes designed to prevent flooding of the lands during high tides, and a system of drainage canals designed to remove excess run-off from the fields. One gated structure located across the main drainage canal was proposed to provide a control of fresh water discharge from the project area and of salt water discharge from the ocean.

Construction drawings and detailed specifications were prepared in 1957 by the consulting engineering firm COTHA. Construction was scheduled to proceed under two main contracts: one for dredging of the main canal, and another for construction of the dikes and the gated control structure. The cost of constructing these drainage facilities was estimated to be 271 million CFA francs. However, the French Colonial Administration departed from Guinea before the project could be started.

Agency for International
Development

April 1, 1964

The government of Guinea is now considering the construction of this project with the assistance of international financing agencies, as a means of increasing the production of rice in Guinea and of improving the economy of the Koba area.

## Present Investigations

Our assignment has included both field and office studies to determine the adequacy of the proposed plan and the economic feasibility of the project. We have sent to Guinea a team of six engineers and agronomists who, from April to July and from October to December, 1963, reviewed all available data pertaining to the Koba and other projects. This team carried out field investigations related to hydrology, topography, soils, hydraulics, agronomy and economics, and collected data for the development of a revised plan for reclamation. Analysis of the data and preparation of the plan were then completed in our Chicago office.

## Project Description

The location of the Koba Project is shown on Exhibit A. Our plan for development is shown on Exhibit B, and represents an extension and modification of the previous plan. The project will consist of an enclosed system of surface canals designed to drain toward the ocean the excess run-off that would otherwise remain in the paddies for a prolonged period. The project area will be surrounded by a system of dikes designed to prevent the entrance of salt water from the ocean during periods of high tides, utilizing existing sand dunes to the maximum extent. One control structure will be at the downstream end of the main drainage canal. This structure will be provided with flap gates designed to prevent the uncontrolled entrance of salt water from the ocean.

The drainage system will consist of excavated canals to collect excess water from the paddies and convey this discharge toward a main canal. A total length of 56 kilometers of secondary and tertiary canals will be

excavated by dragline to sections varying from 1.5 to 0.5 meters in bottom width. These canals will receive the discharge from the field ditches or quaternary canals. A total of about 170,000 cubic meters of excavation will be required for construction of the drainage system.

The main canal will be located in the middle of the plains and will be oriented in a general north-south direction. This canal will be 10.5 kilometers long, and will have a bottom width varying from 12 meters at its upper end to 48 meters at its downstream end. The main canal will be excavated by a floating, suction-type dredge. A total of about 1,000,000 cubic meters of excavation will be required for construction of the main canal.

The dikes will extend between existing dunes to close the present gaps. A total of 11.4 kilometers of dikes will be part of the project, of which 2.1 kilometers of the existing dike located at the northern edge of the project area will be rehabilitated and 9.3 kilometers will be newly constructed. The dikes will be homogeneous, rolled earth embankments. Their maximum height will be 1.7 meters above ground level, most of the dikes being about 1.4 meters high. The crest of the dikes will be at elevation 5.5. The dikes will require placement of about 170,000 cubic meters of earth fill.

At the downstream end of the main canal, a gated control structure will be provided. It will be constructed in reinforced concrete, and will be provided with a series of automatic flap gates.

A number of bridges have been included in the project for operation and maintenance access, and for use by the local inhabitants. Maintenance roads will be provided along all dikes and main drainage canals. Construction of the project is estimated to take three years.

## Project Cost

We have estimated the construction cost of the civil works including canals, dikes and structures, to be US$1,850,000 and GF 290,000,000.

The cost of land preparation, including minor leveling and planing is estimated to be an additional $50,000 and GF 40,000,000. Funding arrangements should include additional allowances for interest during construction and possible cost escalation. Financing requirements are estimated to be US $2,000,000 and GF 380 million, equivalent to a total of US $3,520,000, not including interest during construction. The rate of exchange used is GF 248 equal US $1.00.

The average annual cost of operation and maintenance is estimated to be GF 10 million. This amount includes the average cost of a comprehensive program for improvement of farming practices.

## Project Benefits

The presently cultivated area of about 970 hectares can be increased to about 3710 hectares with reclamation. From our studies of the agricultural potential of the soils in the project area, we estimate that the present average annual production of about 1450 tons of rice paddy can be increased to about 3760 tons immediately upon completion of the project. This production can be progressively increased to about 7450 tons in about ten years and to an ultimate amount of 9200 tons in 20 years after project completion. These increases in production will require from the very beginning a comprehensive support program for the improvement of farming practices.

The achievement of these increases in production will represent a sizeable contribution to the Guinean economy, which is now deficient in rice. Annual rice imports have increased steadily in the last few years, and amounted to about 35,000 tons in 1963. Rice imports now cost about $2.5 million yearly, or ten percent of the present deficit in the balance of international trade.

## Economic Value

The economic value of this project has been measured by benefit-cost relationships. Capital costs have been based on an interest rate of six

percent and an economic life of 50 years. The analysis of project benefits is shown on Exhibit C. Included are both direct and indirect benefits that will accrue to the project and for which a monetary value could be assigned. The results obtained are as follows:

All amounts in equivalent U.S. Dollars 1/

| | Upon Completion of Project | After 5 Years of Operation | After 10 Years of Operation | After 20 Years of Operation |
|---|---|---|---|---|
| **Annual Benefits** | | | | |
| Direct Benefits | 188,000 | 392,000 | 524,000 | 814,000 |
| Indirect Benefits | 40,000 | 78,000 | 106,000 | 136,000 |
| Public Benefits | 30,000 | 40,000 | 46,000 | 60,000 |
| Total Annual Benefits | 258,000 | 510,000 | 676,000 | 1,010,000 |
| Equivalent Annual Direct Benefits 2/ | | | $565,000 | |
| Equivalent Annual Total Benefits 2/ | | | $727,000 | |
| **Annual Costs** | | | | |
| Capital Costs | | | $228,000 | |
| Operating Costs | | | 40,000 | |
| Total Annual Costs | | | $268,000 | |
| **Benefit-Cost Ratios** | | | | |
| With Direct Benefits only | | | 2.1 to 1.0 | |
| With Total Benefits | | | 2.7 to 1.0 | |

1/ Data in this table have been presented in equivalent U.S. Dollars for the convenience of non-Guinean readers, although most benefits will accrue in domestic currency.

2/ Determined by calculating the present-worth of future annual benefits accruing over a 50-year period, and amortizing this amount over 50 years at an annual interest rate of 6.0 percent.

We consider that the project is economically justified in view of the satisfactory benefit-cost ratios. For achievement of the potential benefits from the drainage of the lands, a supporting program of agricultural extension services will be required.

## Financial Analysis

The source and terms of project funds are not yet known. For purposes of analysis we have assumed loans bearing interest at an annual rate of 0.75 percent, to be repaid in 40 years, with the first amortization payment due ten years after the completion of construction.

Our analysis of future revenues and costs shows that after only three years residual revenues will be greater than the interest, amortization, and operation costs for completion of the project. In fact, substantial surpluses will occur in future years, indicating that less liberal financing terms can be met by the project.

## Timing of the Project

The timing of the Koba Project will be dependent on the total need for projects of this type in Guinea and upon the relative feasibility of the several projects. Ultimately four projects will be studied by us, plus additional projects programmed for study by the Food and Agriculture Organization of the United Nations. However, at present, the only basis for comparison is with the Monchon and the Kakossa Projects.

On the basis of cost of development per hectare, the Koba Project would be less economical than the Kakossa Project, but as economical as the Monchon Project. On the basis of benefit-cost ratios, the Koba investment would yield the same returns as the Monchon investment. The investment per ton of rice that would be produced in the next 50 years is slightly higher than that of the other two projects. These facts are demonstrated by the following comparison:

| Basis of Comparison | Monchon Project | Kakossa Project | Koba Project |
|---|---|---|---|
| Net reclaimable area, hectares | 2,400 | 2,260 | 3,710 |
| Investment cost, GF million | 580 | 400 | 900 |
| Cost of reclamation, GF per hectare | 240,000 | 180,000 | 240,000 |
| equiv. US $ per acre | 390 | 290 | 390 |
| Benefit-cost ratios: | | | |
| With direct benefits only | 2.1 | 2.4 | 2.1 |
| With all benefits | 2.7 | 3.1 | 2.7 |
| Anticipated rice production increase over the next 50 years, tons (paddy) | 240,000 | 190,000 | 350,000 |
| Capitalized value of proposed investments in project, GF million | 675 | 510 | 1,060 |
| Cost invested in project per ton of rice to be produced in 50 years, | | | |
| GF per ton (paddy) | 2,800 | 2,700 | 3,000 |
| US $ per bushel (paddy) | 0.23 | 0.22 | 0.25 |

However, it appears that all projects which are economically feasible will be needed, if Guinea is to become self-sufficient in rice. Consequently, we believe that the Kakossa, Monchon, and Koba projects should be undertaken as the initial step of a major agricultural program.

## Recommendations

We recommend that negotiations be started by the Government of Guinea for financing of the proposed Koba Project, and that commitments be obtained for all necessary funds, both in foreign and domestic currencies before construction begins.

The Government of Guinea should engage an experienced consulting firm to revise and bring up to date the contract documents and detailed drawings that were prepared in 1957, and to supervise and inspect construction of the works.

Agency for International
Development

April 1, 1964

Bids should be taken from qualified contractors for construction of the civil works. Preparation of the project lands for agricultural use can be carried out by the Center of Rural Mechanization.

We recommend that a rice agronomist be engaged by the Government of Guinea to direct a program for improvement of farming practices, and that consideration be given to the reactivation of the Koba Experiment Station as part of the national effort toward an increase of the rice production.

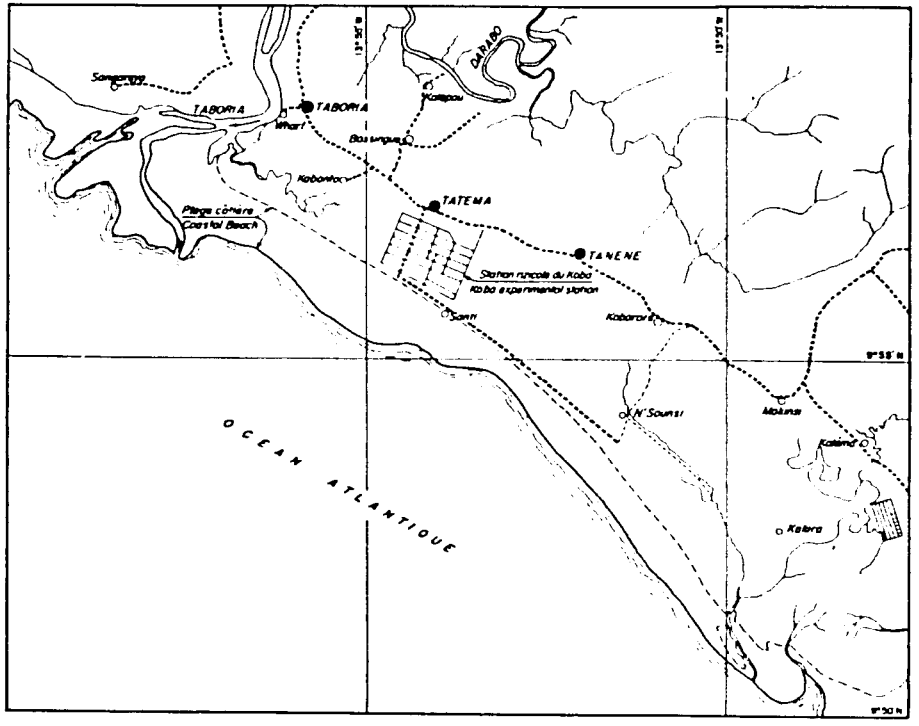
Very truly yours,

HARZA ENGINEERING COMPANY

Richard D. Harza

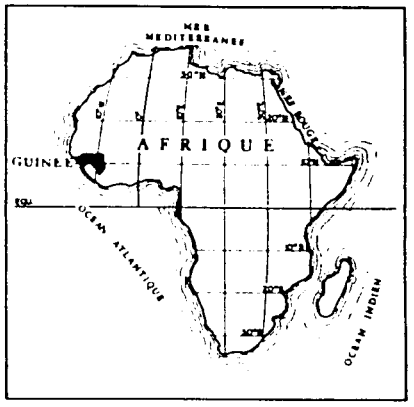
Richard D. Harza
Vice President

PLANCHE A
EXHIBIT



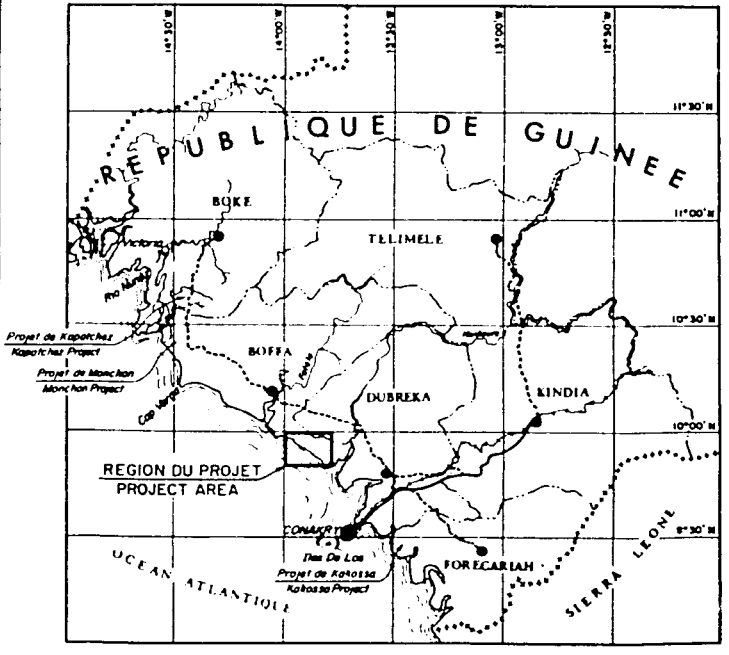

CARTE REGIONALE
PROJECT AREA

Echelle 0 1 2 Kilomètres
Scale Kilometers




SITUATION
KEY MAP

Echelle 0 1000 2000 3000 Kilomètres
Scale Kilometers




BASSE GUINEE
LOWER GUINEA

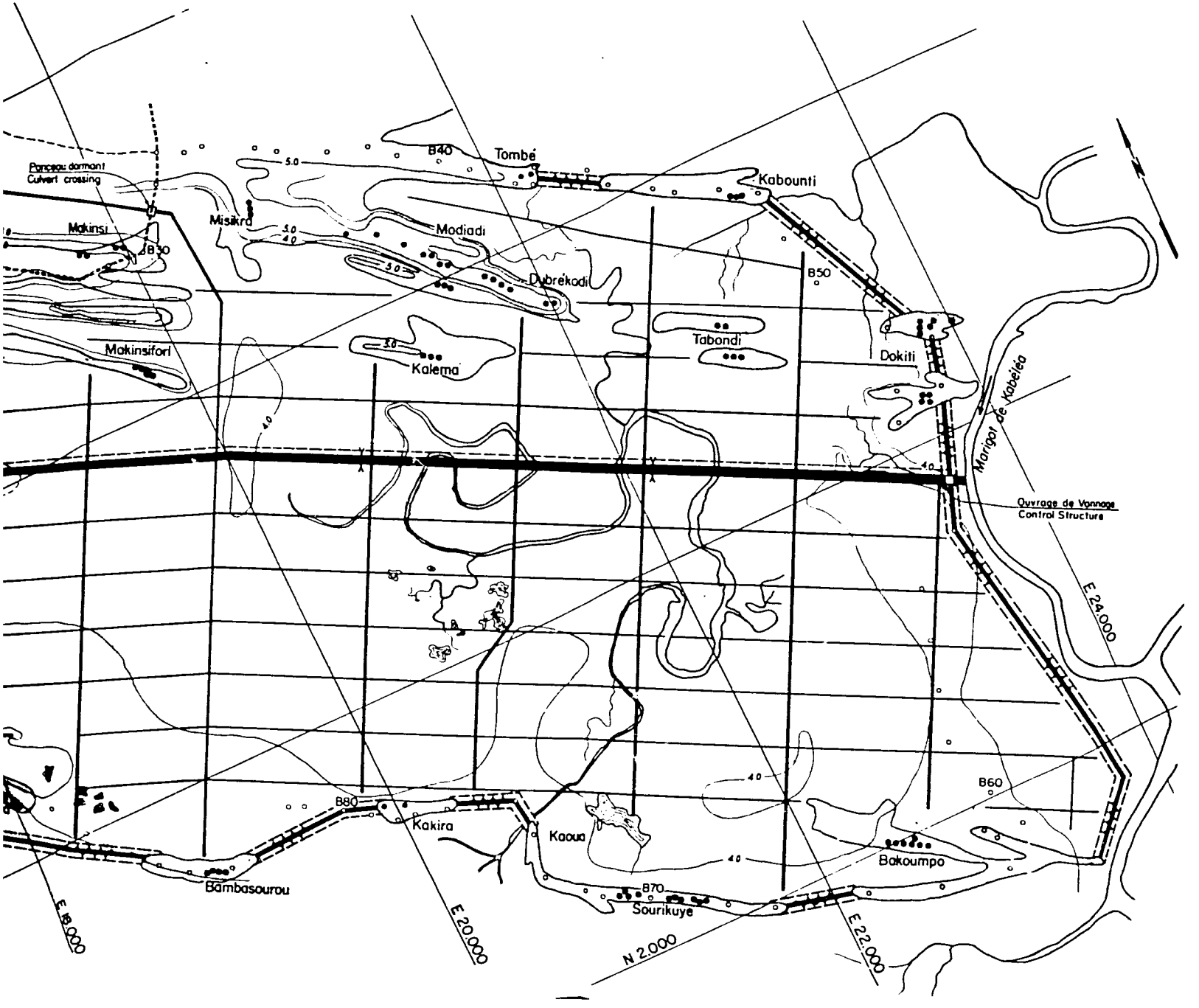
Echelle 0 10 20 30 40 50 Kilomètres
Scale Kilometers

LEGENDE
LEGEND

- Route / Paved road
- Piste / Unpaved road
- Chemin de fer / Railroad
- Villes et villages / Main cities and villages
- Frontière / National boundary
- Limite de région administrative / Regional boundary
- Réseau de canaux de drainage / Drainage canal system
- Cours d'eau / Streams
- Sentier / Path

CARTES D'ENSEMBLE
GENERAL MAPS

PLANCHE / EXHIBIT B



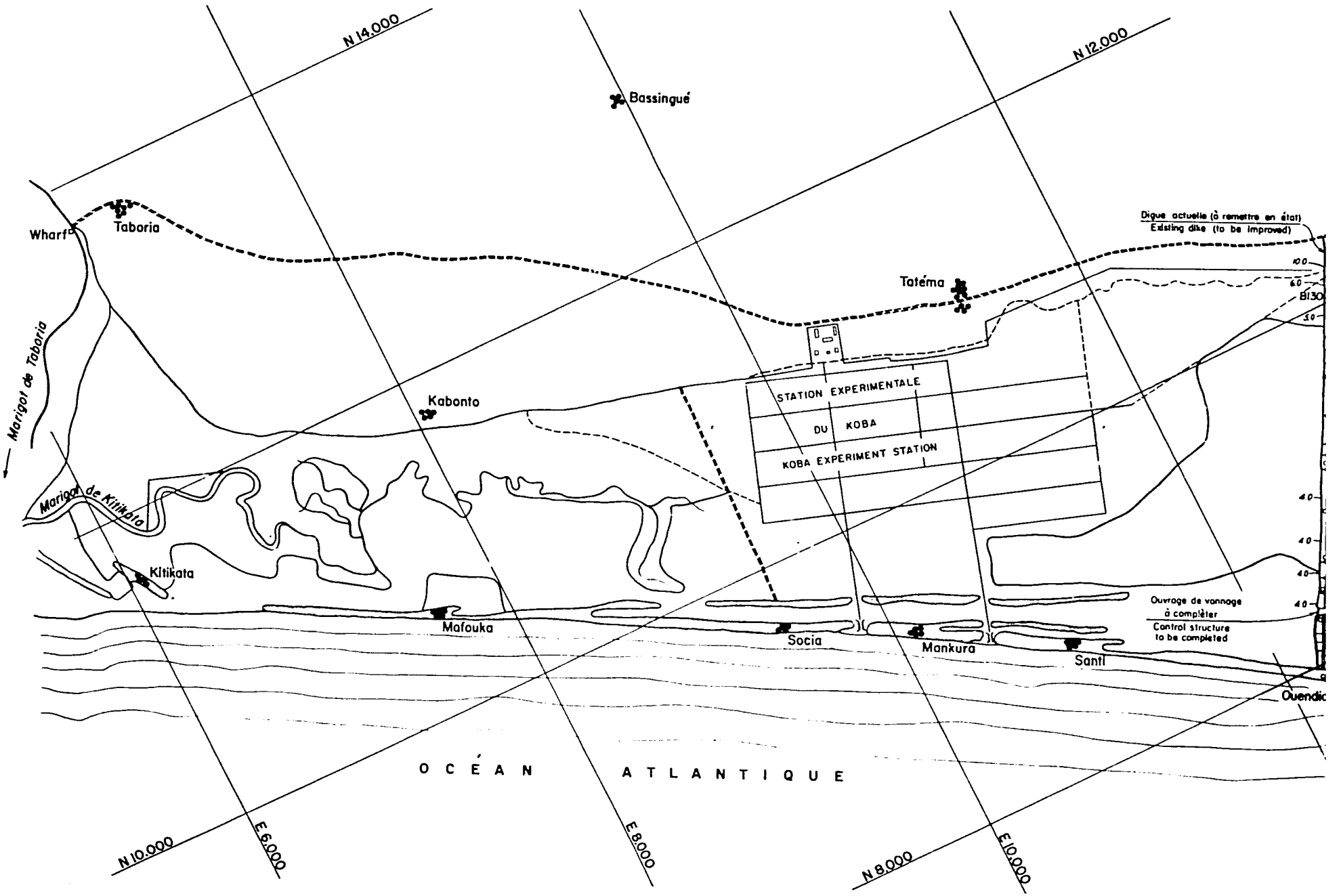

LEGENDE
LEGEND

- Canal principal / Main canal
- Canal secondaire / Secondary canal
- Canal tertiaire / Tertiary canal
- Ponceau / Foot bridge
- Piste et sentier / Road and track
- Piste d'entretien et exploitation / Operation and maintenance road
- Digue actuelle / Existing dike
- Digue proposée / Proposed dike
- Cours d'eau / Stream
- Village
- Dune
- B70 o Borne / Bench mark

NOTE: Les détails topographiques et courbes de niveau sont basés sur les cartes topographiques COTHA préparées en 1956.
Topographic details and contours are based on 1956 COTHA topographic maps.

Echelle / Scale 0 — 500 Mètres / Meters

PLAN D'ENSEMBLE DE L'AMENAGEMENT
PLAN OF RECLAMATION PROJECT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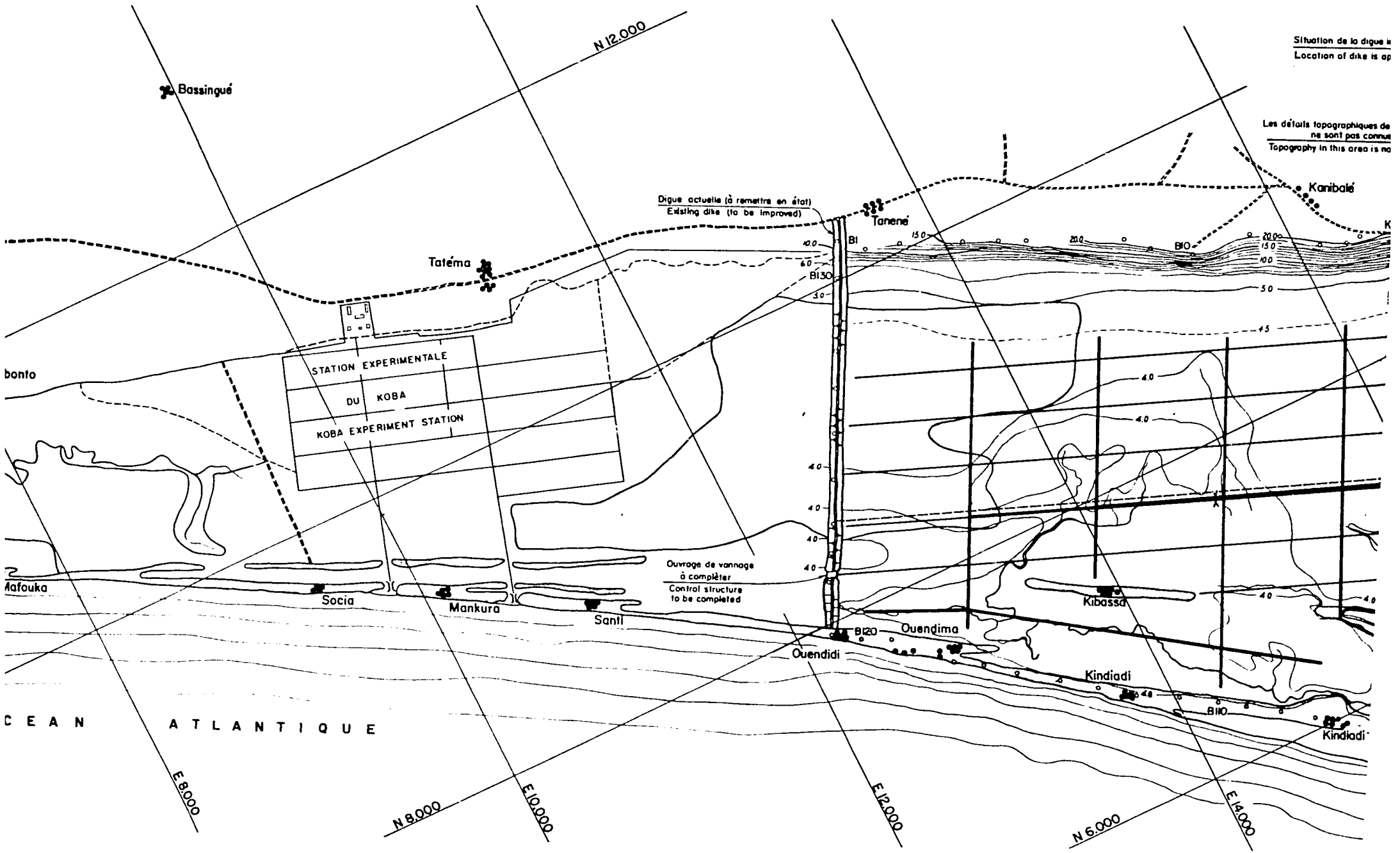
N 12.000
N 10.000
N 8.000
E 6.000
E 8.000
E 10.000
Bassingué
Wharf
Taboria
Tatéma
Kabonto
Kitikata
Mafouka
Socia
Mankura
Santi
Ouendic
Marigot de Taboria
Marigot de Kitikata
STATION EXPERIMENTALE
DU KOBA
KOBA EXPERIMENT STATION
Digue actuelle (à remettre en état)
Existing dike (to be improved)
Ouvrage de vannage
à compléter
Control structure
to be completed
OCÉAN ATLANTIQUE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ne sont pas connus
Topography in this area is no
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Digue actuelle (à remettre en état)
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B1
B10
B130
STATION EXPERIMENTALE
DU KOBA
KOBA EXPERIMENT STATION
bonto
Ouvrage de vannage
à compléter
Control structure
to be completed
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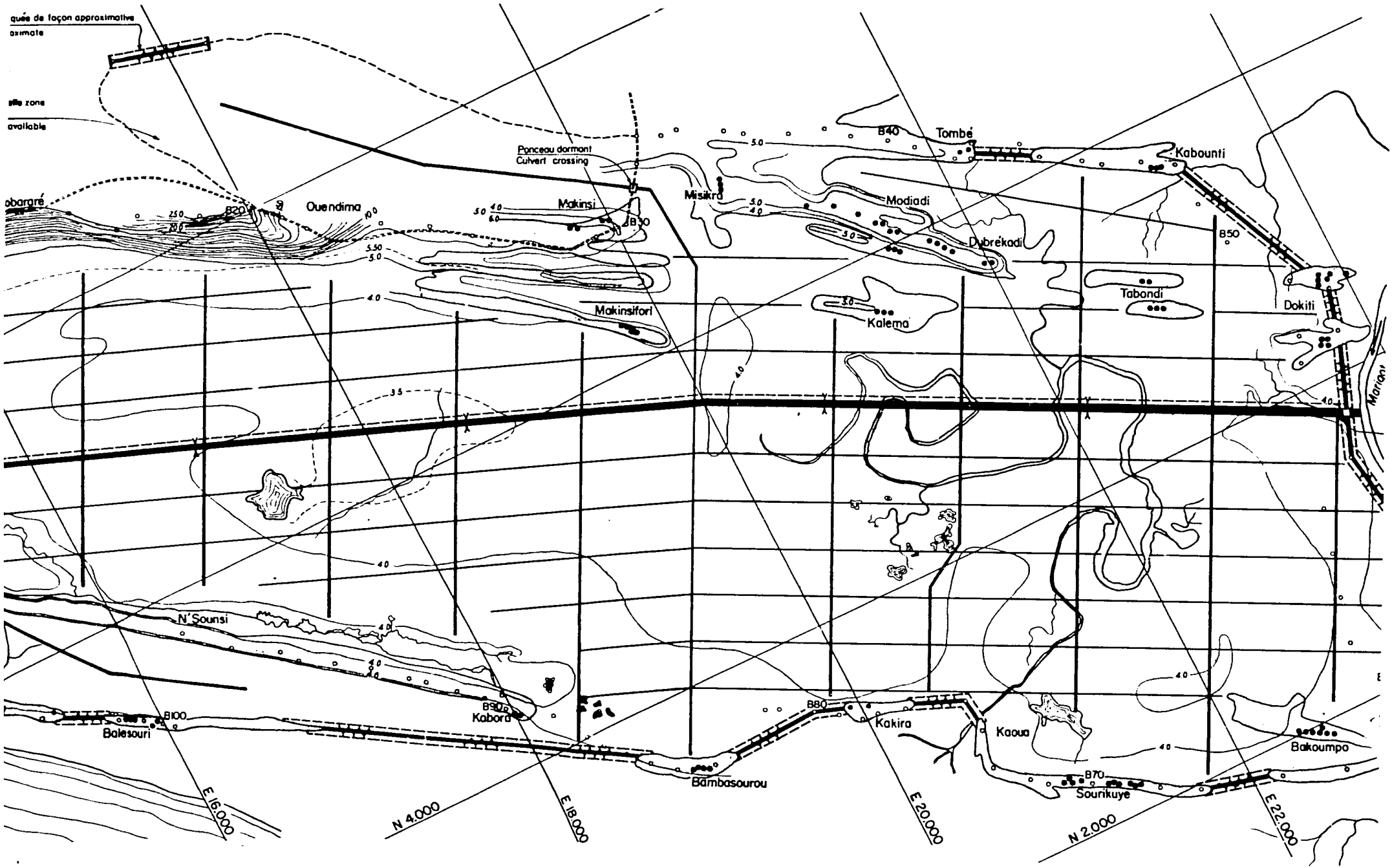
Socia
Mankura
Santi
Kibassa
B120
Ouendima
Ouendidi
Kindiadi
B110
Kindiadi
C E A N
A T L A N T I Q U E
E 8.000
N 8.000
E 10.000
E 12.000
N 6.000
E 14.000


quée de façon approximative
aximate
ible zone
available
Ponceau dormant
Culvert crossing
Ouendima
Makinsi
Makinsifori
Misikro
Modiadi
Dubrekadi
Tombé
Kabounti
Tabondi
Kalema
Dokiti
N'Sounsi
Kabora
Balesouri
Bambasourou
Kakira
Kaoua
Sourikuye
Bakoumpo
B20
B30
B40
B50
B70
B80
B90
B100
E 16.000
N 4.000
E 18.000
E 20.000
N 2.000
E 22.000

## ANNUAL BUDGET OF 6-HECTARE FARM UNIT*

| Item | Unit | Under Present Conditions | With Reclamation Project: Upon Completion | After 5 Years of Operation | After 10 Years of Operation | After 20 Years of Operation |
|---|---|---|---|---|---|---|
| **Farm Production and Cash Value** | | | | | | |
| Average rice yield | kg/ha | 1,500 | 1,700 | 2,400 | 3,000 | 3,700 |
| Farm production, rice (paddy) | kg | 6,000 | 6,800 | 9,600 | 12,000 | 14,800 |
| Part of rice production consumed (paddy) | kg | 1,200 | 1,500 | 1,500 | 1,500 | 1,500 |
| Part of rice production used for seed | kg | 180 | 230 | 230 | 230 | 230 |
| Total amount of rice used on farm | kg | 1,380 | 1,730 | 1,730 | 1,730 | 1,730 |
| Total amount of rice available for sale | kg | 4,620 | 5,070 | 7,870 | 10,270 | 13,070 |
| Amount available for sale (polished) | kg | 3,230 | 3,550 | 5,510 | 7,190 | 9,150 |
| Cash receipts from rice sales, at GF 45/kg | GF | 145,350 | 159,750 | 247,950 | 323,550 | 411,750 |
| Equivalent net income from other crops | GF | - | - | 5,100 | 17,600 | 79,952 |
| Value of rice used on farm, at GF 32/kg | GF | 44,160 | 55,360 | 55,360 | 55,360 | 55,360 |
| **Farm Investments** | GF | | | | | |
| Land development | | - | 44,500 | 44,500 | 44,500 | 44,500 |
| Dwelling (farm share) | | 50,000 | 50,000 | 87,500 | 87,500 | 87,500 |
| Other developments | | 15,000 | 20,000 | 25,000 | 30,250 | 35,500 |
| Equipment and supplies | | 15,600 | 15,600 | 19,700 | 25,250 | 32,000 |
| Livestock | | - | - | - | 22,500 | 45,000 |
| Miscellaneous | | 4,030 | 6,500 | 8,800 | 10,500 | 12,200 |
| Total Farm Investments | GF | 84,630 | 136,600 | 185,500 | 220,500 | 256,700 |
| **Current Farm Expenses** | GF | | | | | |
| Interest on investments | | 5,080 | 8,200 | 11,130 | 12,230 | 15,400 |
| Taxes | | 3,500 | 3,500 | 7,000 | 7,000 | 7,000 |
| Depreciation & repairs: buildings & improv. | | 7,120 | 7,665 | 12,320 | 12,895 | 13,500 |
| equipment | | 2,230 | 2,230 | 3,630 | 4,185 | 4,740 |
| Rice processing | | 17,460 | 19,710 | 28,110 | 35,310 | 43,710 |
| Hired labor | | 10,000 | 11,000 | 13,000 | 15,000 | 20,000 |
| Marketing (hauling) | | 8,075 | 8,875 | 13,775 | 17,975 | 22,875 |
| Fertilizers | | - | 5,025 | 10,050 | 13,150 | 19,000 |
| Equipment rental | | - | - | - | 15,300 | 18,000 |
| Crop seed | | - | - | 1,000 | 1,500 | 3,900 |
| Plant protection | | - | - | - | 2,500 | 6,500 |
| Livestock expenses | | - | - | - | 400 | 1,000 |
| Miscellaneous | | 2,675 | 3,310 | 5,000 | 6,920 | 8,780 |
| Total Current Farm Expenses | GF | 56,140 | 69,515 | 105,015 | 145,365 | 184,405 |
| **Financial Statement** | GF | | | | | |
| Cash sales | | 145,350 | 159,750 | 253,050 | 341,150 | 491,702 |
| Farm privileges: used on farm | | 38,400 | 48,000 | 53,100 | 59,125 | 64,577 |
| rental value of house | | 5,475 | 5,475 | 9,375 | 9,375 | 9,375 |
| Total income | | 189,225 | 213,225 | 315,525 | 409,650 | 565,654 |
| Total expenses | | 56,140 | 69,515 | 105,015 | 145,365 | 184,405 |
| Net income | | 133,085 | 143,710 | 210,510 | 264,285 | 381,249 |
| Return to family labor and management | | 133,085 | 138,000 | 148,000 | 158,000 | 170,004 |
| Repayment capacity | | | 5,710 | 62,510 | 106,285 | 211,245 |

* 4-hectare farm unit has been considered for conditions without the project.

## SUMMARY OF PROJECT BENEFITS

| Item | Unit | Under Present Conditions | With Reclamation Project: Upon Completion | After 5 Years of operation | After 10 Years of operation | After 20 Years of operation |
|---|---|---|---|---|---|---|
| Reclaimed area | ha | 970 | 3,320 | 3,710 | 3,710 | 3,710 |
| Equivalent number of farm units | | 243 | 553 | 618 | 618 | 618 |
| Net project income | GF 1000 | 32,340 | 79,472 | 133,095 | 163,328 | 235,612 |
| Increase in net income | GF 1000 | | 47,132 | 100,754 | 130,988 | 203,722 |
| Direct project benefits (rounded) | GF 1000 | | 47,000 | 98,000 | 131,000 | 203,500 |
| Indirect benefits | GF 1000 | | 10,000 | 19,500 | 26,500 | 34,000 |
| Public benefits | GF 1000 | | 7,500 | 10,000 | 11,500 | 15,000 |
| Total Annual Benefits | GF 1000 | | 64,500 | 127,500 | 169,000 | 252,500 |

| | | |
|---|---|---|
| Equivalent annual direct benefits | GF 1000 | 141,000 |
| Equivalent annual total benefits | GF 1000 | 182,000 |
| Average annual project cost (including O&M) | GF 1000 | 67,000 |
| **Benefit-cost ratios** | | |
| With direct benefits only | | 2.1:1 |
| With total benefits | | 2.7:1 |

# TABLE OF EQUIVALENTS

## Length

| | |
|---|---|
| 1 - Millimeter (mm) | 0.039 Inches |
| 1 - Centimeter (cm) | 0.394 Inches |
| 1 - Meter (m) | 3.281 Feet |
| 1 - Kilometer (km) | 0.621 Miles |

## Area

| | |
|---|---|
| 1 - Square meter ($m^2$) | 1.196 Square yards |
| 1 - Hectare (ha) | 10,000 Square meters |
| 1 - Hectare | 2.471 Acres |
| 1 - Square Kilometer ($km^2$) | 0.386 Square miles |

## Volume

| | |
|---|---|
| 1 - Cubic meter ($m^3$) | 35.31 Cubic feet |
| 1 - Cubic meter | 1.308 Cubic yards |
| 1 - Million cubic meters (MCM) | 810.7 Acre-feet |

## Weight

| | |
|---|---|
| 1 - Kilogram (kg) | 2.205 Pounds |
| 1 - Metric ton (mT) | 1,000 Kilograms |
| 1 - Metric ton | 2,205 Pounds |
| 1 - Metric ton | 1.102 Tons (short) |

## Flow

| | |
|---|---|
| 1 - Cubic meter/second ($m^3$/sec.) | 35.31 Cubic feet/second |
| 1 - Cubic meter/second | 70 Acre-feet/day |

## Agriculture

| | |
|---|---|
| 1 - Ton/hectare (paddy) | 20 Bushels per acre |
| 1 - Ton of paddy rice | 49 Bushels (paddy) |
| 1 - Bushel of rice (U.S.A.) | 45 Pounds of rice paddy |

## Currency

| | |
|---|---|
| 1 - Guinean Franc (GF) | 0.004 US Dollars |
| 1 - U.S. Dollar | 248 Guinean Francs |
| 1 - CFA Franc | 0.004 US Dollars |

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# THE KOBA PROJECT

## The Reclamation Works

### The Project Area

The Koba Project is located on the Atlantic coast of Guinea, within the Administrative Region of Boffa, about 30 kilometers to the southeast of Boffa and 50 kilometers north of Conakry. The relationship of the project to the country of Guinea is shown on Exhibit A, and details of the project area are indicated on Exhibit B.

The plains of Koba, of which the project area is a portion, are about 20 kilometers in length and vary in width from two to five kilometers. They are bounded on the northwest and on the southeast by tidal streams, and on the southwest by the Atlantic Ocean. They consist of relatively flat lands located 1.3 to 2.4 meters above mean sea level. Thick mangrove vegetation covers substantial areas in the northwest and southwest portions of the plains but the center portions, with minor exceptions, are relatively bare or covered with fresh water marsh vegetation.

Rice cultivation has been practiced in parts of the plains for many decades, and in the early 1950's the French Colonial Administration established the Koba Experiment Station for the purpose of carrying out research related to rice cultivation. The lands that were part of the station are presently under intensive cultivation.

The project area occupies an elongated area about twelve kilometers long and three kilometers wide, a small portion of which is presently under cultivation. A series of dunes oriented in a general

northwesterly direction separate the project area from the Atlantic Ocean. To the southeast, a tidal stream, the Marigot de Kabelea, forms the boundary of the southern portion of the project area. To the northwest, the project area is separated from the reclaimed lands that were part of the Koba Experiment Station by a dike, only partially completed. On its eastern side, the project area is bounded by a road originating at Taboria and passing through the villages of Tatema, Tanene, Kobarare, and Makinsi. At Makinsi, this road changes its general direction and joins the main road from Conakry to Boffa at a point about 40 kilometers from Boffa.

About 3900 hectares of fertile land are included within the project boundaries. In the early 1950's this area was studied by the French Colonial Administration for the purpose of increasing the rice production. From these studies it was concluded that inadequate drainage was the chief obstacle to the achievement of full potential use of the land.

In 1955, the consulting engineering firm COTHA[1/] performed engineering studies for the development of a plan of reclamation. These studies ended with the preparation of contract drawings and specifications. The COTHA plan consisted of peripheral dikes surrounding a total area of about 4200 hectares, of which 3450 hectares were cultivable. The dikes were designed to prevent flooding of the lands by tide waters. A main canal, about 10 kilometers in length, was proposed along the center of the plains to drain the area toward the Marigot de Kabelea. A gated control structure was to be located across the

---

1/ Presently SOGETHA

canal about 350 meters from the marigot (tidal stream). The estimated cost of this project was 271 million CFA francs. Contracts for this project were not awarded, as the French Administration left Guinea in 1958.

## The Modified Project Plan

The plan proposed in this report for reclamation of the Koba ricelands is an extension of the COTHA plan of reclamation, with some modifications. A more reliable knowledge of the area's hydrology is now available, and its agricultural potential has been re-evaluated in the light of the fields surveys recently conducted. These surveys and subsequent analyses have served to define the lands worth reclaiming and to permit designs of a complete flood control system. A general plan of the proposed reclamation project is presented on Exhibit B.

The proposed facilities will serve two main purposes:

(a) prevent flooding of the lands by salt water during high tides;

(b) prevent sustained flooding of the fields by fresh water from rainfall.

The area located within the proposed dike system will be somewhat larger than that originally proposed by COTHA. The dikes will be constructed to elevation 5.5 meters, thus allowing an adequate amount for foundation subsidence. The dike height will be sufficient to prevent the most extreme tides from inundating the lands. The alignment of the dikes will extend in a southwesterly direction, generally parallel to the coast line. They will close gaps in the southwesterly dunes near Kindiadi, Bambasorou, Kakira, and Bakoumpo.

Another dike beginning at the dune near Bakoumpo will follow generally the course of the Marigot de Kabelea in a northerly direction and tie into the dune at Dokiti. Gaps between Dokiti and Kabounti and in the dune southeast of Tombe also will be closed. These dikes will serve as a protection against tidal inundations. One dike is proposed to prevent the intrusion of fresh water from an adjoining drainage basin to the north. It will tie into a ridge about 1.5 kilometers east of Kabelea and will extend due east for about 700 meters, to tie into high ground.

The dike separating the project area from the Koba Experiment Station will require rehabilitation, consisting of earth fill placement and completion of the control structure.

The new dikes will be embankments made of rolled earth excavated from near-by borrow pits. They will have a top width of three meters, suitable for operation and maintenance traffic. Their side slopes will be 2.5 to 1.0, and their average height about 1.4 meters. A 4 meter right-of-way strip will be provided along all dikes for passage of heavy equipment for maintenance purposes.

Drainage of the project area will be provided by a main canal about 10.5 kilometers in length, extending along the center of the plains. A network of secondary tertiary and quaternary canals will convey the excess surface runoff to the main canal. The canals will be excavated by a suction dredge and draglines to their design sections. The main canal will have a bottom width varying from 12 meters at the upper end to 48 meters at the downstream end. A total of 56 kilometers of secondary and tertiary canals will be excavated, with bottom widths varying from 0.5 to 1.5 meters.

The Marigot de Kabelea, into which the main canal will discharge, is subject to tidal fluctuations. Salt water could back into the canal system during high tides in an uncontrolled manner, unless a barrier is provided. To control salt water intrusions from this source, a concrete structure is proposed on the main canal about 80 meters from the Marigot de Kabelea. This control structure will also permit the unobstructed discharge of water drained from the project area into the Kabelea toward the ocean during low tide levels.

Basically, this structure will differ from that proposed by COTHA. Several design modifications have been introduced for the sake of economy, such as the use of timber piles, the greater utilization of reinforced concrete and the adoption of precast concrete elements for wing walls. Because of practical problems of operation and maintenance, seven automatic flap gates will be installed with provision for manual operation. Each gate will be 2.5 meters wide and 4.0 meters high.

Access roads and bridges are an important adjunct to the project. At present, access to the plains by wheeled vehicles is not possible, except along the northern dike over part of its length. A simple network of operation and maintenance roads will be provided along the canals, dikes, and the existing dunes. They will be used by the local residents. Several population centers located on the southwesterly side of the project area, which are now almost inaccessible, will be easily reached. Five foot bridges will be provided across the main canal for use by the population. These bridges, of the suspension type, will have reinforced concrete towers and creosoted timber decks.

## Drainage Design

It is neither practical nor economical to protect agricultural land against maximum flooding from rainfall. In the case of the Koba Project, we believe that the optimum benefits to the use of the land will result with control of surplus waters from rainfall which might occur once in ten years.

In our investigations, we examined precipitation records in Guinea, and analyzed the meteorologic conditions in the Koba area. We have concluded that a total rainfall of 562 millimeters in seven days and 942 millimeters in 15 days is the minimum for which the project should be designed. This intensity would correspond to a recurrence interval somewhat smaller than ten years. However this is about 60 percent more than the 354 millimeters in seven days adopted by COTHA in the original design of the project. The difference results partly from the longer period of record available for the present studies, and also from a more detailed study of the rainfall records. The drainage system has been designed to cope with these intensities, taking into account groundwater percolation, evaporation, and field retention.

During rainfall less than the design intensity, the canal system can rapidly and effectively remove excess water. With full design intensity, some ponding of surplus waters would occur on the rice paddies. Our calculations indicate that this ponding would reach the top of the youngest rice plants, and would endure no longer than one day. Subsequently, the water levels in the fields could be lowered to about two-thirds of plant height and held at this level for several days before another severe rain might be expected. With these limitations on inundation the production of rice would not be adversely affected. However,

any significant reduction of the canal size would result in a period of submergence of at least seven days and water levels in the fields would return to an elevation not more than five centimeters below the top of the plants. Such ponding would result in considerable crop damage.

Adequate drainage and control of salt water intrusion can be achieved by the proposed works, sufficient to protect the fields against all but the most infrequent and severe conditions.

## Agricultural Production

The lands of the Koba plains are fertile and well suited to agriculture, rainfall is ample, and increased rice production is needed in Guinea. The Koba Project can convert the potentials of the area into positive contributions to the regional and national economy.

### The Soils and Land

The soils of the Koba plains are predominantly alluvial clay soils. In the southern part of the project area, subject to salt water intrusions, the soils are acid sulphate, or cat clays. In the remainder of the area, where fresh water flooding is predominant, these clayed soils have a lighter texture in surface. These soils have a moderate permeability.

In the project area, the soils were generally found to be acid. Their natural phosphorus content is above normal in the northern non-saline areas of the project area, and adequate in the saline areas.

The soils of the Koba plains will be well adapted to rice culture when fresh water flooding is prevented and when the intrusion of salt water is controlled.

Certain precautions are necessary when the project lands are drained. Lowering of the groundwater table could encourage excessive oxidation, an increase of free iron and aluminum content in the soil, and an acidity level which might be toxic to the crops. This condition was observed in the reclaimed lands located to the north of the project area. The control gates of the structure across the main drainage canal should be operated in a manner that will prevent the ground-water level from being lowered more than is necessary.

The lands of the area have been classified according to their suitability for agriculture, taking into account soil quality, topography, and present drainage. With the improvements of the proposed project, much of the land will be upgraded. A summary of the land classification within the reclaimable area of the project is given in Table 1.

TABLE 1

Summary of Land Classification

| Land Class | Quality | Total Area - Hectares Present | Total Area - Hectares Future |
|---|---|---|---|
| 1 | Very Good | - | 1650 |
| 2 | Good | 335 | 2250 |
| 3 | Fair | 685 | - |
| 4 | Presently unsuited | 2880 | - |
| | Total | 3900 | 3900 1/ |

1/ An allowance of about five percent for canals, dikes, maintenance roads and other unproductive areas reduces the cultivated area to 3710 hectares.

## Crop Yields

About 970 hectares within the project area are presently under rice cultivation. Average annual production is estimated to average about 1450 tons of rice paddy,[1/] or about 1.4 tons per hectare.

Substantial increases in rice yield should result from the reclamation program. Our estimates of the yields that can be expected from the various land classes are shown in Table 2.

TABLE 2

Anticipated Rice Yields

| Land Class | Annual Yield Tons per hectare |
|---|---|
| 1 | 4.0 |
| 2 | 2.0-3.5 |
| 3 | 1.0-2.5 |
| 4 | 0 |

We estimate that the conversion of land from one class to the next higher class and the achievement of higher yields will take place gradually over a period of 20 years, after the lands have been reclaimed.

## Cropping Pattern

The project area is predominantly suited for rice. However, continuous rice cropping would not be proper, and one-third of the land should be left fallow each year or devoted to some other crop. With

1/ 100 kilograms of unpolished rice, or rice paddy, yields about 70 kilograms of polished rice.

drainage of the lands and control of the salt water in the reclaimed area, it is possible that other crops could be introduced to the area over an extended period of time. Maize, grain sorghum, and lespedeza could be used for production of poultry. Some of the land of the Koba plains, after reclamation, would be expected to support other food crops during the time when the land is not used for rice. Such crops as beans, maize, and improved varieties of sweet potatoes would be well adapted to the better drained, less saline soils. These crops would add both quantity and variety to the food crops. Nutritionally, these crops would be beneficial.

A three-year rotation of rice on two-thirds of the reclaimed land is anticipated for the first five years of operation. Thereafter, other crops mentioned above could be advantageously introduced on the remaining one-third of the land. A cropping intensity of 100 percent should be feasible after 20 years of project operation. The projections of crop land use and cropping intensity are shown in Table 3. The intensities shown could be advanced, if sufficient technical and financial assistance were made available to the farmers.

TABLE 3

Projected Crop Land Use and Cropping Intensity

(In Percent of Reclaimed Land)

| | Number of Years After Reclamation | | | |
|---|---|---|---|---|
| | 1 | 5 | 10 | 20 |
| Rice | 67 | 67 | 67 | 67 |
| Lespedeza (clover) | - | 8 | 15 | 20 |
| Maize | - | - | 3 | 9 |
| Grain Sorghum | - | - | - | 4 |
| Cropping Intensity | 67 | 75 | 85 | 100 |

## Total Crop Production

The cropping patterns and anticipated yields have been combined for estimates of future agricultural production, as shown in Table 4.

TABLE 4

Estimated Annual Agricultural Production in the Koba Area

(Metric Tons)

| Crops | Number of Years After Reclamation | | | | |
|---|---|---|---|---|---|
| | Present | 1 | 5 | 10 | 20 |
| Rice (paddy) | 1,450 | 3,760 | 5,930 | 7,450 | 9,170 |
| Lespedeza | - | - | 3,100 | 5,600 | 7,420 |
| Maize | - | - | - | 190 | 770 |
| Grain Sorghum | - | - | - | - | 370 |
| Total | 1,450 | 3,760 | 9,040 | 13,240 | 17,730 |

# Project Costs

## Construction Costs

The construction costs of civil works and land preparation are based on the quantities of work derived from the preliminary project plans. Appropriate unit costs or lump sums have been applied to these quantities, using price levels of June 1963.

Costs have been segregated into foreign and domestic expenditures. The foreign component has been estimated in U. S. Dollars and the domestic component in Guinean Francs (GF), with an exchange rate of GF 248 equal to one U. S. Dollar.

The construction of the Koba Project will require the services of a foreign contractor. Although the project is of only moderate size, facilities available locally are not considered sufficient to have the project constructed either by a local contractor, or under force account by the Guinean government. We have assumed that the construction contract will be awarded, after public advertising and submittal of sealed competitive bids, to a private American or European contractor with the required experience, equipment, and working capital. Most of the construction equipment, and such materials as steel, timber, cement, and fuel will need to be imported. Skilled labor is also expected to come from abroad. Common labor, however, should be available locally. Local labor rates used in the estimates conform with wages now officially in force, and liberal fringe benefits customary in Guinea have been taken into account. The construction prices include allowances for contractor's plant, equipment, labor, home office and local overhead, profit, performance bond, insurance and taxes. Customs duties and taxes on imported equipment and materials have not been included.

A contingency allowance of 15 percent was added to the subtotal of direct costs obtained from the quantities and unit prices. This allowance is intended to cover possible unforeseen difficulties of construction, omissions from the estimates, and possible variations in unit prices. The contingencies provided should be adequate in view of the detailed field information now available and the conservative values used in the individual estimates.

The addition of the contingency allowance established the total direct cost. An allowance of 15 percent was then applied for such

indirect costs as engineering, supervision of construction, and owner's overhead. The addition of this allowance to the total direct cost gives the estimate of total construction cost. The total construction cost of the civil works is estimated to be U. S. $1,850,000 and GF 290,000,000, or a total equivalent to U. S. $3,010,000.

The cost of land preparation allows for a limited amount of leveling and planing required in the rice fields. These operations can be carried out by the local government with mechanized facilities, and with local common labor. The cost of land preparation is estimated to be GF 40 million and $50,000. The costs of excavating ditches and constructing levees in each paddy are not included in this amount.

## Project Investment

The project investment includes interest during the estimated construction period of three years, in addition to the construction costs of civil works and land preparation. Since financing terms are not yet established, net interest during construction can only be assumed. We have used for this purpose an annual interest rate of six percent, to be applied as funds are withdrawn for construction. A breakdown of the project investment is shown in Table 5.

TABLE 5

Koba Project Investment

| | Foreign Currency (U. S. $) | Domestic Currency (GF) |
|---|---|---|
| Civil Engineering Works | $1,850,000 | 290,000,000 |
| Land Preparation | 50,000 | 40,000,000 |
| Total Construction Cost | $1,900,000 | 330,000,000 |
| Interest during Construction | 230,000 | 40,000,000 |
| Project Investment | $2,130,000 | GF 370,000,000 |

Total equivalent to U. S. $3,610,000, or GF 900 million.

## Operating Costs

Annual operating costs will be incurred for normal operation and maintenance of the project, and for renewals and replacements beyond normal maintenance. Annual operating costs for the civil works are estimated to be about one percent of the total construction cost, or about GF 8 million.

Other annual costs will be incurred for the agricultural extension services to the farmers. These costs may be greater during the early years of project operation, but the long-term average should be about GF 2 million per year.

Total annual operating costs, not including interest and amortization of the initial investment, will be about GF 10 million.

## Average Annual Costs

Interest, amortization, and operating costs together represent the annual costs of the project. The total investment in the project has been estimated as the equivalent of GF 900 million. At six percent annual interest and 50-year amortization, the annual costs would be as shown on Table 6.

TABLE 6

Average Annual Costs

| | GF Million |
|---|---|
| Interest and Amortization | 57 |
| Operating Costs | 10 |
| Total Annual Costs | 67 |

## Project Benefits

The project will result in substantial direct agricultural benefits to the farmers due to increased crop production above the present level. Other indirect benefits will accrue to the regional and national economy.

### Direct Agricultural Benefits

The direct agricultural benefits are equal to the net increase in farm income due to the effects of the project. Thus the values of future production with the project must be reduced by the values that could be achieved without the project. Also, farm costs which are needed to obtain the increased production must be deducted.

For estimates of the direct benefits, we have analyzed the future budgets of typical four- and six-hectare farms, as shown on Exhibit C. In general, we have used the procedures of the U.S. Bureau of Reclamation. Some modifications were necessary due to the lack of agricultural statistics, and to the unusual conditions of a non-private land tenure system, a nomadic and shifting system of farming, and a government controlled price-wage structure.

Land tenure practices in Guinea do not recognize the right of private sale of agricultural land. Any land not being cultivated may be occupied and developed by new settlers. Also, improvements made during occupancy may not be sold or transferred. Thus, it is impossible to assign a value to land in an economic analysis.

Gross income to the individual farm units will include cash receipts from rice sales and the value of rice consumed on the farm. The price of rice is now set by the government at GF 45 per kilogram for

polished rice, and GF 32 per kilogram of paddy rice. Our budgets are based on these set prices without regard to free-market values or long-term variations.

Farm costs are related to capital investments and operating expenses. The investment to be made by the individual farmer starts with his land developments, which include the excavation of ditches to drain his own paddies, the small levees surrounding each paddy, and some minor leveling. In addition, the farmer must provide his own buildings, equipment and supplies, livestock, and other miscellaneous investments.

These improvements will take place over a period of years as the farmer increases his earnings. As at present, the farmers will be able to grow manioc, palms for oil, and other crops on the sand dunes. Some increase in these crops will result as more people are attracted to the reclaimed area. Although the value of agricultural production outside of the reclaimed areas is not included in the farm budgets, one-half of future on-farm investments has been allocated to use outside the project.

Operating expenses in the budgets include interest on farm investments, taxes, depreciation, and the annual costs of maintenance, supplies, and hired labor. These expenses will increase with time, as greater investments are made, more equipment and labor are employed, and the use of fertilizers and other agricultural aids are extended. Hired labor has been estimated at the present government-controlled rate of GF 28 per hour.

Net income to a typical farm unit is equal to the receipts from cash sales, plus the value of food consumed on the farm and the rental value of the farm home, less farm expenses.

Budgets were made, as shown on Exhibit C, for intervals following completion of the project. An additional budget was made to show what the net farm income would be if the project were not constructed.

The estimated income to the project in future years is shown in Table 7.

TABLE 7

Annual Income to Project

(in GF 1000)

| | Under Present Conditions | With Project | | | |
|---|---|---|---|---|---|
| | | Year 1 | Year 5 | Year 10 | Year 20 |
| Typical Farm Unit | 133.1 | 143.7 | 210.5 | 264.3 | 381.3 |
| Number of Units | (243) | (553) | (618) | (618) | (618) |
| Theoretical Income | 32,340 | 79,472 | 130,095 | 163,328 | 235,612 |
| Net Increase (rounded) | - | 47,000 | 98,000 | 131,000 | 203,500 |

Direct agricultural benefits from the project have been taken equal to the net income increase shown in Table 7.

## Other Benefits

Indirect benefits from the project will accrue to those persons, other than the farmer, who participate in the marketing of the cash crops. We have estimated the unit value of these benefits to be about equal to the difference between farm prices and retail prices of polished rice, or GF 4.5 per kilogram. The total value is proportional to the increased sale of rice due to the project.

Further public benefits will result to the regional and national economy, through the increased employment during construction and

operation of the project, and through the stimulation of other economic activities. Estimates of these public benefits are based on an employment value of the construction labor cost of GF 84 million, plus an annual economic value of five percent of direct benefits.

Benefits will also arise from the opportunity to settle more people in the region as more land is available for cultivation. These, however, are difficult to evaluate and have not been included in the analyses.

## Total Annual Benefits

The net benefits due to the Koba Project are summarized in Table 8.

TABLE 8

Net Annual Benefits

(GF 1000)

| Years after Completion | Direct | Indirect | Public | Total |
|---|---|---|---|---|
| 1 | 47,000 | 10,000 | 7,500 | 64,500 |
| 5 | 98,000 | 19,500 | 10,000 | 127,500 |
| 10 | 131,000 | 26,500 | 11,500 | 169,000 |
| 15 | 182,000 | 32,000 | 14,000 | 228,000 |
| 20 | 203,500 | 34,000 | 15,000 | 252,500 |

## Equivalent Annual Benefits

The values shown in Table 8 show that annual benefits will increase progressively in the future. However, the project investment will be made initially. Therefore, we have determined the present worth of the future benefits accruing to the Koba Project over its economic life of 50 years, as follows:

| | |
|---|---|
| Present worth of future direct benefits: | GF 2,229 million |
| Present worth of all future benefits: | GF 2,868 million |

The corresponding annual values of these benefits, amortized at six percent over 50 years, are:

| | |
|---|---|
| Equivalent annual direct benefits: | GF 141 million |
| Equivalent annual total benefits: | GF 182 million |

Contribution to the National Economy

The Koba Project will increase rice production by about 2,300 tons in the first year of operation, by 4,500 tons five years later, and ultimately by almost 8,000 tons. These increases will make significant contributions to the national economy of Guinea.

The present population of the Republic is estimated to be about three million and increasing by about three percent per annum. At this rate, which is expected to be maintained or possibly exceeded in the future, the total population will reach nearly six million in about 20 years.

Food production per capita in Guinea has been declining since 1958. Production of the major subsistence crops, cassava and rice, have not kept pace with the population increase. The annual production of cassava has been maintained around 350,000 tons, and the production of rice has averaged about 310,000 tons of paddy, equivalent to about 220,000 tons of polished rice.

In the past, the country has generally been self-sufficient in most subsistence crops, except rice. The rice shortages stem from the fact that, in addition to the population increase, the average per capita

consumption of rice has been increasing consistently. It went from about 170 grams of polished rice per day in 1948, to 220 grams per day in 1953, and to 230 grams per day in 1962.

Guinea is the largest rice producer in Africa after Egypt and Madagascar. However, because of the increase in population and in per capita consumption, increasing amounts of rice have had to be imported since 1958, as shown in Table 9.

TABLE 9

Rice Imports

| | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 |
|---|---|---|---|---|---|---|
| Metric tons (polished rice) | 7,000 | 25,000 | 20,000 | 25,000 | 30,000* | 35,000* |
| Cost, equiv. U.S. $ million | 1.0 | 2.2 | 1.7 | 2.1 | (Not available) | |

* Estimated on the basis of present trade agreements.

The projected increase of rice production after full development of the Koba Project will be about 20 percent of the present rice imports. Thus, the project will make a significant contribution to reduction of imports and saving of foreign exchange.

The production of rice at the Koba Project should be dependable, as great fluctuations in rainfall are not common in the area. This is not true in many other areas of Guinea, particularly in the highlands. During the extreme dry year of 1962, national production of rice paddy dropped to only 220,000 tons, or 30 percent below average.

## Economic and Financial Analyses

### Benefit-Cost Ratios

The economic value of the project can best be measured by a comparison of its annual benefits and annual costs. The ratios shown in Table 10 have been derived from benefits and costs previously described.

TABLE 10

Project Benefit-Cost Ratios

(amounts in GF million)

| | Direct Benefits Only | | All Benefits | |
|---|---|---|---|---|
| Equivalent annual benefits | | 141 | | 182 |
| Average annual cost of proposed investment | 57 | | 57 | |
| Average annual cost of O & M | 10 | | 10 | |
| Total average annual costs | | 67 | | 67 |
| Project Benefit-Cost ratios | 2.1 to 1.0 | | 2.7 to 1.0 | |

The ratios given in Table 10 indicate that the incremental investment costs for construction of the proposed facilities will be well justified by the benefits which are anticipated from operation of the project. However, it must be emphasized that the benefits indicated can be achieved only if the proposed reclamation works are accompanied by a modest program of land management and agricultural assistance. Such a program can be simple enough to be easily accepted and put in practice by the local farmers, with the guidance of trained personnel of the regional administration.

## Financial Requirements

The construction costs of the Koba Project amount to U.S. $1,900,000 in foreign expenditures and GF 330 million in domestic expenditures. Neither the local communities nor the Regional Administration could obtain such funds.

The national government could finance the project from appropriations. However, this is only one of several reclamation works being considered, all of which together would reclaim about 40,000 hectares. Collectively, these projects could not be financed out of current income without very adverse effects upon an already serious deficit in the nation's balance of payments. It is probable, therefore, that loans will be sought from sources outside Guinea.

The source and terms of such financing are not now known. For the purpose of our analysis, we have assumed that liberal terms can be obtained, such as are currently offered for this type of project by the International Development Agency (IDA) and by the United States' Agency for International Development (AID). These institutions have been making agricultural development loans to national governments with a 0.75 percent annual service or interest rate and repayable over 40 years following a 10-year initial moratorium period.

With such terms, and including interest during construction, investments of U.S. $1,930,000 and GF 335,000,000 have been used in our financial analyses.

## Effect on Foreign Exchange

Loans received to finance foreign expenditures would probably require repayment in foreign currency. Under the terms cited above,

annual repayments and interest after ten years would be about U.S.$95,000. At the same time the increased rice production alone would reach about 4500 tons per year, reducing annual imports by a value of more than U.S. $450,000. Even at far less favorable terms, a positive saving in foreign exchange would result.

Financial Feasibility

In the case of the Koba Project, the financial obligations to be incurred will probably be made by the national government with international lending institutions. Part of these obligations may require repayment in foreign currency, which only the national government could guarantee. Any assessments against the farmers of the project will be set by the sponsoring government agency, and will be payable in domestic currency.

Although the credit of the national government is ultimate assurance of financial repayment, the economy of the project gives a measure of financial feasibility. The best measure is the relationship between the residual income of the project beneficiaries and the total annual costs of the project.

The farm budgets, shown on Exhibit C, have included an allowance for the return to family labor and management in the computation of residual income available for profit and repayment. The total residual income to the project is equal to that of a typical six-hectare unit times 553 such units until the fifth year, and 618 thereafter.

The annual costs used previously in the benefit-cost analysis were long-term averages based on a six percent return on capital. For a financial analysis, the anticipated year-by-year expenditures should be

used, including specific values for interest and amortization, and considering moratorium periods. In the case of the Koba Project, our financial evaluation is based on the liberal terms of agricultural loans. However, we have recognized that expenditures for agricultural extension services should be greater in the early years.

The computed values of residual income and annual costs are given in Table 11.

TABLE 11

Financial Analysis

(Amounts in GF Million)

| Years After Completion | Residual Income Available for Profit and Repayment | Annual Costs | | | |
|---|---|---|---|---|---|
| | | Interest and Amortization | Operating Costs | Extension Services | Total |
| 1 | 3 | 6 | 8 | 5 | 19 |
| 2 | 10 | 6 | 8 | 5 | 19 |
| 3 | 20 | 6 | 8 | 5 | 19 |
| 4 | 30 | 6 | 8 | 2 | 16 |
| 5 | 39 | 6 | 8 | 2 | 16 |
| 6 | 45 | 6 | 8 | 2 | 16 |
| 7 | 51 | 6 | 8 | 2 | 16 |
| 8 | 57 | 6 | 8 | 2 | 16 |
| 9 | 61 | 6 | 8 | 2 | 16 |
| 10 | 66 | 24 | 8 | 2 | 34 |
| 15 | 105 | 24 | 8 | 2 | 34 |
| 20 | 131 | 24 | 8 | 2 | 34 |

Only during the first three years of project operation will residual income of the farmers be less than the total annual costs of the project. From then afterward, income becomes substantially greater than project

costs. The comparison indicates that the project has financial merit, even if the interest and amortization terms were less liberal than has been assumed.

## Project Repayment

Agricultural and reclamation developments such as the Koba Project must yield sufficient financial return to the beneficiaries as an incentive for private investment and for increased production. Thus, it is not always advisable that the entire cost of the common works be borne by the farmer, even if residual income should indicate such a possibility.

The extent to which the farmers are required to repay project costs is a matter of national policy. For example, in the United States water rates are frequently set a 15 to 25 percent of the computed repayment ability. The term "repayment ability" is usually taken to mean the net income to the farmer less an adequate return for his family's labor and management effort, or what we have herein defined as residual income.

Repayment requirements which are less than project costs amount to a national subsidy. Justification for such subsidy is usually based upon the indirect and public benefits which result from the project.

It will be important, particularly in the early years of operation, that farmers be given the incentive and opportunity to make the best possible use of the reclaimed land. This is particularly true in the case of the Koba area. Constructive participation of the cultivators toward the realization of the potential production will be contingent upon the economic advantages which they will derive therefrom. Assessments which are

initially too great will discourage the farmers or siphon off the capital needed for on-farm improvements. Yet, little or no assessment in future years will encourage indolence on the part of those settlers who are satisfied with only a subsistence living.

A flexible policy on repayment is indicated, beginning at a minimum level and increasing as the productivity of the area reaches its true potential.

## Implementation of the Project

The Koba Project can be economically valuable and is financially feasible. However, its success will depend upon prudent arrangements for financing, engineering, construction, administration, fiscal control and operation, and upon an adequate agricultural extension program.

### Financing Arrangements

A construction start of the Koba Project should only be made if the full financial needs of the project are firmly committed in advance, including both foreign and domestic currency.

To insure that funds will be adequate, loan authorizations should include a supplemental financing contingency to allow for possible cost increases during any delayed negotiations and during the subsequent construction period. This financing contingency should be about five percent of foreign currency requirements and 15 percent of local currency requirements. Loan applications should be made for U.S. $2,000,000 and GF 380 million, not including interest during construction. The terms of the loan should be as liberal as possible with the first payment on principal deferred for several years to allow an initial development period.

## Engineering

Planning and engineering studies were made by COTHA in 1955. Specifications and detailed construction drawings prepared by COTHA in 1957 were to form the basis for a proposed contract award at that time. While they can be advantageously used for preparation of the proposed construction work, they must be modified to reflect changes in the project plan, and new contract documents should be established.

The changes in economic conditions that have taken place since 1957 and the new administrative and legal conditions in force in Guinea will require different contract specifications. International financing will require a strict accounting of expenditures and a rigid supervision of construction. Changes in the size of the required structures that resulted from the recent hydrometeorological studies will require important modifications to the COTHA designs.

A competent and independent consulting engineering firm should be retained for the preparation of new contract documents and modified construction drawings. Such a firm should be free of any association with contractors, manufacturers, or other adverse interests, to allow unbiased professional direction of the work.

## Construction

Construction of the project should be carried out under one general contract. Any division of the work into separate contracts would lessen the interest of the larger and more competent firms, reduce competition, and add to administrative costs. Only pre-qualified contractors, with proven experience and adequate resources, should be allowed to bid. Contracts should be let at fixed unit prices with adequate guarantees of performance bond and insurance.

Preparation of the project lands for agricultural use should proceed concurrently with the construction of the civil works. This work can be carried out under force account by the Center of Rural Mechanization (C.M.R.), an agency of the Service of Production of the Administrative Region of Boffa, or any other governmental agency to which suitable mechanized equipment and operators are available.

Proper coordination between the land preparation and the contractor's operation will allow a partial rice crop to be harvested at the end of the first construction year.

## Administration

As soon as the project is authorized, an organization should be established for the administration of construction and of subsequent operation. This organization should be a regional agency, with budgetary support from the national government. It should have a reasonable degree of autonomy and be held responsible for the success of the project. This agency should exercise fiscal and operational control of the project, be able to employ expert assistance when needed, and have call upon the agricultural supporting facilities of other agencies.

The administrative agency should have a fiscal department to control construction funds released by the national government and the lending agencies for the project, and later to control assessments on the farmers and payments for operation. A department closely associated to the project is needed to insure that proper certification is made for disbursements, that assessments are made in accordance with project obligations, and that collections due are in fact received.

An operations and maintenance department will be needed to control outlet gates, keep canals free of obstructions, and maintain the dikes.

## Agricultural Extension Program

It is of utmost importance for the success of the proposed project that all of the reclaimed lands be brought to cultivation as early as possible and that farming practices be improved.

We recommend that an experienced rice agronomist be employed full time in the project area for a period of several years from the beginning of the construction phase. Because of the present shortage of trained Guinean technicians, this agronomist may have to be an expatriate. He should direct the agricultural program, and guide and advise the farmers on methods of increasing production.

The agronomist could also direct the program of land levelling and farm preparation.

Under the direction of the agronomist, pilot demonstration plots should be formed in the project area for experimentation with rice varieties and fertilizers. The results of these research programs should be disseminated in an easily understood manner among the farmers. Practical demonstrations of improved cultural practices, particularly through mechanization, should be given to the farmers. Also, the agronomist should perform routine physical and chemical tests on the project soils.

If the agronomist engaged for the project is an expatriate, he should be assigned a Guinean assistant who should be a young agronomist with college training.

A reactivation of the Koba Rice Experiment Station would benefit the project to a consderable extent.

# PART II

## SUPPORTING INFORMATION


| | | |
|---|---|---|
| Chapter | I | Geography of the Project Area |
| | II | History of the Koba Project |
| | III | Field Investigations |
| | IV | Project Lands |
| | V | Agriculture |
| | VI | Project Design |
| | VII | Project Construction |
| | VIII | Project Economics |
| | IX | Project Operation and Development |

## Chapter I

# GEOGRAPHY OF THE PROJECT AREA

### General Description

The Republic of Guinea is located on the Atlantic coast of the "Bulge of Africa" 700 kilometers southeast of Dakar (Republic of Senegal) as shown on Exhibit A. It extends from latitude 9° to 12.5° N and from longitude 17° to 10° W. The country is bounded by Portuguese Guinea on the northwest, the Atlantic Ocean on the west, Sierra Leone on the southwest, Liberia on the south, the Republic of Ivory Coast on the southeast, and the Republics of Senegal and the Mali on the north. The country has an area of about 250,000 square kilometers.

Guinea is divided into four regions. The coastal area (Lower Guinea) forms a band along the Atlantic which averages 40 kilometers in width. This area is characterized by heavy rainfall from May to September. There is little variation in temperature throughout the year -- the average maximum temperature is 85°F and the average minimum 75°F. The second region, occupying over half the total area, is the Fouta Djallon, a plateau averaging about 300 meters above sea level but rising in places to over 1000 meters. This area has less rainfall and lower temperatures than does the coastal region. Upper Guinea, the third region, is a low land to the north and east of the Fouta Djallon, where the Sahara belt is approached. The rainfall is relatively light and the temperatures are much higher than on the coast. Finally, there is the forest region, immediately north of Liberia. This is an area of typical West African tropical rain forest with high temperatures. The rainfall, while heavy, is somewhat less than on the coast.

The plains of Koba are located about 50 kilometers north of Conakry, Guinea's capital city, and 30 kilometers to the southwest of Boffa, which is the seat of the Administrative Region of Boffa. Their general location is shown on Exhibit A. The plains follow the Atlantic coast from the Marigot de Kabelea (tidal stream) on the south to the Taboria River on the north. They extend over a length of approximately 20 kilometers and an average width of three kilometers. The Koba Project occupies the southern 12 kilometers of these plains.

Like a large part of the Guinean coastal zone, the plains of Koba are fertile, with a great potential for rice production. Climatologic, physiographic and hydrologic factors play an important role in the successful exploitation of ricelands. This chapter presents the conditions that prevail in the Koba area which are typical of those in Lower Guinea, as well as conditions that are peculiar to the Koba area.

## Climatology

### General

The climate of Lower Guinea is monsoonal, characterized by a dry season followed by a very wet one. Representative climatological data are presented on Exhibit 1.

The dry season extends from December through April. It is hot, with high relative humidity, but is somewhat tempered by cool marine winds. There is generally no precipitation in the Koba area during the December-April period. Vegetative growth may cease for several months because of the complete lack of precipitation.

The wet season extends from May through November. The monsoon is at a maximum in July and August, with a high persistence. Precipitation during the wet season is in the form of violent and continuous rains. Relative humidity is very high during the wet season. Total precipitation for the May-November period averages slightly over 4000 millimeters in the Koba area.

## Air Masses

The fundamental cause of the climate of Lower Guinea is the seasonal migration of two air masses, the Tropical Continental and the Tropical Maritime. Some role is also played by the Inter-tropical Front.

The Tropical Continental Air, warm and dusty, extends from the Sahara southward, reaching its maximum extent in January between about 5 and 7° N. Associated with it are dry north-easterly or easterly winds. The mass of Tropical Maritime Air, warm and humid, trends from the ocean inland in July or August to about 17° N on the coast and to about 21° N in the interior. Associated with it are wet south-westerly or westerly winds.

These two masses alternate seasonally over Lower Guinea. Owing to different densities of the two air masses, the front slopes upward toward the south, so that the maritime air forms a wedge under the continental air. This wedge penetrates northward as the maritime mass become predominant in and after May, and brings the heavy monsoonal precipitations. It retreats southward in August or September.

Between these two main air masses is the Inter-tropical Front, which lies north of the Equator throughout the year. With the penetration

inland of the maritime air mass, the Front pushes north-westward. It returns south-eastward upon the retreat of the maritime tropical air.

## Prevailing Winds

Line Squalls. At the change of season in May, with the north-westward advance of the Inter-tropical Front, the dominant winds may change suddently. This is accompanied with thunderstorms or "line squalls," often misnamed tornadoes. These north-easterly storms are the partial cause of almost all rain received on the Guinea coast between May and July, and again from September to October.

"Line squalls" are preceded by a day or two of high temperatures and oppressively still air. Finally, the sky darkens, there is vivid lightning and the noise of rushing wind. Winds become south-westerly and temperatures drop by 10 to 20°F (5 to 10°C). Heavy rain, up to 50 millimeters in less than an hour, follows the wind and dust. This rain then gives way to a gentler rain without lightning. When the rain ceases, the clouds disappear and temperatures rise again.

South-westerlies. Associated with the moist maritime air mass are south-westerly winds. They prevail all the year south of Guinea, and penetrate up the coast in July. During the prevalence of these winds, continuous rains may occur for long periods. Skies are frequently cloudy, and early morning mist is common. Visibility is good, except during actual rainfall.

Sea Breeze. The sea breeze in Lower Guinea may reverse the normal winds. In January, for example, a westerly wind frequently replaces the North-east Trades during the afternoon. They may also reinforce the south-westerly winds during the monsoon period.

## Precipitation

In Lower Guinea substantial precipitation generally starts in the beginning or the middle of May and ends in the first half of November. The number of rainy days as well as the amount of rain varies considerably from year to year and from north to south.

The average number of rainy days in the year varies from 100 to 150, and the average annual precipitation varies from about 2850 to 4300 millimeters depending upon the location. The highest annual precipitation in Lower Guinea generally occurs around Conakry.

Average Rainfall in the Project Area. A rain gage station was located at the Koba Agricultural Experiment Station which is adjacent to the project area, and at an elevation about 15 meters higher than the plains. This station maintained rainfall records during the period 1953 through 1961. Three other rain gage stations are located within 40 kilometers of the project, at the Conakry airport (Conakry-Aviation), Boffa, and Dubreka.[1/] The Conakry station was installed in 1949; the Dubreka and Boffa stations were installed in 1950. All three have been in service from the time of installation to date. In addition, a rain gage station was in service during the rainy season of 1955 at Bakoumpo, a village located in the southern part of the Koba plains. This station was installed to obtain basic data in connection with the COTHA studies.

Average monthly precipitation for the periods of record at Koba, Boffa, Dubreka, and Conakry-Aviation is given in Table I-1. Precipitation outside of the May-November period is small and is not indicated in this and the following tables.

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1/ Another station is located at Conakry (city). This station has not been used because of its proximity to the ocean. The data recorded at Conakry-Aviation are more indicative of conditions prevailing on the coast of Lower Guirea.

Table I-1 - Average Monthly Rainfall

(in millimeters)

| Month | Koba (1953-1961) | Conakry-Aviation (1949-1963) | Dubreka (1950-1962) | Boffa (1950-1955 1956-1962) |
|---|---|---|---|---|
| May | 93 | 148 | 144 | 89 |
| June | 422 | 487 | 493 | 341 |
| July | 1403 | 1297 | 1040 | 900 |
| August | 1105 | 1264 | 1250 | 1070 |
| September | 631 | 758 | 756 | 620 |
| October | 295 | 306 | 378 | 259 |
| November | 97 | 127 | 132 | 78 |
| Average for the wet season | 4046 | 4387 | 4393 | 3357 |

The precipitation recorded at Bakoumpo during the wet season of 1955 is shown in Table I-2. Also shown are the corresponding values as recorded at the other four stations. Comparative data are also indicated for the month of August, which is generally the wettest month.

Table I-2 - Comparison of Rainfall Recorded at Bakoumpo in 1955 with that Recorded at Other Stations

(in millimeters)

| Record Period | Bakoumpo | Koba | Boffa | Dubreka | Conakry-Aviation |
|---|---|---|---|---|---|
| Total for the wet season of 1955 | 3461 | 3742 | 3104 | 3916 | 4570 |
| Wet season average for the periods of record | | 4046 | 3357 | 4393 | 4387 |
| August, 1955 | 1009 | 986 | 1046 | 921 | 1256 |
| Average August precipitation for the periods of record | | 1105 | 1070 | 1250 | 1264 |

Chapter IV

# PROJECT LANDS

## Introduction

A reconnaissance survey of the arable lands located to the southwest of the Koba Station was made to determine to what extent these lands are suitable for the cultivation of rice. Approximately 4000 hectares were covered in the course of this survey. The area investigated was found to include lands with varying degrees of adaptability to rice production. A map of present land use is presented on Exhibit 2. These lands were classified with respect to their agricultural potential on the basis of topography, natural drainage, salt water flooding and soil properties.

The results of soil analyses and permeability tests made by the team of the Harza Engineering Company are given in Chapter III. This chapter presents details with respect to soils, land use, land evaluation, and land management problems.

## Soils Evaluation

### Soils Classification

The soils of the Koba plains are mainly heavy alluvial clay soils. Dunes containing lighter textured soils cross the plains longitudinally, forming the eastern and western boundaries of the project area.

The 1953 pedology report[1/] of the Koba Experimental Station grouped the soils according to the elevation of the ground water table

1/ See Reference 2, page II-8.

and its degree of salinity, and the texture and organic matter content of the soil profile. The 1954 pedologic map[1/] was based on the texture and organic matter content of the soils, and the relative degree of drainage or salt water intrusion.

For the purpose of evaluation, the soils of the project area have been classified into two main groups: saline alluvial soils, and non-saline alluvial soils.

Saline Alluvial Soils. These soils are located in the areas subject to surface and sub-surface salt water intrusions. The frequency of these intrusions has determined the various stages of the profile development. Undeveloped saline soils (poto-poto) are found in areas subject to frequent flooding by high tides, in the areas that are permanently submerged by salt water, or in the areas with mangrove vegetation. In the marine flood plain, these soils exhibit some of the characteristics of acid sulphate soils, or cat clays. The more developed soils are found in areas less subject to salt water intrusions. Their profiles exhibit a characteristic color from ochre brown to yellow or red resulting from the oxidation of iron.

Non-Saline Alluvial Soils. These soils occupy the areas submerged by fresh-water flooding, or those under the influence of a non-saline water table. The soil types in this group are organic silty clays, organic clays, sandy clays and clays. The lighter textured surface soils are located mainly along the edge of the dunes. The submerged soils generally have a higher content of organic matter.

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1/ See Note 1, page III-10.

## Soil Properties

Physical and chemical properties were derived from laboratory analyses performed on soil samples obtained from auger holes. The locations of the auger holes are shown on Exhibit 2.

Soil profiles were established on the basis of texture and other properties. Some of these properties are shown with the soil profiles on Exhibit 3. They include the soils texture, pH, conductivity of the saturated extract, presence of carbonates and the position of the water table at the date of sampling. The results of detailed laboratory analyses performed on selected, representative soil samples are presented in tabular form on Exhibit 4.

Composition and Physical Properties. The surface soils of the area are mainly heavy clays. A typical sample of these soils was taken from hole No. 6 at 0 to 15 centimeters depth. This sample contains approximately 80 percent clay, 19 percent silt, and 1 percent sand. The cation exchange capacity of these soils varied from 15.6 to 40.0 milliequivalents per 100 grams. These low base exchange capacities indicate that the clays are probably illite or kaolinite, with a small proportion of montmorillonite. Medium base exchange capacities indicate an increase in the proportion of montmorillonite clays present.

The clay soils have a well developed horizon differentiation with respect to color, texture, and organic matter, but are without structure or have a weak structure, depending on their stage of development. The more developed soils are granular to nutty and very friable, or sometimes blocky to slightly prismatic.

The depth of developed soil is variable. In the wet areas, the developed profile is from 30 to 60 centimeters deep, and in some of the better drained areas it extends to a depth of 90 centimeters.

The subsurface soils have a slightly higher clay content than the surface soils. These heavy textured soils are considered to be slowly permeable and therefore suited for rice culture. Some decayed root spaces exist in the soil profile. Their presence will tend to increase the rate at which water will move through the profile, until the spaces are finally closed by natural settlement.

Chemical Properties. Many of the characteristics and properties of the soil can be ascribed to the constitution of the soil mass. Some of their properties are low to medium exchange capacity and absence of a well developed blocky or prismatic structure. The high percentage of organic matter may have been responsible for some of the higher base exchange capacities obtained.

The soils of the Koba project area are very acid in reaction. The pH of the saturated soil paste of representative soil samples for land presently under continuous cultivation varied from 5.5 to 5.9. The pH of soils in recently reclaimed areas varied from 4.2 to 4.8. Since the soil samples were taken from the cultivated areas at the end of the rainy season, the pH obtained is considered representative of the general conditions in which the plants will grow.

The chemical composition of the soil partly reflects the acid conditions. The soil profiles with the lower pH's were generally found to contain a small quantity of $CaCO_3$ in contrast to the high percentage of free iron and aluminum. The content of iron in the soil profile is generally higher in the subsoil, indicating that some leaching of soluble iron may have taken place during the rainy season.

The chemical analyses of the representative samples show that the saline alluvial soils have higher contents of sodium, potassium,

magnesium, sulfates and chlorides than the non-saline alluvial soils. In most cases, the non-saline alluvial soils were found to contain higher levels of phosphate, free iron, and extractable aluminum. There is a possibility that the so-called magnesium clays could be formed if there were no accumulation of sulphides or $CaCO_3$ These magnesium clays have the same poor characteristics as the sodium clays: they have a very unstable and very unfavorable structure.

Salinity. The salt contained in the alluvial soils is generally associated with the marine origin of the sediments. It may also be caused by salt water intrusions and subsequent evaporation of water from the ground surface. These salt deposits have remained in the soil because of lack of effective drainage. The degree of salinity is based on the measurement of the conductivity of the saturation extract.

The ponding of water in the low areas has had an ameliorating effect on the degree of soil salinity. The soils subjected to fresh water ponding or intermittent fresh water flooding were found to be generally non-saline to slightly saline. These soils are found in the area to the southwest of the Koba Station, between the dike and the line from Kalema to Bambasourou. From this line to the Marigot of Kabelea, the degree of salinity varies from slight to moderate in the topsoil, and to strong in the subsoil. During the dry season, the salts that are accumulated in the subsoil move up to the ground surface by capillary action, thereby increasing the degree of salinity of the topsoil. Heavy rains are needed to leach these salts prior to transplanting rice, in order to create proper conditions for seed germination.

Although rice exhibits a natural tolerance to moderate contents of salt, particularly when transplanting is practiced, salinity conditions

presently prevailing in about 35 percent of the project area may limit the potential yields.

Fertility. The degree of fertility of the soils in the project area is indicated by the content of organic matter in the top layers, the content of available phosphorus, and the content of exchangeable potassium.

The content of organic matter in the top six to eight centimeters of the soil profiles ranges from 1.6 percent in a cultivated area to 14.4 percent in a non-cultivated area. The organic matter content for either profile decreases in depth. Low organic content of the soil is a result of continuous cropping without replenishment by plant residues or green manure, which is a major factor for existing low crop yields.

The available phosphorus content of the topsoil within the project area, expressed as $P_2O_5$, varies from 14 to 144 kilograms per hectare. A favorable response to phosphate fertilizers is probable for the lands located in the vicinity of soil profiles 4, 16, and 20. A response to phosphate fertilizers for lands around soil profiles 2, 6, and 27 is unlikely. Since phosphate fixation in tropical soils is large, because of the formation of insoluble compounds of iron and aluminum, the addition of phosphate fertilizers as early as practicable will be helpful if the expected yields are to be achieved.

The tests for exchangeable potassium show contents in the topsoil ranging from 0.12 to 1.22 milliequivalents per 100 grams. These amounts will be adequate to obtain the yields that are expected during the first few years of cultivation. In highly acid soils, potassium is quite soluble and may be rapidly leached. Therefore, the addition of potash fertilizers may be necessary to replace the potassium lost by leaching.

Table I-2 indicates that 1955 was a dry year at Koba, Boffa, and Dubreka. The heavier-than-normal rains at Conakry may be attributed to its peculiar geographic location. The 1955 precipitation recorded at Bakoumpo was lower than that at Koba and higher than at Boffa. The precipitation recorded in August at Bakoumpo was in the same range of magnitude as the long term averages at Koba and Boffa.

Extreme Precipitation. In the relatively short period of record annual precipitation near the project area has varied from year to year by not more than about 15 percent above or below the yearly average. At Koba, where the average annual precipitation is about 4100 millimeters, the driest year on record was 1957, when about 3600 millimeters of rainfall were recorded. The wettest year was 1954, with a total precipitation of about 4600 millimeters. The monthly precipitation for these years is shown on Exhibit 1.

Monthly precipitation is more variable, as is evidenced by the data summarized in Table I-3.

Table I-3 - Range in Monthly Precipitation at Koba

| Month | Driest on Record | Average | Wettest on Record |
|---|---|---|---|
| May | 2 | 93 | 209 |
| June | 169 | 422 | 874 |
| July | 1007 | 1403 | 2096 |
| August | 614 | 1105 | 1584 |
| September | 272 | 631 | 904 |
| October | 171 | 295 | 493 |
| November | 48 | 97 | 163 |

## Atmospheric Humidity

Atmospheric humidity in Lower Guinea does not vary much from year to year. However, its monthly variations are great, and so are

its diurnal variations. The minimum and maximum monthly humidity at Bakoumpo determined from observations made in 1955, are presented in Table I-4.

Table I-4 - Average Minimum and Maximum Monthly Humidity at Bakoumpo, in percent

| Month | Minimum | Maximum |
|---|---|---|
| June | 72 | 96 |
| July | 75 | 97 |
| August | 78 | 98 |
| September | 73 | 98 |
| October | 67 | 97 |
| November | 64 | 97 |
| December | 58 | 97 |

The diurnal variations of the relative humidity follow, in reverse, those of the temperature. The humidity is highest at night and lowest during the day. A graph showing typical variations of the relative humidity recorded at Boke in 1962 at 6:00 a.m., 12:00 noon, and 6:00 p.m. has been presented in an earlier report [1/] These variations are representative of conditions at Koba and in Lower Guinea in general.

The shapes of the curves reflect the movements of the maritime and continental air masses.

## Temperature

Only limited temperature data are available for Koba, but conditions are similar to those at Conakry-Aviation. The average minimum

1/ "Feasibility Report on Riceland Reclamation in Guinea-Monchon Project," by Harza Engineering Company, October 1963.

and maximum monthly temperature at Conakry-Aviation for the period 1949 through 1963, as compared to 1955 temperatures at Koba, are presented in Table I-5.

Table I-5 - Average Minimum and Maximum Monthly Temperature at Conakry-Aviation and Koba, in °C

| Month | Minimum Temperature | | Maximum Temperature | |
|---|---|---|---|---|
| | Long Term Conakry | 1955 Koba | Long Term Conakry | 1955 Koba |
| January | 22 | 20 | 31 | 31 |
| February | 22 | 19 | 31 | 31 |
| March | 23 | 21 | 32 | 31 |
| April | 23 | 21 | 32 | 32 |
| May | 23 | 22 | 31 | 32 |
| June | 23 | 22 | 29 | 30 |
| July | 22 | 22 | 28 | 29 |
| August | 22 | 22 | 27 | 28 |
| September | 22 | 22 | 29 | 30 |
| October | 22 | 22 | 30 | 31 |
| November | 23 | 21 | 30 | 31 |
| December | 22 | 20 | 31 | 31 |

Table I-6 indicates that Koba temperatures during 1955 closely approximated long term average temperatures at Conakry. The maximum and minimum temperatures recorded at Conakry during any day generally do not depart from the corresponding monthly values by more or less than three degrees centigrade.

## Physiography

### The Coastal Belt

The coastal belt of Lower Guinea is a continental shalf that was submerged by the ocean in recent geologic times. In earlier eras it

was crossed by important rivers flowing to the ocean in well-defined valleys. Structural upsets of the Fouta Djallon then displaced and faulted the old summit line. New tectonic breaks, generally oriented along two perpendicular directions, deeply modified the relief. Later, the level of the ocean rose, flooding the old alluvial valleys which became the estuaries of rivers whose watersheds were made smaller by the surface twisting of the Fouta Djallon. Thus were formed the broken coast line and numerous islands that are now present along the coast.

There is no smooth coast, because the continental shelf is comparatively wide, the tidal range is relatively high, tidal scour is strong, and because the coast is oriented directly across the path of south-west or north-west winds that agitate the waters.

The relief of the coastal plain is cut deeply inland by the old estuaries. During the dry season, when surface runoff in the coast belt is practically non-existent, the submerged valleys become tidal inlets bordered by saline, muddy lands. The coast line and the coastal plain of Lower Guinea are broken at two points by rock spurs, at Cape Verga and behind Conakry. The former consists of micaceous schists and quartzite, and the latter of granite and ultra-basic eruptive rocks, found also in the Los Islands and north-east of Conakry.

## The Tidal Estuaries

Tidal variations extend far inland into the deep estuaries, since the coastal plain is at an elevation of only a few meters above mean sea level. During the wet season, the estuaries provide natural drainage outlets for the large surface runoff of fresh water. The discharge capacity of the channels is substantially reduced during the high tides, and increases during low tides. During the dry season, there is practically

no fresh water discharge in most of these channels, and salt water flows up and down the channels under the influence of the tide. Their downstream reaches carry water with a high salt content, somewhat reduced during the rainy season.

These tidal streams, called locally "marigots," generally present pronounced meanders which, in places, cause real archipelagos. Deltas do not exist, primarily because of the turbulence that prevails at the estuaries.

Salt water vegetation in the form of mangrove is present along those reaches where the salt content remains high throughout the year. The mangrove forms a border, several hundred meters wide, along the tidal streams. It is thick, and mangrove trees may reach an impressive height in the vicinity of the ocean. They become smaller and less dense in the upper reaches, where the tidal variations are smaller and where the salinity decreases during the wet season.

Along the tidal streams and their estuaries, the coast is covered by an alluvial, muddy sediment which is very viscous, called locally "poto-poto." Its bluish-black color and its marine salt content indicate an oceanic rehandling of its continental, clayey consistuents. These soils are very soft when wet. Their moisture content can be extremely high. They constitute a good support for the mangrove-type vegetation.

The Taboria River and the Marigot de Kabelea which bound the plains of Kakossa on the north and south are two such tidal streams.

## The Taboria River and the Marigot de Kabelea

The Taboria River and the Marigot de Kabelea are shown on Exhibit B. They are typical tidal streams that discharge fresh water into

the ocean during the wet season and salt water to and from the ocean, alternately, during the dry season. The Taboria River drains an area of approximately 380 square kilometers and the Marigot de Kabelea drains an area of about 60 square kilometers. Both streams have well defined channels. The Taboria River is navigable for small river vessels at all tide stages to the village of Taboria, where an adequate concrete wharf is available. The Marigot de Kabelea is suitable only for small boat navigation at low tide. Mud flats are exposed along the sides of both the Taboria and Kabelea estuaries at low tide.

## Tidal Variations

### Ocean Tides

The coast of Guinea along the Atlantic Ocean is subject to comparatively large tidal variations. Tide tables for Conakry, with corrections for the harbors of Benty and Taboria, are published yearly[1/]. Also, tide tables for Casablanca, Morocco, are published yearly[2/] with corrections for Tanna Island (Estuary of the Mellacoree River), Conakry, Dubreka, and Taboria.

Tidal variations at Conakry have an amplitude reaching a maximum of approximately four meters. From north to south of the Guinean

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1/ "Table des Marees des Territoires Francais d'Outre-Mer et de quelques Ports Etrangers" (Tide Tables for French Overseas Territories and some Foreign Harbors), Imprimerie Nationale, Paris.

2/ "Tide Tables - Europe and West Coast of Africa, including Mediterranean Sea," U. S. Department of Commerce and Coast and Geodetic Survey, U. S. Government Printing Office, Washington 25, D. C.

coast the amplitude varies by less than 0.2 meters. The tides do not reach their ebb and flood levels at the same time on all points of the coast, although the difference is not very great. Maximum and minimum levels at Taboria (at the northern edge of the plains of Koba) may be reached about 25 minutes after they occur at Conakry.

Each tidal cycle has a period of 28 days, with two subcycles characterized by a series of high and low levels reached at full moon (spring tide), and another series of high and low levels, although not as extreme as the former, reached at new moon (neap tide). The maximum flood levels of each year do not occur in a given season because the solar and lunar cycles are not in phase.

Tide Propagation in the "Marigots"

Variations of the ocean level induce corresponding water level fluctuations in the tidal streams or "marigots." These variations are propagated in an upstream direction along the streams according to well-defined patterns.

In the absence of fresh water discharge in the tidal streams, rising (or flooding) tides induce a flow of salt water from the ocean in an upstream direction. As the level of the ocean stops rising and begins falling (ebbing), the flow in the tidal streams decreases, a reversal of the current occurs and the marigot empties itself into the ocean where the water level is dropping to its ebb.

At a given point of a tidal stream, the water level undergoes fluctuations similar in character to the ocean tides that cause them. The amplitude of these tidal fluctuations decreases as the distance from the ocean to the point considered increases. The length of the period of

tidal fluctuations is about the same as at the ocean, but the occurrence of the maximums and minimums is delayed by a period of time (lag) that increases as the distance from the ocean increases. These two changes in the characteristics of the tidal fluctuations in a tidal stream -- decrease in amplitude and lag of peaking time -- result from the frictional resistance which the stream channel opposes to the propagation of tidal currents. Smaller and longer channels cause a greater resistance and, therefore, result in a greater dampening of tidal waves.

When substantial fresh water flows are discharged in the tidal streams, the downstream current may be strong enough to prevent the upstream flow that occurs in the dry season, but during high tides the channel discharge capacity is invariably reduced by an amount that can be considerable.

Tidal Fluctuations in the Marigot de Kabelea

Five water level recorders were installed by COTHA in 1954 in the project area to collect data on tidal fluctuations. Three recorders were installed on the Marigot de Kabelea. These were located at:

(a) 1000 meters downstream from the confluence of the Marigot de Kabelea and the Bolonta Kasomi;

(b) 700 meters upstream from the confluence; and

(c) 1900 meters upstream from the confluence of the Marigot de Kabelea and the Bolonta Kasomi.

The remaining two water level recorders were installed in the plains themselves. One was near Oyendima, on the northwestern side of the project about 10 kilometers northwest of the Marigot de Kabelea. The second at Makinsifori, which is nearer the center of the plains and about

4.5 kilometers to the northwest of the Marigot de Kabelea. The recorders were operated from May 1955 through January 1956. Graphs showing the flood and ebb levels recorded at these stations were included in the COTHA reports[1/].

Throughout the period of record these water level observations show that the Marigot de Kabelea is a typical tidal stream. The amplitude of the ocean tides is reduced as the tidal waves are propagated upstream into the marigot. For example, COTHA observed a reduction in tidal wave amplitude of 70 centimeters within the distance of six kilometers from the estuary to the most upstream recording site on the Marigot de Kabelea. This observation was made during a particularly high spring tide. Similar amplitude reductions may be expected in other tidal streams.

## Water Level Fluctuations in the Plains of Koba

The two water level recorders installed within the plains of Koba indicated significant high water elevations. Near the end of the dry season of 1955 water levels had receded to elevation 3.6 meters, with only small isolated areas being covered with water. By the height of the rainy season in July the water had risen to approximately elevation 4.6, and the entire plain was flooded by fresh water. The water began to recede in September, but not until after January did the waters subside again to elevation 3.6 meters. The water level in the plains did not seem to be influenced significantly by the tidal variations in the marigots.

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1/ See reference 7, page II-8

## Chapter II

# HISTORY OF THE KOBA PROJECT

### Introduction

The plains located in the Koba area are fertile lands where the cultivation of rice has been practiced to some extent for many decades by local Soussou and Baga populations. The potential of the plains for rice cultivation was investigated in the early 1950's by the French Colonial Administration for the purpose of increasing the production of rice in Guinea.

### The Koba Agricultural Experiment Station

In 1934 and 1935, a private company (the "Société du Koba") obtained a concession to develop about 700 hectares of land located between the village of Tatema and the sand dunes that border the ocean. These lands were divided in ten-hectare plots, 500 meters in length and 200 meters in width, and a banana plantation was organized.

It soon became apparent that a large portion of the lands was subject to fresh water flooding. The first harvest had to be done in canoes. The Société du Koba made improvements to the natural drainage system of the area by constructing canals and gated closure structures, but the area occupied by banana plantations decreased continuously until 1950, when only 50 hectares were covered by banana trees. The remainder of the property was leased to the local residents for rice cultivation. Compensation to the Société du Koba for leasing this land amounted to 100 kilograms of paddy rice per hectare leased.

In 1950 the French Colonial Administration purchased the entire property from the Société du Koba at a cost of 16 million CFA francs. This property included about 732 hectares of land, two residential homes, two hangars serving as warehouses, storage facilities and machine shop, and a wharf located at Taboria, about six kilometers away. Also included in the property were the hydraulic installations that had been made by the Société du Koba.

In purchasing this property, the Colonial Administration planned to develop an agricultural experiment station at the site. The station would be specialized in rice cultivation and would serve Lower Guinea and, possibly, the remainder of West Africa. A number of improvements were made from 1951 to 1954 at Koba toward this objective. These included residences, laboratories, a mechanical workshop, a machine shop, a water supply system and an electrical distribution system. In addition, existing drainage canals were rehabilitated and supplemented, dikes were constructed around the area, and the fields were levelled. At the same time, a staff of engineers and technicians was assigned to the station, and an operating budget in the order of 10 to 20 million CFA francs was made available annually to the station.

In 1954 and the following years, a substantial amount of research was done at the station in the selection of various rice varieties, trials of organic fertilizers, pedologic studies, agricultural practices, and protection of rice against disease and pests.

Very significant results were achieved in the course of the work performed at the Koba Station from 1954 to 1958, although in the last few years only limited budgetary appropriations were made to the station for capital improvements. The area not used by the station for

experimentation was leased to the local residents, and this reached over 300 hectares in 1957.

The concept of the role to be played by the station changed from year to year. First intended to serve primarily the needs of all the territories of West Africa, the station was in 1953 a "Central Station for Agricultural Research" with branches extending to the Mali, Ivory Coast, and Senegal. In 1955 the purpose of the station was modified and its activities limited to rice research for Lower Guinea. Moreover, the responsibility of rice research was not definitely given to any government agency, and this complicated the problem of efficient utilization of the existing facilities. By 1958, only one agronomist remained at the station and its future was quite uncertain.

After the departure from Guinea of the French Colonial Administration, the situation became worse because of the lack of operating funds. Finally, the technical operations of the station were discontinued. The laboratories and other facilities were closed, and the Government of Guinea turned over the lands to the local inhabitants. The existing structures and other facilities are now being operated as well as possible by the farmers, and a fairly high production is obtained from the lands that were formerly a part of the Koba Agricultural Station.

## COTHA Investigations (1954-1957)

The similarity between the lands of the Koba Station and the adjoining lands was apparent to the agricultural technicians, and the Agricultural Department of the former colonial administration decided to investigate the potential of the Koba plains. The first studies indicated

that natural conditions were very favorable to the cultivation of rice, with the exception of severe fresh water flooding in most of the plains and salt water intrusion in some of the area.

The Service du Genie Rural, recently organized in Guinea, developed the basic concept of a hydro-agricultural plan aimed at the reclamation of approximately 4000 hectares in the Koba plains. An aerial photographic coverage of the plains was then ordered by the Genie Rural.

In November 1954, the performance of engineering studies aimed at the development of detailed construction drawings of the reclamation project was entrusted to the Compagnie des Techniques Hydrauliques et Agricoles (COTHA), a French consulting engineering firm specializing in the design of similar projects. The COTHA studies, started about March 1955, consisted of the following:

(a) collection of basic data in the fields of climatology, hydrology, topography, and soil mechanics;

(b) planning studies for the purpose of developing a plan of reclamation, consisting of dikes preventing the flow of salt water to the lands, drainage canals designed to discharge excess runoff, and a gated structure across the main canal to permit fresh water flow toward the ocean during low tide levels;

(c) preparation of contract drawings and specifications for construction of the various structures involved.

The COTHA studies were completed in December 1957, at a total cost of about 12 million CFA francs. They resulted in two sets of contract documents, including detailed drawings and specifications for the construction of the project in two parts:

(a) dikes surrounding the project area and a gated control structure;

(b) a main drainage canal.

The COTHA plan of reclamation consisted of several dikes surrounding the project area on the north, east, and southeast sides. The top elevations of the dikes were designed so as to be about 0.75 meters above the highest tide levels, thus providing the project area with full protection against salt water. The dikes, with heights up to about 2.0 meters but generally on the order of 1.1 meters, would have their crests between elevations 4.75 and 5.25. They would tie into natural dunes. The total length of the dikes amounted to about 9000 meters.

Drainage of the plains surrounded by the dikes would be effected in a southeasterly direction by a main canal leading to the Marigot de Kabelea. The design of the canal was based on 332 millimeters of precipitation in six days (estimated by COTHA to have a five-year recurrence interval). The average flow to be discharged was estimated to be about six liters per second per hectare. The maximum discharge at the downstream end of the canal was estimated to be 38 cubic meters per second.

The dimensions of the canal were determined so as to limit the rise of the water level in the northern part of the plains to elevation 4.13. The bottom width of the canal varied from 50 meters at its downstream end to 17 meters at its upstream end. Its length would be approximately 10,000 meters. Excavation of the main canal was to be performed by a floating dredge discharging excavated materials into the ocean.

To prevent the entrance of salt water into the project area, a control structure was to be provided across the main canal. This structure,

made of reinforced concrete founded on steel sheet piles resting on bedrock, was to be provided with eight manually operated flap gates, 60 inches in height by 60 inches in width.

The main quantities and construction costs estimated by COTHA are summarized in Table II-1.

Table II-1 - Estimated Cost of COTHA Project

| Structures | Main Items of Work | Estimated Cost (CFA Francs) |
|---|---|---|
| Dikes | Length: 9 km<br>Volume of fill: 61,000 $m^3$ | 46,500,000 |
| Canal | Length: 10.0 km<br>Volume of excavation: 730,000 $m^3$ | 164,000,000 |
| Control Structure | Volume of concrete: 300 $m^3$<br>Sheet Piles: 150,000 kg | 43,000,000 |
| Contingencies | 5 percent | 17,500,000 |
| | Total | CFA 271,000,000 |

The Genie Rural carried out by force account methods the construction of a dike separating the Koba Station from the northern part of the plains at a cost of 5 million CFA francs. Construction of the project itself was scheduled to be started in January 1959 and to be completed in June 1960. Payment for this work was to be on the basis of unit prices submitted by the prospective contractor with his bid. However, these prices were to be based on economic conditions prevailing in January 1958. The contract documents provided for changes in the unit prices to take into account possible variations of economic conditions by means of a formula of price variations.

The COTHA project did not include the secondary and tertiary drainage facilities. Their design was scheduled to be carried out in 1960-61, and their construction in 1962-63.

Implementation of these programs was not started because of the departure from Guinea of the French Administration in 1958.

## Recent Investigations

In 1960, upon request by the Government of Guinea, two experts[1/] of the Food and Agriculture Organization of the United Nations (FAO) investigated the steps to be taken to increase the production of rice in Guinea. Among other recommendations, they proposed to increase the area of lands suitable for land cultivation by construction of hydraulic control structures, and to increase the yield of cultivated areas by means of an agricultural extension program.

More particularly, with regard to the Koba Project, the following steps were recommended:

(a) Construction of the primary works including the dikes, the main canal, and the control structure, at a cost of GF 306 million;

(b) Performance of detailed engineering and agronomic studies for the planning of the secondary and tertiary facilities, at an estimated cost of GF 38 million;

(c) Construction of the secondary works at an estimated cost of GF 160 million;

(d) Construction of the tertiary canals by the local beneficiaries, at a cost for which no estimate was made.

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1/ Messrs. J. de Meredieu and H. A. A. M. Wirtz

In addition, reactivation of the Koba Experiment Station at an estimated initial cost of GF 10 million was recommended.

## List of Reports Relative to the Koba Project


1. "Rapport Pedologique" (Soils Report), Secteur des Recherches Rizicoles, Service de l'Agriculture de Guinee (Department of Rice Research, Service of Agriculture of Guinea), 1950.

2. "Archives du centre de Recherches Rizicoles" (Proceedings of the Center for Rice Research), 2nd Part, Pedology, Campaign 1952-53, Gouvernement General de l'AOF, 1953.

3. "Projet d'Execution du Plan Quadriennal 1953-57 - Production (Riz) - Rapport Complementaire" (Project of Implementation of the Four-Year Plan 1953-57 - Production (Rice) - Supplementary Report), undated. The date of publication is estimated to be May 1953.

4. "Les Plaines Rizicoles de la Basse-Cote de Guinee - La Riziculture Actuelle - Persepctive de Developpment" (The Rice Producing Plains of the Coast of Lower Guinea - The Present Rice Cultivation - Outlook for Development), undated. The date of publication is estimated to be 1955.

5. "Compte-rendu d'Activite de la Section du Genie Rural dans le cadre du programme FIDES 1953-57" (Report on the Activities of the Section of Rural Engineering within the scope of the 1953-57 program of the FIDES), No. 523 GR, undated. The date of publication is estimated to be June, 1955.

6. "Note Succinte, Amenagement Hydro-Agricole des Plaines du Koba" (Memorandum on the Koba Reclamation Project), Report No. RCT 245 by COTHA, undated.

7. "Etudes Preliminaires" de l'Amengaement Hydro-Agricole des Plaines du Koba (Preliminary Studies of the Reclamation Project for the Koba Plains), Report No. RCT 250, by COTHA, June, 1956.

8. "Sondages de Reconnaissance," Amenagement Hydro-Agricole des Plains du Koba (Exploratory Drilling, Reclamation Project for the Koba Plains), by COTHA-SASIF, undated.

9. "Prelevements et Analyses Mecaniques d'Echantillons de Sol" (Sampling and Mechanical Analyses of Soil Samples), by COTHA, undated.

10. "Projet d'Execution de l'Amenagement Hydro-Agricole des Plaines du Koba" (Contract Documents for Construction of the Koba Reclamation Project), Premiere Partie, Digues et Ouvrages d'Evacuation de Kabelea (Part One, Dikes and Kabelea Control Structures), Report No. RCT 384, by COTHA, July, 1957.

11. "Complements Topographiques, Amenagement Hydro-Agricole des Plaines du Koba" (Supplementary Topographic Survey, Koba Reclamation Project), Report No. RCT 388, by COTHA, September, 1957.

12. "Projet d'Execution de l'Amenagement Hydro-Agricole des Plaines du Koba" (Contract Documents for Construction of the Koba Reclamation Project), Deuxieme Partie, Canal de Drainage (Part Two, Drainage Canal), Report No. RCT 409, by COTHA, December, 1957.

13. "Memoire Presente par le Service du Genie Rural au Comite Consultatif Local de la Production Agricole-Annee 1957" (Report presented by the Department of Rural Engineering to the Advisory Committee on Agricultural Production - for 1957), No. 491/GR. Service de l'Agriculture, Ministere de la Production, Guinee Francaise.

14. "Rapport au Gouvernement de la Republique de Guinee sur les Possibilites d'Amenagement Hydro-Agricole des Terres Riziculturables de la Basse-Guinee" (Report to the Government of the Republic of Guinea on the Feasibility of Hydro-Agricultural Installations in the Potential Ricelands of Lower Guinea), by J. de Meredieu, Food and Agriculture Organization of the United Nations, Rome, Italy, January, 1961.

15. "Augmentation de la Production de Riz en Basse-Guinee-Rapport au Gouvernement de la Guinee" (Report to the Government of Guinea for increasing the Production of Rice in Lower Guinea), by H. A. A. M. Wirtz, Food and Agriculture Organization of the United Nations, Rome, Italy, 1961.

## Chapter III

# FIELD INVESTIGATIONS

### Introduction

In compliance with the terms of their contract with the United States and its executing agency, the Agency for International Development (AID), the Harza Engineering Company sent to Guinea a team of six engineers and agronomists for the purpose of making field investigations for four reclamation projects, including the Koba Project. This team included the following personnel:

Project Manager
Hydrologist and Field Engineer
Irrigation and Drainage Engineer
Soils Agronomist
Rice Agronomist
Agricultural Economist

The activities of the team were directed toward the following:

(a) review of all existing data;

(b) conduct of field reconnaissance and studies for the purpose of determining the adequacy of the existing data; and

(c) supplementing of existing data as necessary for an evaluation of the project.

The team remained in Guinea from April 1963 until the start of the rainy season, in July. This allowed only sufficient time for investigation of the Monchon Project and the Kapatchez Project, and for collection of miscellaneous basic data applicable to all four projects. The team returned to Guinea after the rainy season, and spent in Guinea the

months of November and December, 1963. This schedule permitted observations to be made both at the beginning and at the end of the rainy season. Investigations of the Koba and the Kakossa projects were completed during the second campaign. The investigations that were conducted and the results that were obtained are summarized in the remainder of this Chapter.

## Review of Existing Documents

A large number of reports and various documents relative to the production of rice in Lower Guinea were reviewed in Conakry. A fairly complete documentation relative to the Koba Project was found to be available. This consisted primarily of reports prepared by the consulting engineering firm COTHA relative to a plan of development of the Koba Project.

Very little was found concerning the works actually carried out within the project. A small area was reclaimed at the southern edge of the project area by the Koba Station as part of an experimental program and not as an integrated part of the Koba Reclamation Project. No "as built" drawings concerning these works were found at Koba or at Conakry. It is believed that none were prepared. A pedologic report relative to the soils of Koba was found to be available. The data contained in that report were reviewed and found to be useful.

The analyses of the data contained in these various reports permitted a reasonable understanding of the basic ideas that guided previous planning of the Koba Project.

## Field Reconnaissance

A field reconnaissance of the project area was made for the purpose of determining the present condition of existing structures, to identify the problems involved, and to gain an intimate knowledge of possible solutions. This reconnaissance also served to formulate a program of more detailed field investigations.

Included in the reconnaissance and field observations program was the area located beyond the northern project area boundary. This area was reclaimed under the French Colonial Administration, and is presently almost entirely under cultivation. Although this area was outside the scope of the Harza assignment, it was considered appropriate to comment on a few improvements that could be made. Also, it provided the opportunity of observing the conditions prevailing at a more advanced stage of development in an area similar in all respects to the project area.

### The Koba Project Area

The proposed reclamation area was found to be suffering from severe annual fresh water flooding. Because of mild natural slopes, most of the project area is under water most of the year. Poor natural drainage conditions are aggravated by a dense surface vegetation and the lack of adequate drain outlets. During the field inspection made in June 1963, at the end of the dry season, little standing water was observed in the plains. However, near the end of the rainy season in November, the entire central portion of the project area, covering over half of the arable lands, was found to be flooded.

The team traversed the flooded area in dug-out canoes. The water depth reached nearly 0.90 meters in the plains, and deeper over the natural waterways. The water level reached approximately elevation 4.2 meters. A dense growth of tule and water grasses rose to a height of about 1.2 meters above the water surface. Few significant drainage canals were found in this area.

A small area located at the southern edge of the project area, in which the ground elevation is high enough above normal high tides, was found to be fairly well developed. This area had been reclaimed under the direction of the Koba Experiment Station and is presently well drained by a network of man-made canals.

Potential borrow areas containing suitable fill material were found to be located along the western and eastern sides of the project. Access roads and haul routes were inspected. It was concluded that adequate quantities of fill material were available within reasonable hauling distances of the embankment sites.

## The Koba Station

The existing facilities of the Koba Station and the adjoining fields were found to be in various states of repair. The two gated control structures on the northern boundary of the station were found to be sound and in operating condition. Their outlet channels were excavated about 500 meters toward the north, where they joined together with a natural channel which continues north to discharge into the Taboria River. Sediment has been deposited in most of these channels and their sections are obstructed by tree stumps in places.

The two outlet structures located on the west (ocean) side of the station are structurally sound but are not in operating order because

their outlets into the sea are obstructed by sand bars blown by the wind or brought by the waves. Annual cleaning of these outlets will be required if adequate drainage is to be achieved. One control structure on the southern boundary dike of the station was found to be structurally sound, but the gate has not been installed.

The major dike system at the station consists of north and south boundary dikes. These are complete, except for a short reach near the control structure on the south. Only minor rehabilitation and completion of the short reach at the southern dike are necessary to render the system completely serviceable.

The drainage network within the station has not been operated or maintained properly since 1957. However, surprisingly little damage has occurred. A program of minor rehabilitation could put the system back into service within a relatively short time.

## Topography

The following topographic data were found in Conakry:

(a) a set of aerial photographs at a scale of 1:20,000, taken in the 1950's and covering the entire project area;

(b) a topographic map by COTHA, at a scale of 1:20,000 with contours of 50 centimeter spacing and numerous spot elevations.

The accuracy of the COTHA topographic map was verified in the field. Numerous bench marks were identified and the difference in elevation between bench marks was determined by the team. The results established that the survey is acceptable as a basis for design. This map was used to prepare the drawings presented in this report.

The topographic map prepared by COTHA used an arbitrary reference datum. However, by comparison of tide elevations measured at Koba and given in the tide tables, it was established that the datum of the COTHA survey is about 0.35 meter below the tide table datum, which, in turn, is about 2.1 meters below mean sea level. Therefore, the COTHA reference datum is about 2.45 meters below mean sea level.

## Hydrography

Hydrographic investigations were carried out for the following purposes:

(a) to determine the present condition of the main outlets with respect to accumulation of sediment;

(b) to collect data on the cross-section of the main channels and the tidal streams, to be used in hydraulic design; and

(c) to collect data on tidal variations for hydraulic studies.

A detailed reconnaissance of the Marigot de Kabelea, the Taboria River, and the drainage outlet channels of the Koba Station was carried out aboard a 12-foot boat powered with an outboard motor. Particularly difficult areas were reached with the assistance of native boatmen and their canoes. Soundings of the water depths were taken at appropriate locations. Surface widths were measured and side slopes were determined. Significant data on these marigots are given in Table III-1.

Table III-1 - Dimensions of Tidal Streams that Drain the Project Area

(measured near high tide)

| Stream | Approximate Location | Side Slope | Surface Width (meters) | Max. Depth (meters) | Water Area (square meters) |
|---|---|---|---|---|---|
| Structure Outlet | 15 meters upstream into natural waterway | 2:1 | 10 | 1.7 | 11 |
| Kabelea | 50 meters downstream of control structure outlet | 5:1 | 65 | 4 | 190 |
| Kabelea | 100 meters upstream confluence with Bolonta Kasomi | 5:1 | 80 | 5.0 | 275 |
| Bolonta Kasomi | 250 meters upstream confluence with Kabelea | 5:1 | 80 | 5.3 | 300 |
| Kabelea | 200 meters downstream confluence with Bolonta Kasomi | 5:1 | 120 | 5.0 | 400 |

The Marigot de Kabelea, which will receive the runoff from the project area, was found to be in good condition. Its channel is wide, deep and stable and shows no evidence of either degradation or aggradation. Its confluence with the Marigot Bolonta Kasomi is smooth and its estuary is clear.

The Marigot de Kabelea and the Marigot Bolonta Kasomi are typical tidal streams throughout their lengths. They extend inland not more than 20 kilometers from the coast.

The two drainage outlet channels that serve the Koba Station on the north have been excavated in a northerly direction to join a natural channel which continues north to the Taboria River. Sediment seemed to have been deposited in the excavated channels. Typical dimensions of these channels are indicated in Table III-2. The cross-sectional areas at the excavated channels are smaller in the downstream reaches than in the upstream reaches. This is indicative of aggradation originating near the outlets. The aggradation is not presently serious, but will become so if permitted to progress at its present rate. Yearly maintenance is required.

Table III-2 - Dimensions of Tidal Streams that Drain the Station Grounds

| Structure | Approximate Location | Side Slope | Surface Width (meters) | Max. Depth (meters) | Water Area (square meters) |
|---|---|---|---|---|---|
| Western excavated canal | 10 meters downstream western control structure | 2:1 | 8.0 | 1.9 | 8 |
| Western excavated canal | 30 meters upstream confluence with natural canal | 2:1 | 8.0 | 1.4 | 7 |
| Eastern excavated canal | 10 meters downstream eastern control structure | 2:1 | 8.0 | 1.9 | 8 |
| Eastern excavated canal | 30 meters upstream confluence with natural canal | 2:1 | 8.0 | 1.4 | 7 |
| Natural Canal | 30 meters downstream confluence with excavated canal | 6:1 | 30.0 | 2.0 | 36 |
| Natural Canal | 200 meters upstream from mouth | 6:1 | 30.0 | 2.0 | 36 |

The natural channel which receives the discharges of the two excavated channels is wide and stable. It exhibits no evidence of aggradation, but its flow is seriously restricted by uncontrolled brush growth. The drain outlet into the estuary of the Taboria River is wide and clear. There is a well defined channel which extends from its mouth through the tidal flats into deep water. This channel may be expected to be blocked from time to time by sand bars moving under the action of the wind and waves. Frequent inspection and periodic maintenance will be required to keep the channel clear.

Water surface elevations at high and low tides were measured at the main canal control structure site proposed by COTHA. These elevations were compared to those observed by COTHA in 1955, as recorded in their report. The structure site is located on a waterway, about 100 meters from its confluence with the Marigot de Kabelea.

Table III-3 sets forth the comparison between observations made by COTHA in 1955 and those made by the team of the Harza Engineering Company in 1963. Because of the close agreement it was concluded that the 1955 observations are acceptable and may be used as a basis for design.

Table III-3 - Comparison of Tide Elevations

(referred to COTHA reference datum)

| Designation | Dokiti Structure Site (Nov. 3, 1963) | Marigot de Kabelea (Nov. 2, 1955) | Ocean Tides (Nov. 2, 1963) |
|---|---|---|---|
| High tide elevation | 4.2 | 4.2 | 4.3 |
| Low tide elevation | 1.4 | 1.4 | 0.9 |
| Amplitude, meters | 2.8 | 2.8 | 3.4 |

## Foundation Investigations

The foundation conditions of the proposed structure site near Dokiti were investigated. Preliminary investigations consisted of three auger holes bored to a depth of 4.5 meters below the surface. The material encountered consisted of very soft, blue-gray, organic clay. Samples were taken and brought to the United States for testing. The results of these tests are summarized in Table III-4.

Table III-4 - Results of Soil Tests at Dokiti Structure Site

| | |
|---|---|
| Natural Moisture Content | 76 to 81 percent |
| Liquid Limit | 70 to 84 percent |
| Plasticity Index | 39 to 53 percent |
| Grain Size Ranges (mm) | |
| smaller than 0.001 | 23 to 56 percent |
| 0.001 - 0.01 | 16 to 41 percent |
| 0.01 - 0.1 | 16 to 24 percent |
| 0.1 - 1.0 | 3 to 24 percent |

The materials encountered were classified as clays of medium to high plasticity (CH). The behavior of such soils as foundation materials is characterized by a low resistance to shearing, a low permeability, and a high compressibility.

## Soils Investigations

A pedologic map of the Koba plains was prepared by the Service of Agriculture of Guinea in 1954[1/]. That map supplied general

1/ "Plaine du Koba, Carte Pedologique," by F. de Cock, Service de l'Agriculture, No. 285B/GR/AGR, scale 1:20,000, dated July 28, 1954.

information on the types of soils encountered in the project area. Although the map was found to be useful, it was not adequate for an evaluation of the present suitability of the land for rice production and of the yields that can be expected after reclamation. Consequently, a supplementary soil survey and chemical analyses of representative soil samples were necessary and were performed by the team.

A total of 28 auger holes were bored within the area of the Koba Project and in the neighboring area. The location of the holes is indicated on Exhibit 2. The profiles were examined to depths ranging from 0.3 meters to 1.8 meters and preliminary, visual classification of the horizons encountered was made in the field. About 100 representative samples were taken, and tested in a laboratory set up in Guinea with equipment brought from the United States. These tests consisted of the determination of the pH (degree of acidity) and of the conductivity of saturation extracts (degree of salinity). The logs of the auger holes and the results of these tests are presented on Exhibit 3.

This series of preliminary tests led to the selection of 24 representative soil samples from six typical areas for detailed chemical analyses. These samples were tested in the United States at the soils laboratory of the Department of Agronomy, University of Arkansas. The analyses performed were for the purpose of determining pH, total salt content, anions and cations of the saturated extract, cation exchange capacity, exchangeable aluminum, total sulphur, and percent of water saturation. Other determinations included organic matter, percent free iron, available phosphorus, and particle size distribution (mechanical analysis). These analyses are considered adequate for the economic feasibility studies.

## Subsurface Drainage Investigations

For the purpose of subsurface drainage studies, the coefficient of permeability of the subsoil was determined in the field. Three typical areas were selected on the basis of the soils survey. One auger hole was bored in each of these areas, at the locations shown on Exhibit 2. A permeability test was performed at each of the auger holes.

The auger hole was bored with a standard auger, 10 centimers in diameter, to a depth of about one to two meters below the groundwater table. Water was pumped out of the hole by means of a plunger pump. The rate of rise of the water in the hole after interruption of pumping was measured with a float and a chronometer.

The data supplied by this test allowed determination of the order of magnitude of the coefficient of permeability of the subsoil. The test is relatively easy to perform and generally provides reliable results. The results obtained for the Koba area are summarized in Table III-5.

Table III-5 - Results of Permeability Tests

| Auger Holes | Location | Soil Classification | Coefficient of Permeability (cm/sec) |
|---|---|---|---|
| A | E. of Dokiti | Clay | $0.4$ to $0.6 \times 10^{-3}$ |
| B | W. of Ouendidi | Clay | $0.3$ to $0.4 \times 10^{-3}$ |
| C | W. of Socia | Clay | $0.6$ to $0.8 \times 10^{-3}$ |

The values of permeability as shown in Table III-5 indicate that:

(a) subsurface soil textures and subsurface drainage properties are generally uniform throughout the project area; and

(b) the coefficient of permeability is in the range of 0.3 to 0.8 centimeters per second.

Prior experience in other parts of Lower Guinea and other parts of the world indicates that the values found above are representative of soils having the textures as described. Therefore, the tests are considered to be reliable. The values they yielded reflect a relatively high degree of permeability for the materials encountered.

## Rice Agronomy

In the course of field reconnaissance and other field investigations made in the Koba area, present land uses were observed and recorded. The result of these observations is shown as a land use map on Exhibit 2.

The fields presently cultivated were inspected for the purpose of determining the present cultural practices and production rates. Rice was observed in various stages of growth. These stages included rice in primary beds, transplanting of the seedlings, and established rice in paddies from the late vegetative stage to full maturity. Estimates of the total area under cultivation and estimates of the rice yields of each field were made by inspection. The results of these estimates are given in columns (1) through (4) of Table IV-3.

The fields located to the north of the project area, which were reclaimed earlier as part of the Koba Experiment Station, were also inspected with interest, since they are representative of what can be expected from the project area after its reclamation. The water control procedures used by the farmers in these fields appeared to be in need of improvement. There seemed to be a conflict between the farmers cultivating the lower fields and those cultivating the higher areas. Because of improper conservation of water in the areas located at a higher elevation, the farmers try to keep the control gates shut or at a small

opening. This results in poor drainage of the lower fields, which results in reduced yields.

The rice varieties presently used in the Koba plains were examined. All were local varieties, varied in color, and appeared to be well adapted to the prevailing salt and water conditions. These varities included Mamoussou, Malock, Kourkousomine, Toma, and Yaye. Of these, Mamoussou appeared to be the most resistant to salt and was the major variety grown in the Koba area. Well developed fields were found in the southernmost part of the project area, where experimental fields had formerly been cultivated as part of the Koba Station program. However, the yields obtained from this variety are low, and economic development of the project area seemed to require the control of salinity in order to permit the use of more productive varieties. The next prominent variety found in the plains was Malock.

The extreme uniformity of the existing paddy fields and also the complete absence of weeds in most of the rice fields were evidences of the good training the farmers of the area received from the Koba Experiment Station.

The records of the station were found to contain valuable information on trials made in the adjoining fields, on rice varieties, and on cultural practices. These data were used in the evaluation of the agricultural and economic potential of the arable lands of the Koba project area.

## Miscellaneous

Important basic data and information were obtained through direct contacts with various officials and individuals. Conferences were held

with officials of several ministries in Conakry to obtain economic, agricultural and other data; with the Governor of the Region of Boffa and his staff to obtain detailed information relative to local conditions; with village officials and individual farmers to secure first hand information on the agricultural practices; with government agencies to obtain miscellaneous data on the availability and cost of various commodities; with foreign contractors presently engaged in civil engineering works to obtain information relative to construction practices, labor and materials availability, and their experience in Guinea; and with U.S. Embassy and AID officials to obtain economic and other data already compiled by them.

All individuals contacted were anxious to help, and their cooperation is appreciated. The information received from the various sources was sometimes contradictory, but this reflects the scarcity of accurate statistical data. First hand information was secured whenever possible and all other data were examined critically, with judgement being used to interpret apparent discrepancies.

## Land Evaluation

### Topography

The project area is nearly flat. The ground slopes gently southward towards the Kabelea. Three main depressions are present in the project area. These low areas are subject to ponding of water.

Most of the project area will require little land preparation. Some levelling will be required to fill the existing depressions and insure drainage of surface water toward the canals. Land planing will be required over most of the project area.

### Present Land Use

About one quarter of the project area is presently under cultivation. Present use of these lands was investigated to gain information on the problems particular to the project lands and to determine the present agricultural production of the project area.

The present project land use was grouped into six designations, I through VI. Each designation corresponds to a grouping of lands with similar characteristics and present production capabilities. Groups I, II and III correspond to areas with fresh water problems, whereas groups IV, V and VI correspond to areas with salt water problems. The boundaries of each group are delineated on the map of present land use, presented on Exhibit 2.

Group I includes about 620 hectares of land presently under cultivation in areas subject to intermittent fresh water flooding. Rice yields are estimated to average about 1.5 tons per hectare.

Group II includes about 1790 hectares of low marshy land submerged by fresh water during the wet season, and for sometime thereafter. These lands are not cultivated at the present time.

Group III includes about 205 hectares of land with trees, subject to intermittent fresh water flooding. These lands are not cultivated at the present time.

Group IV includes about 455 hectares of land subject to salt intrusion and tidal flooding. Approximately 88 percent of this area is presently cultivated. Rice yields are estimated to average about 1.0 tons per hectare.

Group V includes about 630 hectares of low-lying marshy lands subject to tidal action, and not cultivated at the present time.

Group VI includes about 200 hectares of land that is subject to salt intrusions and tidal action, with mangrove vegetation or mangrove stumps. This land is not cultivated at the present time.

This analysis of present land use indicates that, although one-quarter of the project area is under cultivation, rice yields are severely limited by adverse natural conditions.

## Reclaimable Area

Inspection of the lands located in the project area enabled the identification of those parts of each area which are susceptible of economic reclamation. These data are summarized in Table IV-1. It shows that, in addition to the 26 percent of total arable lands presently under cultivation, about 74 percent can be reclaimed, thus bringing the gross area under cultivation to about 100 percent of the total arable land area.

Table IV-1 - Presently Cultivated and Reclaimable Areas in Each Present Land Use Class

| Present Land Use Designation | Arable Land Area (hectares) | Presently Cultivated Area | | Reclaimable Area 1/ | |
|---|---|---|---|---|---|
| | | ha | % | ha | % |
| I | 620 | 590 | 95 | 620 | 100 |
| II | 1,790 | 0 | 0 | 1,790 | 100 |
| III | 205 | 0 | 0 | 205 | 100 |
| IV | 455 | 380 | 84 | 455 | 100 |
| V | 630 | 0 | 0 | 630 | 100 |
| VI | 200 | 0 | 0 | 200 | 100 |
| Total | 3,900 | 970 ha | 25% | 3,900 ha | 100% |

The data in Table IV-1 indicate that reclamation will result in a very substantial increase of the cultivated area. However, this is not the only effect that will result from it. In addition to an increase of the useful area, the yields obtained from the lands presently under cultivation will be greatly increased as a result of drainage and land management.

## Classification According to Potential

The lands located in the project area were classified to estimate their potential value for rice cultivation. This classification takes into account the present land use, soils evaluation, and topography.

Four classes of land were established to represent significant degrees in the potential of lands for rice cropping. Each class corresponds to a grouping of lands having similar present uses, physical and

1/ Includes presently cultivated area.

chemical properties, and topographic features. Each class corresponds, therefore, to a certain productivity capacity and to a certain cost of land preparation for satisfactory production. The classes are defined below:

Class 1. Lands with features of soils, topography and drainage which will provide for high yields at low production costs.

Class 2. Lands which are slightly less adaptable; therefore, with lower productive capacity and increased production cost.

Class 3. Lands with features which materially restrict their production capacity such as flooding, salinity, salt water intrusion, or pH. Greater expenses for drainage, leaching and land preparation will be necessary.

Class 4. Lands which are temporarily unsuited for agriculture because of flooding, tidal action, salinity, and tree cover.

Each land class was assigned a rating indicating the yields that can be expected. The rating for each land class is indicated in tabular form on Table IV-2.

Table IV-2 - Rice Yields that can be Expected from Each Land Class

| Land Class | Rice Yield Range (tons/hectare) |
|---|---|
| 1 | 4.0 |
| 2 | 2.0 - 3.5 |
| 3 | 1.0 - 2.5 |
| 4 | 0 |

Under present conditions the project area includes about 335 hectares of Class 2 land which yields about 2.0 tons of rice per hectare. About 685 hectares of land that is in Class 3 under present conditions yields from 1.0 to 1.5 tons per cultivated hectare. The remainder of the project area includes 2880 hectares of land that is in Class 4 under present conditions, and is not being cultivated. Of these. 405 hectares are covered by vegetation which would have to be cleared prior to cultivation. These data are shown in Column (1) through (4) of Table IV-3.

It is estimated that immediately upon completion of the proposed drainage system, the resulting surface drainage of the field will upgrade most of the lands that are presently Class 4 lands to a Class 3 rating. At the same time, the yields of all arable lands will be increased, as shown by columns (5) and (9) of Table IV-4. Thus, about 2760 hectares will have a Class 3 rating, with production yields ranging from 1.5 to 2.0 tons per hectare. Considering that about five percent of the area will be occupied by canals and levees, the net area of cultivable lands will then be about 2620 hectares, with an average yield slightly above 1.5 ton per hectare. Similar comments could be made about the lands that will be upgraded to Class 2. About 405 hectares will remain unproductive until they are cleared of trees (mangrove). These data are shown in Columns (6) through (9) of Table IV-4.

After a short period of development of five years, it is expected that the yield of these lands can be increased substantially: the best lands would yield between 2.5 and 2.8 tons of rice per hectare, the remainder between 1.0 and 2.5 tons per hectare. This is also indicated on Table IV-4. Included in this development period are: very limited land preparation, surface leaching, agricultural extension, some

## Table IV-3 - Project Land Class Ratings through Development Period

| Present Land Use Designation | Area of Reclaimable Lands | Present Conditions | | After Project Construction | | After 5 Years | | After 10 Years | | After 20 Years | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Land Class Rating | Rice Yield (tons/ha) | Land Class Rating | Rice Yield (tons/ha) | Land Class Rating | Rice Yield (tons/ha) | Land Class Rating | Rice Yield (tons/ha) | Land Class Rating | Rice Yield (tons ha) |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| I | 335 | 2 | 2.0 | 2 | 2.5 | 2 | 2.8 | 2 | 3.5 | 1 | 4.0 |
| | 285 | 3 | 1.5 | 3 | 2.0 | 2 | 2.5 | 2 | 3.0 | 2 | 3.5 |
| II | 1110 | 4 | 0 | 3 | 1.5 | 3 | 2.5 | 2 | 3.3 | 1 | 4.0 |
| | 680 | 4 | 0 | 3 | 1.5 | 3 | 2.5 | 2 | 3.0 | 2 | 3.5 |
| III | 205 | 4 | 0 | 4 | 0 | 3 | 2.0 | 2 | 3.0 | 1 | 4.0 |
| IV | 400 | 3 | 1.0 | 2 | 2.0 | 2 | 2.5 | 2 | 3.0 | 2 | 3.5 |
| | 55 | 4 | 0 | 3 | 1.5 | 3 | 2.2 | 2 | 2.8 | 2 | 3.5 |
| V | 630 | 4 | 0 | 3 | 1.5 | 3 | 2.2 | 2 | 2.8 | 2 | 3.5 |
| VI | 200 | 4 | 0 | 4 | 0 | 3 | 1.0 | 3 | 2.0 | 2 | 3.0 |
| Total | 3900 | | | | | | | | | | |

Table IV-4 - Reclaimed Area and Yields Expected from Each Land Class

| Land Class Rating | Present Conditions | | | | After Project Construction | | | | 5 Years After Reclamation | | | | 10 Years After Reclamation | | | | 20 Years After Reclamation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area, in Hectares | | Yield, in tons/ha | | Area, in Hectares | | Yield, in tons/ha | | Area, in Hectares | | Yield, in tons/ha | | Area, in Hectares | | Yield, in tons/ha | | Area, in Hectares | | Yield, in tons/ha | |
| | Gross | Net | Range | Av. | Gross | Net | Range | Av. | Gross | Net | Range | Av. | Gross | Net | Range | Av. | Gross | Net | Range | Av |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) |
| 1 | | | | | | | | | | | | | | | | | 1,650 | 1,570 | 4.0 | 4.0 |
| 2 | 335 | 320 | 2.0 | 2.0 | 735 | 700 | 2.0-2.5 | 2.2 | 1,020 | 970 | 2.5-2.8 | 2.6 | 3,700 | 3,520 | 2.8-3.5 | 3.1 | 2,250 | 2,140 | 2.0-3.5 | 3.5 |
| 3 | 685 | 650 | 1.0-1.5 | 1.2 | 2,760 | 2,620 | 1.[illegible]-2.0 | 1.55 | 2,880 | 2,740 | 1.0-2.5 | 2.3 | 200 | 190 | 2.0 | 2.0 | | | | |
| 4 | 2,880 | - | 0 | 0 | 405 | - | 0 | 0 | | | | | | | | | | | | |

fertilizing, and other improvements of present agricultural practices. The project lands are not considered suitable for other crops at the present time, nor for the first few years of project operation.

The yields that can ultimately be expected from each area are shown in the last columns of Table IV-4.

## Land Management

### General

Maximum production from the lands of the project will depend to a great extent on the way in which the soil, water, and land management problems are handled. Important management problems will be connected with land drainage and its effects on the chemical and physical properties of the soils, salinity control, and soil fertility. Immediately after completion of the proposed dikes and other works, it will be advisable to begin a measurement program to establish records on the properties of the soils. Any changes in these properties during the period of development of the project can then be noted. If necessary, any action program will follow, aimed at correcting the problems that may arise.

It is possible at this time to anticipate three major sources of difficulty that can be kept under control if properly diagnosed and treated. They are associated with soil toxicity, salinity, and fertility. The presence in the area of acid sulfate soils and soils with a high percentage of iron and extractable aluminum will probably pose the most difficult management problems.

## Toxicity

Acid sulphate soils generally contain a high content of sulphides. The lowering of the water table that results from surface drainage changes the reduction process to one of oxidation, indicated by a decrease of the measured pH. As a result of the formation of sulphuric acid, free iron and aluminum appear in the soils. These elements, when present in excessive quantity, may be toxic to the rice plants and hinder their growth. It will be important, therefore, to maintain the degree of acidity within a range that is high enough to prevent the formation of toxic elements. One way of accomplishing this consists of controlling the position of the groundwater table, thereby decreasing the rate of oxidation.

## Workability

Some of the alluvial soils in the project area contain a high percentage of sodium and a fairly low amount of calcium. Leaching of the calcium may change the absorption complex to one of sodium. This may affect the structure of the soil, causing it to be easily puddled and difficult to work. Such an objectionable soil complex can be modified by the addition of an electrolyte such as $CaCO_3$ or by the introduction of water containing calcium salts.

## Salinity

Control of the degree of salinity will be very important, particularly in the areas affected by salt intrusions. When the salt content level is high the best time to leach them effectively will be at the beginning of the rainy season. Drainage must be effective at that time so as to remove the salts from the soil profile.

## Fertility

The maintenance of soil fertility is also important to the success of the project. Organic matter decomposes rapidly in tropical conditions, particularly in well-drained areas. Maintenance and improvement of the content of organic matter should be accomplished for the following reasons:

(a) to preserve and improve soil physical conditions by maintaining good tilth and reducing soil erosion.

(b) to maintain the nutrient level of the soil and increase its base exchange capacity.

Crops residues, when ploughed back into the soil, help maintain soil fertility and act as a source of organic matter and plant nutrients. The addition of fertilizer will also contribute to an increase of soil organic matter by increasing the amount of crop residue, including both stubbles and roots.

Chapter V

# AGRICULTURE

## National Production Requirements

### National Economy

A presentation of the Guinean economic structure is difficult because of the lack of accurate statistical data. The following data, based on estimates by Guinean and U. S. agencies, are intended to provide an economic background of the Koba Project.

The population of Guinea is estimated to be about three million. Over 90 percent of the people receive their living directly or indirectly from agriculture, largely on a subsistence basis. Only about 120,000 persons are wage earners, most of them being employed in non-agricultural enterprises. The income per capita in rural areas is much lower than in the urban areas.

The gross national product appears to have been increasing constantly since 1959, largely as a result of gains in the mining industry. However, the per capita value of the gross national product has remained at about $100. The production per man-hour of agricultural labor is believed to have declined.

The amount of cash income received per capita is estimated to be about $40. However, for a large majority of the people, money is of little use except to buy a few products not available from the land. The usual pattern is for the family to consume most of the goods they produce and to use a small part for sale, or to barter for other products.

The shortage of transportation facilities handicaps the movement of products beyond a relatively small radius.

## Foreign Trade

For many years Guinea has suffered from a serious trade deficit. This deficit will probably continue for some time unless energetic measures are taken toward self-dependency and economic development programs. A comparison of imports and exports is given in Table V-1.

The principal exports of Guinea are bananas, coffee, diamonds, and alumina.

Table V-1 - Guinea's Foreign Trade, 1957-63
(GF millions)

| | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 |
|---|---|---|---|---|---|---|---|
| Imports | 12,600 | 15,300 | 15,300 | 12,300 | 18,000 | 16,200 | not |
| Exports | 7,200 | 5,700 | 7,200 | 13,600* | 15,200 | 11,100 | avail. |
| Balance | -5,400 | -9,600 | -8,100 | +1,300* | -2,800 | -5,100 | -4,000 |

* Restudy of 1960 export figures by the U.S. Embassy indicated that errors made in that year's trade figures would actually show a barely balanced account, if not an actual deficit.

Prior to 1959 three-quarters of the country's total value of exports were agricultural products and the remaining quarter were minerals. However, since that time, the composition of Guinea's exports has changed significantly. Agricultural commodities accounted for 62 and 40 percent of exports in 1959 and 1960, respectively, but only 32 and 30 percent in 1961 and 1962.

The main imports consist of machinery, cotton cloth, petroleum products, and rice. The value of agricultural imports in 1962 amounted to 18 percent of total imports, with rice being the most important, amounting to about 53 percent of total agricultural products.

The value of agricultural exports has exceeded that of agricultural imports in all recent years. However, in 1962 the difference was small because of large imports of rice and wheat flour.

Available data indicate that Guinea has become more dependent on imports to provide adequate food for her people, particularly rice and flour. Imports of rice amounted to approximately ten percent of domestic production in 1962. Although it is believed that domestic production of food has increased slightly in recent years, population appears to have increased at a greater rate. However, official statistics on this point may be misleading because it is suspected that important quantities of agricultural commodities are smuggled out of the country.

## Agricultural Production

Although mineral production has become increasingly important in Guinea's export trade, agriculture remains the foundation of the country's economy. Guinean agriculture is segmented into an export sector and a subsistence sector. The export sector is the plantation-type farming consisting mainly of bananas, palm nuts, peanuts, coffee, pineapple, and rubber. The major staple food crops produced on subsistence farms are cassava, rice, millet, corn, and sweet potatoes. Livestock production is important economically but cattle are of poor quality and pastures are seriously over-grazed. It is estimated that there are about 1,300,000 head of cattle in Guinea, mostly undersized bush animals.

It is the custom for farmers to be either a cultivator or a herdsman but not both. The grazing of livestock is free to cattle owners, who are usually nomad farmers.

Agricultural land in Guinea is held under three general types of ownership, each with distinct production practices and problems. Over 80 percent of agricultural land is farmed by the individual subsistence farmer. Individual holdings are generally small and crop yields are low. For the most part, these farmers have no cash surplus to spend on fertilizers or insect sprays. There is little money for even basic mechanization, although the majority of holdings are so small that mechanization would generally not be profitable. There is little understanding of crop rotation or proper land utilization. Burning of the vegetative cover to develop new fields is the usual practice. Imports of fertilizers go mostly to export crops.

The second type of ownership, that of the large commercial plantations, was introduced by the former colonial administration by issuing titles to land that was either not claimed or was tribal land not in use. These lands are used mostly for coffee and bananas.

The third general type of land ownership is a commercial kind of ownership, based on tribal affiliation. It is estimated that ten percent of the arable land in Guinea is tribal land, existing mainly in Upper Guinea and in the coastal region of Lower Guinea. The land is owned in common by tribal groups but is divided into small plots and farmed by individual families. In practice, plots remain with the same family from generation to generation.

Much of the deficiency in agricultural production stems from the social condition of the average farmer. Lacking capital and training,

he barely succeeds in feeding himself. However, one of the most important factors holding down productivity is the high incidence of crop diseases. For this reason, serious failures have occurred in recent years for many crops.

Economic development programs for Guinea have recently been adopted by the Government with heavy emphasis on an increase of agricultural production. A Ministry of Rural Economy was organized in January, 1961, to carry out the proposed agricultural programs. Development is to be concentrated on the reorganization of land tenure into cooperative holdings to the greatest extent possible, most of them to be owned either by the state or by commercial organizations. Production centers have been organized for the principal crops with emphasis on export crops. The Ministry of Rural Economy plans to furnish each of about 5000 villages with agricultural tools and machinery not now available.

## Rice Production

Estimates of total production of rice in Guinea are presented in Table V-2. Total production in 1962 was approximately one-third higher than in 1952-53, however, there has been practically no change since 1957-58. On the basis of a per capita index, rice production has consistently declined since 1958.

It is estimated that approximately 240,000 hectares of land are devoted to rice. The yield of rice is extremely variable but averages less than 1.5 tons of rice paddy per hectare.

Table V-2 - Production of Rice in Guinea

(rice paddy)

| Year | Total Production (metric tons) | Production Index (percent) | Per Capita Production Index (percent) |
|---|---|---|---|
| 1952-53 and 1954-55 (ave.) | 243 | 100 | 100 |
| 1957-58 | 312 | 128 | 113 |
| 1958-59 | 299 | 123 | 106 |
| 1959-60 | 319 | 131 | 109 |
| 1960-61 | 320 | 132 | 108 |
| 1961-62 | 320 | 132 | 104 |

## Food Requirements

Guinea is the third largest producer of rice in Africa, after Egypt and Madagascar, yet is unable to meet her own consumption requirements. Annual imports have increased consistently from about 7000 tons in 1959 to 30,000 tons in 1962 (polished rice). It is estimated that approximately 35,000 tons will be imported in 1963.

Much of the rice imported in recent years came from the United States. The quantity imported in 1962 under the surplus commodity program authorized by U.S. Public Law 480 amounted to almost 27,000 metric tons.

Rice is the basic staple in the average Guinean diet. It is estimated that each person consumes food equivalent to 2100 to 2400 calories per day of which almost 50 percent is supplied by rice.

Table V-3 - Guinea's Import of Rice

| Year | Metric Tons |
|---|---|
| 1959 | 7,000 |
| 1960 | 20,000 |
| 1961 | 25,000 |
| 1962 | 30,000 |
| 1963 | 35,000 1/ |

1/ Estimated on basis of present trade agreements.

On the basis of production estimates plus imports, the consumption of rice per capita has increased consistently during the past 15 years. Consumption of milled rice was computed at 170 grams per day in 1948 but increased to 220 grams in 1953, and 230 grams by 1962. It is expected that consumption per capita will continue to increase if adequate supplies are available.

As was seen in Table V-2, production per capita has consistently decreased since 1958. Unless this downward trend is reversed, the national deficit of rice will continue to rise and increasing amounts of imports will be required to meet the increasing demands of a growing population. At current consumption rates, an annual increase in supply of over 20,000 tons is necessary to meet requirements for the increase in population. This situation could easily become more critical if the rate of population growth exceeds the present rate of three percent per annum. This appears now highly probable.

Among the ricelands presently under cultivation in Lower Guinea, only those located in the valleys of the Konkoure or the Forecariah rivers produce relatively high yields. The large flows of these rivers prevent the intrusion of salt water on the land during the growing season, and yields of over four tons per hectare are not rare.

Most of the other ricelands in Lower Guinea suffer from excessive flooding during the wet season by fresh water due to lack of drainage or from salinity by salt water intrusion during high tide. The cultivators have attempted to reclaim some of these areas by construction of dikes and drainage channels but yields still are generally very low. Although reclamation of most of these lands is technically possible, the magnitude of the work involved is beyond the financial and physical capabilities of the cultivators.

Most of the rice is produced by antiquated hand methods, but attempts by the government are being made to mechanize and improve cultural practices. Present efforts are concentrated on reorganization of land tenure into cooperative holdings owned by the State or communal organizations (C. A. P.). To assist the cooperatives, Centers of Rural Mechanization (C. M. R.) are being established. These are, in effect, combination experiment stations, machinery pools, and land agent services. It was announced in March, 1962, that 295 cooperatives, and 27 C. M. R. 's had been established. Machinery and equipment are being imported, including about 400 tractors. The C. M. R. 's are operating rice enterprises by force account, mostly on new reclaimed land.

Though progress is being made, total production of rice from C. M. R., C. A. P., and private enterprises have fallen short of established goals. Primary problems are associated with lack of trained

Table V-4 - Estimated Production of Rice for Guinea and Lower Guinea, 1947-49 and 1952-54

(metric tons)

| Area | 1947-49 | 1952-54 |
|---|---|---|
| Guinea | | |
| Mountain rice | 100,000 | 140,000 |
| Plain or marsh rice | 75,000 | 103,000 |
| Total all Guinea | 175,000 | 243,000 |
| Lower Guinea | | |
| Mountain rice | 24,000 | 23,000 |
| Plain or marsh rice | 25,000 | 36,000 |
| Total for Lower Guinea | 49,000 | 59,000 |

Although the production from marsh lands in Lower Guinea is presently a relatively small portion of the total Guinean production, it is in this coastal zone that the potential for increasing rice yields is the greatest. Heavy precipitation during the wet season from June to November permits the culture of one annual crop of rice without irrigation. The soils, composed mainly of heavy alluvial clays, are for the most part fertile and suited for rice production.

Because of their low elevation, these areas are poorly drained during the wet season and subject to the influence of salt water during high tides. The potential amount of riceland in Lower Guinea has been estimated at about 150,000 hectares of which 90,000 hectares are below sea level. Approximately 50,000 hectares are now sparsely cultivated. In recent years, 8000 hectares have been reclaimed and are being cultivated by methods generally adapted to local conditions, although this varies considerably from one area to the next.

and the seed bed is prepared by mere scratching of the surface with simple native grubbing hoes. The seed is planted in primary beds in June or early July, depending on flooding conditions, and after about six weeks, the seedlings are transplanted to the paddy. Harvesting is done in about 145 days after planting, usually in November-December.

The value of weeding is recognized and weeds are apparently not a serious problem. Generally several families work together and go from one field to another, cleaning out and destroying the weeds. After the rice is in head, the fields are guarded by watchers to scare away birds. Losses caused by animals are significant.

The rice is cut by hand with a sickle or knife. Usually, only the heads are cut, leaving stubbles about eight to ten inches long which are subsequently burned-off in preparation for the next crop. The rice is carried by women on their heads, usually to the native village, where it is dried and threshed. Threshing is done with flails and the straw separated from the rice by tossing it into the air. Hulling is accomplished by placing small amounts at a time in a crude basin hued out of a log and then pounding with a stick or pole. The rice kept for home use is stored in the family hut, with the portion kept for seed usually better protected against insects than the rice used for food. The rice storage problem will become more critical as production increases.

Modern methods of controlling diseases and insects are not used. Frequently, complete crop failures are experienced and in most every year some damage and loss in production occurs. Since fertilizers are not used, yields diminish rapidly after two or three years of continuous cropping. The cultivator then moves to paddies that others have left, or to new land, allowing the old paddy to remain out of production for a

personnel, machinery parts, fertilizers, and storage facilities, with losses from diseases and insects; and with poor cultural practices. Much of the machinery that has been imported is useless because of being unsuited to local conditions and because of lack of mechanics, trained operators, and spare parts for machinery.

Practices in the Project Area

As in most ricelands of Lower Guinea, widespread flooding by fresh water during the wet season and, to a certain extent, by salt water during high tides is the major limitation to rice production in the Koba area. Little, if any, increase in production through improved management and cultural practices can be expected without first introducing an effective control of flooding. Excessive flooding by fresh water is common to the entire plains, while flooding and intrusion of sea water is confined to specific areas, thus resulting in varying degrees of soil salinity. The lands adversely affected by salinity from tidal flooding are shown on Exhibit 2.

The cultivators have adopted rice production practices which reflect influences of the flooding, and of age-old cultural practices. The Mamoussou variety is grown on the more saline areas, while the Malock variety is grown on the less saline areas. Thus, Mamoussou would be the major rice variety in the early development stage, especially on the lands designated IV, V and VI on Exhibit 2.

Nearly all of the rice in the project area is produced in small paddies, mostly for subsistence for the cultivator and his family. With the exception of clearing the land and preparing the seed bed, most of the work is performed by women. Clearing is accomplished by burning,

cultivators themselves do not have sufficient information to even estimate their average yield per hectare. The only published yield data are estimates provided by local officials for the entire Region of Boffa. In 1962, a total of 11,500 hectares produced 13,431 metric tons, or 1167 kilograms per hectare, in the Administrative Region of Boffa.

Our estimates of yields presently obtained in the Koba area are shown in Table IV-3. Estimated production from each of the areas delineated on Exhibit 2 is given in Table V-5. The total production from the cultivated area of 970 hectares is 1450 metric tons, or an average of about 1500 kilograms per hectare.

Table V-5 - Estimated Crop Yields and Total Production of Rice on Project Lands

| Present Land Use Designations | Cultivated Riceland (hectares) | Average Yield (tons per ha) | Total Production (tons) |
|---|---|---|---|
| I | 590 | 1.8 | 1070 |
| II | - | - | - |
| III | - | - | - |
| IV | 380 | 1.0 | 380 |
| V | - | - | - |
| VI | - | - | - |
| Project Area | 970 | | 1450 |

These estimates are based on interviews with local cultivators and government officials acquainted with the area, and on personal knowledge of the productivity of rice as evaluated by such factors as thickness of stands, extent of salinity and productive capacity of the soil, known performance of existing varieties, and estimated losses from diseases, insects, etc.

year or so, and then eventually moving back or leaving it to another family to cultivate. Although government officials indicated that there is ample land for the local population at the present time, it seems to be increasingly difficult to obtain plots that have been out of production long enough to regain the original fertility.

## Transportation and Markets

The surplus rice above the family's need for food and seed is bartered for other products among the natives, or sold to government stores, called "Comptoirs." No Comptoir is located on the island of Kakossa, and much of the excess rice is exchanged among the inhabitants. As modern means of transportation and even animal-drawn wheeled vehicles are not available, the rice is carried on a man's head in bags weighing up to 50 kilograms to the nearest village. Walking distance may be as much as ten kilometers.

Until recently (September, 1963), the government of Guinea, through the Comptoirs, was in charge of distribution between regions. Private traders are now authorized to handle inter-regional commerce. The government sets the price to be paid the cultivator for the rice, usually prior to planting time, and presumably on the basis of supply and demand conditions existing throughout the country. The Comptoir also acts as the retailer and sells rice at prices set by the Government, as well as private traders.

## Present Production

Statistics on actual yields of rice on the project lands are lacking. Estimates by cultivators and local officials vary considerably, mainly because the exact area or the production are seldom measured. The

efficient operation. Additional forage for grazing of livestock will be available as a result of the enlarged and more productive cultivated area. Although rice cultivation and livestock raising are not integrated operations, the opportunity for integration will be improved as the lands will be more adaptable to systematic rotation with crops that are now restricted because of flooding and salinity conditions.

It is expected that a few years will be required after the project is in operation before the full productive potential is attained. Numerous changes and improvements in cultural practices are necessary which will take considerable time even if extension and research programs and financial assistance to the cultivators are available.

Estimates have been made of the production potentials due to drainage and reclamation and to anticipated technological advancements for 20 years after the project is in operation. Estimates of yields, cropping intensities, and crop rotations were analyzed for four five-year time intervals over this period. Progressively higher crop yields corresponding to consistent improvement due to drainage and gradual reduction in salinity, increasing use of fertilizers, better seed, mechanization, plant protection, and systematic crop rotations were assumed.

## Rice Submergence Criteria

The lands in the project area are flat and surface drainage toward the marigots is effected on small natural slopes. It would not be economical to design the drainage system so as to avoid occasional submergence of the rice plants in the paddies. Consequently, it was determined to what extent rice plants could be submerged without being damaged.

Rice, when still in the vegetative stage of growth, can be completely submerged in clear water for short periods of time without being

The characteristics of the soil, as affected by salt water and shortage of water during the dry seasons, limit production to one crop per year. Provision of water from surface or underground storage during the dry season would enable double cropping. This possibility is beyond the scope of this investigation but does not appear to be feasible in this area.

## Anticipated Project Production

### Methods of Improving Production

Without provisions for drainage and reclamation of saline soils, production of rice on the project lands will remain at low levels. With proper drainage and reclamation of saline soils, lands now only partially productive and most of the non-productive swampy lands will be capable of full production. Sustained production is possible providing adequate fertilizers are added and systematic rotations are introduced. Large increases in total production of rice will be possible as a result of: (1) bringing swampy and marshy lands into full production, (2) increased yield from varieties better adapted to well drained and non-saline soils, and (3) more intensive use of lands presently cultivated.

Early transplanting of the rice to take advantage of the frequent but not too excessive rains at the end of the wet season will insure adequate good quality water for the rice, encourage maximum rice production and an early harvest. An adequate supply of good quality water is essential, especially in areas where salinity is a problem, as it is in some parts of the Koba project area.

New and fertile riceland will be provided for additional cultivators, and existing plots could be enlarged to permit mechanization and more

then taller and precipitation is less intense. Flooding of the lands that may have occurred in August will be relieved by the drainage system shortly after its occurrence.

The implication of the above submergence criteria is that direct seeding in the fields will not be possible without risk of losing the crop. The use of seed beds and transplanting when the plants are about 30 centimeters tall will be necessary. Although this method requires additional labor, it is believed that the yields can be higher than those obtained from direct broadcasting.

## Projected Crop Yields

Rice yields that can reasonably be expected over the 20-year development period have been presented in Table IV-3. For the first crop-year after the project is in operation, an average yield increase from 0.5 to 1.5 tons per hectare is expected. Most of this increase would be attributable to the improved drainage conditions, with little change from cultural practices or from reduction in soil salinity anticipated.

It is believed that five years will be required to leach the saline soils by alternate flooding and drainage from natural rainfall. At that time production levels equal to those presently obtained on non-saline soils could be realized. It is estimated that yields will be increased by 0.8 to 2.5 tons per hectare during this time, most of which would be attributable to the combined drainage and reclamation program. The average yields estimated with the project are similar to those obtained on well drained and non-saline soils using present cultural practices. With drainage and reclamation, higher yielding non-saline tolerant rice

seriously affected insofar as production of seed is concerned, if the water is moving around the plants. The rice plants will withstand intermittent periods of complete submergence for about four days provided that the water level is subsequently lowered to about one-half of the plant height for at least four days before complete submergence occurs again. An allowable cycle of submergence following these principles has been shown graphically on Exhibit 5. It was assumed that before initial submergence the rice plants would be about 30 centimeters tall, which is about the plant height when they are transplanted from the seed beds to the paddies.

If the rice is planted on butts or ridges that are 25 centimeters high, as is presently the practice in Lower Guinea, the allowable water surface elevations can be correspondingly higher.

These criteria are based on the fact that light penetrating shallow depths of clear water will enable the process of photosynthesis to continue. The criteria apply to water allowing at least 70 percent of light transmission. When sediments are in suspension, the allowable depth of submergence or the length of the period of submergence must be reduced.

The time of change from vegetative stage of growth to the reproduction cycle of the rice plant occurs from 70 to 80 days after seeding. After the rice plant has entered the reproduction phase, it rapidly becomes more susceptible to excess flood water. This is particularly true during the period starting two weeks before the panicle emerges and ending two weeks after panicle emergence.

However, taking into account the fact that this generally occurs in September, this period does not appear to be critical. The plants are

Table V-6 - Projected Crop Land Use and Cropping Intensity

(in percent)

| Crops | Number of Years After Reclamation 1 | 5 | 10 | 20 |
|---|---|---|---|---|
| Rice | 67 | 67 | 67 | 67 |
| Lespedeza* | - | 8 | 15 | 20 |
| Maize* | - | - | 3 | 9 |
| Grain sorghum* | - | - | - | 4 |
| Percent cultivated | 67 | 75 | 85 | 100 |

* Or equivalent legume forages and grain crops.

## Projected Agricultural Production

Total production anticipated for various time intervals after the project is in operation are summarized in Table V-7. These estimates are based on average yields for rice given in Table IV-3. The gross reclaimed area has been reduced by ten percent to allow for land utilized by dikes, levees, and drainage channels from which no production will be obtained. The net reclaimed project area is 3710 hectares.

Table V-7 - Estimated Total Agricultural Production with the Project

(metric tons)

| Years | Crop: Rice Ha. | Rice Prod. | Lespedeza Ha. | Lespedeza Prod. | Maize Ha. | Maize Prod. | Grain Sorghum Ha. | Grain Sorghum Prod. | Idle Ha. | Total in Prod. (ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2215 | 3760 | - | - | - | - | - | - | 1110 | 2215 |
| 5 | 2475 | 5930 | 310 | 3100 1/ | - | - | - | - | 925 | 2785 |
| 10 | 2475 | 7450 | 560 | 5600 1/ | 95 | 190 | - | - | 580 | 3130 |
| 20 | 2475 | 9170 | 740 | 7420 1/ | 310 | 770 | 185 | 370 | - | 3710 |

1/ Equivalent green weight.

## Land Settlement

There is no specific national or regional policy for selection of settlers for the new project lands after reclamation. Assuming an average of six-hectare farm units, sufficient land would be available to support 618 families. This would be equivalent to an addition of 365 units over those in existence at present.

Local officials anticipate no problems in getting voluntary movement of families from other areas immediately upon completion of the project. There is also the possibility that cooperatives may be developed to operate large sections of land with the help of mechanization. However, for the purpose of analysis, it is assumed that the lands would be settled for subsistence farming in units averaging six hectares each.

varieties will replace the low-yielding varieties. Also, increased yields will be possible because rapid drainage will permit better timing of planting and control of the fresh water supply. Improvements in cultural practices, fertilization, etc. are expected to be slow and will, therefore, not be significant factors towards increasing yields during the initial five-year period. Allowances for nominal applications of fertilizers, particularly phosphorus, were made in estimating probable yields and costs of production. Progressive increases due to these improvements are practical after this time up to 20 years after the project is in operation.

The potential for continued increases due to improvements in cultural practices is great. These will not occur, however, without technical assistance from agronomists working with the farmers and financial assistance to obtain fertilizers, insecticides, etc. It has been assumed that this assistance will be provided as an integral part of the reclamation program after the project is in operation.

## Anticipated Land Use and Crop Rotations

The anticipated land use, cropping intensities, and cropping rotations for each five-year period are presented in Table V-6. We have assumed a three-year rotation with rice occupying two-thirds of the cultivated land area but with increasing amounts of other crops occupying the remaining one-third of the land. The cropping intensity is expected to increase gradually from 67 to 100 percent. A cropping intensity of 100 percent will be possible sooner than 20 years if ample technical and financial assistance is available to the cultivators.

# Chapter VI

# PROJECT DESIGN

## Introduction

In 1955 the French consulting firm COTHA conducted field investigations for the purpose of collecting basic hydrologic, topographic and other data relative to conditions in the Koba plains. On the basis of these data, they later prepared detailed construction drawings and cost estimates for the canal and structures needed to reclaim the potential ricelands. The French Colonial Administration withdrew from Guinea in 1958 before bids could be taken for construction of the civil engineering works.

The basic concept of the COTHA plan of reclamation consisted of drainage of the plains in a southerly direction toward the Marigot de Kabelea and protection of the project area against tidal intrusions by dikes and a gated control structure. This concept was reviewed within the scope of the studies reported herein, and found to be sound. Consequently, this plan was preserved in principle. However, a review of the hydrologic design criteria developed by COTHA indicated that the drainage facilities would not be adequate. Extensive engineering studies were performed to develop satisfactory design criteria and determine the dimensions of the canal and structures required to insure proper control of flooding in the project area.

## Water Supply

### Consumptive Use Requirements

An estimate of the consumptive use requirements of rice was made on the basis of evaporation recorded at Koba and the results of systematic

experiments made by the Rice Pasture Experiment Stations, Beaumont and Eagle Lake, presented in a report of the Texas Board of Water Engineers.[1/]

Monthly evaporation data for Koba are presented in Table VI-1. These data indicate relatively low rates of evaporation during the wet season, probably due to the high relative humidity that prevails at that time.

Table VI-1 - Measured Monthly Piche Evaporation at Koba in millimeters - 1961

| | | | |
|---|---|---|---|
| February | 67 | July | 33 |
| March | 87 | August | 25 |
| April | 78 | September | 36 |
| May | 76 | October | 45 |
| June | 55 | November | 48 |

To arrive at maximum monthly evaporation at Koba comparison was made with the data recorded at Conakry-Aviation from 1949 through 1962.[2/] It was found that the evaporation data recorded at Koba in 1961 should be increased by 37 to 80 percent to obtain the maximum evaporation. The values applicable to each month are shown in Table VI-2.

Although Piche measured evaporation is somewhat higher than the theoretical lake surface evaporation, data derived from measured

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1/ "Consumptive Use of Water by Major Crops in Texas," Bulletin 6019, by Louis L. McDaniels, Texas Board of Water Engineers, November 1960.

2/ Table VI-1, page VI-4, "Feasibility Report on Riceland Reclamation in Guinea, Kakossa Project," by the Harza Engineering Company, February 1964.

evaporation were used without correction. These maximum evaporations were multiplied by the use coefficients (KU) found by the Texas experiment stations for the corresponding stage of growth, except that the June coefficient was used for the month of July, for conservatism. The results are summarized in Table VI-2.

Table VI-2 - Estimated Consumptive Use Requirements of Rice in Koba Plains

| Month | June | July | Aug. | Sept. | Oct. | Nov. | Total |
|---|---|---|---|---|---|---|---|
| Maximum evaporation measured at Conakry | 78 | 48 | 39 | 54 | 72 | 78 | |
| Monthly evaporation measured in 1961 at Conakry | 51 | 27 | 24 | 30 | 48 | 57 | |
| Ratio of maximum evaporation to 1961 evaporation at Conakry | 1.53 | 1.78 | 1.63 | 1.80 | 1.50 | 1.37 | |
| Monthly evaporation measured in 1961 at Koba | 55 | 33 | 25 | 36 | 45 | 48 | |
| Estimated maximum evaporation at Koba, mm | 84 | 59 | 41 | 65 | 68 | 66 | |
| Use coefficient (KU) | 1.8 | 1.8 | 2.0 | 1.5 | 1.0 | 1.6 | |
| Consumptive Use Requirement, mm | 151 | 106 | 82 | 98 | 68 | 105 | 610 |

## Available Moisture Supply

It is generally accepted that the moisture available from natural rainfall over the Koba plains is sufficient for the cultivation of one crop of rice. This belief is based on the heavy precipitation that occurs during the growing season that extends from July through December. Rice generally requires from 1000 to 1500 millimeters of rain from seeding time to harvesting. Annual precipitation at Koba in the period of record 1954 to 1961 varied between about 4600 and 3500 millimeters. It would appear, since most of the annual precipitation occurs during the wet season, that the wet season rainfall is well in excess of the requirements for rice cultivation.

It is reported that unusually dry years result in lower rice production in some parts of Guinea. Apparently, this has not been a common occurrence in the Koba plains because the lack of drainage causes the water to pond for an extended period of time, thus storing all the water needed for the growth of rice. As a matter of fact, decreases in production in this area are more likely to result from excessive rainfalls, such as happened during the 1962 wet season. This condition will be corrected by construction of the proposed drainage facilities. It is important, therefore, to determine whether the expected rice production will be affected by possible droughts.

A temporary rain-gaging station was installed by COTHA in 1955 at Bakoumpo. Readings were obtained for the period from May through December of that year. The correlation of monthly and annual records at Bakoumpo and Koba to that of Forecariah indicated that Bakoumpo precipitation is about 84 percent of that at Koba. Since the period of comparison was the same as that available to COTHA in 1956 (the

Bakoumpo station was discontinued in 1956) much the same result was obtained. Consequently, Koba precipitation was reduced by 15 percent to obtain estimates of precipitation at Bakoumpo.

Rainfall distribution recorded in 1955 was selected for the investigation of possible effect of droughts. The annual precipitation recorded in 1955 at Koba was about 4000 millimeters. While this seems to be about an average annual figure, nevertheless the drought period, from Bakoumpo readings, is the most critical on record.

A mass curve of cumulative rainfall at Bakoumpo for the months of October and November was drawn, as shown on Exhibit 5. The mass curve shows that an average daily rate of eight millimeters could be sustained until the end of November, provided that a storage of 25 centimeters is available. This can be accomplished easily since the rice fields are surrounded by levees generally 30 centimeters in height, and cultural practice consists of storing water in the paddies until the beginning of November for the purpose of preventing the growth of weeds and storing water between rainfall periods. Towards the end of November, the paddies are drained in anticipation of harvesting.

## Adequacy of Water Supply

The consumptive use requirements of rice, including evapotranspiration, was estimated (Table VI-2) to be 2.0 millimeters per day in October and 3.0 millimeters per day in November. This would leave about four or five millimeters per day for losses by percolation. This is considered adequate, considering the properties of the soils as indicated by the permeability tests and the high groundwater table. Therefore, a recurrence of conditions as severe as the 1955 drought would not result in any deficiency of water supply.



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It is concluded from this study that the water supply available from natural rainfall is sufficient for cultivating rice in paddies in the Koba plains.

## Drainage Requirements

### General

The plan developed in 1958 by the consulting engineering firm COTHA for the reclamation of the Koba plains was designed to dispose of the runoff corresponding to a total precipitation of 332 millimeters in six days over the drainage area. They considered this precipitation to have a recurrence of once in five years.

Criteria for allowable flooding of rice were developed, as explained in Chapter V, for the purpose of the present studies. These criteria are:

(a) rice can be submerged without undue damage for a period of not more than four days;

(b) after submergence, the water level in the paddies must be lowered so as to leave 15 centimeters of the rice plants above water within a period of not more than five days; and

(c) the water level must not be allowed to rise above this level for a period of not less than four days, after which a new submergence can be tolerated.

On the basis of these criteria, the distribution of rainfall over a period of 15 days had to be considered. Therefore, an analysis of rainfall records was made to determine whether the proposed drainage system would have a discharge capacity sufficient to satisfy the above

conditions in the event of a storm that could be expected to occur reasonably often.

Design Precipitation over the Project Area

COTHA Studies. COTHA observed that the watershed draining into the plains consisted of the following areas:

(a) 750 hectares where rainfall conditions could be represented by those recorded at the Koba gaging station; and

(b) 3450 hectares where rainfall conditions could be represented by those recorded at the Bakoumpo gaging station.

COTHA's approach to cumulative precipitation was to determine the five-year rainfall at Koba and Bakoump. The short period during which rainfall was recorded at these two stations did not permit a direct statistical study. Consequently, in the COTHA study, the Forecariah records for a period of over 30 years were investigated and the magnitude of precipitation with a five-year recurrence interval was determined. A correlation between the Forecariah rainfall and the Koba and Batoumpo rainfall was then established for the respective short-term concurrent periods of record of two years and one year. From this, the five-year rainfall over the project area was estimated.

The details of the COTHA analysis were conducted as follows. The one-day, two-day, three-day, five-day, and ten-day precipitations at Forecariah as recorded from 1923 through 1955 were ranked in order of magnitude. The frequency of each event was determined, and frequency was plotted against precipitation for each of the number of consecutive days mentioned above. The precipitation corresponding to a

five-year recurrence interval was obtained, as well as the ten-year precipitations. These were plotted against the number of consecutive days, and rainfall-duration curves with a frequency of once in five years and once in ten years were determined.

The rainfall at Koba was correlated with that at Forecariah on the basis of the 1954-55 precipitation records for both stations. Comparisons were made of June, July, and August monthly accumulations and individual storms for one to ten days. On the average, the precipitation at Koba was found to be 14 percent greater than that at Forecariah.

A similar correlation was made on the basis of the 1955 precipitation records at Bakoumpo and at Forecariah. From this analysis it was concluded that the precipitation at Bakoumpo was four percent smaller than that at Forecariah.

The values of the five-year precipitation at Forecariah were then adjusted on the basis of the above percentages. The resulting values, applied to the appropriate area of the watershed of which they were representative, yielded an average rainfall-duration to which a recurrence interval of five years was assigned. The corresponding values are summarized in Table VI-3.

Table VI-3 - Five-Year Storm as Developed by COTHA, in millimeters

| Number of Days | Cumulative Precipitation | | |
|---|---|---|---|
| | Koba | Bakoumpo | Average Over Project Area |
| 1 | 176 | 148 | 153 |
| 2 | 235 | 198 | 204 |
| 3 | 276 | 233 | 240 |
| 4 | 314 | 264 | 273 |
| 5 | 348 | 293 | 303 |
| 6 | 378 | 320 | 332 |
| 7 | 405 | 342 | 354 |
| 8 | 436 | 368 | 380 |
| 9 | 460 | 388 | 402 |
| 10 | 490 | 412 | 426 |

Review of COTHA Studies. It became apparent in the course of our investigations that the results obtained by COTHA should be revised, for the following reasons:

(a) The duration of the Koba and Bakoumpo records available to COTHA, on which their correlation was based (two years and one year, respectively) was extremely short and advantage could now be taken of additional length of records.

(b) The distance between the project area and Forecariah is about 90 kilometers, and the rainfall geographic distribution pattern varies greatly between the two areas which are being compared. Consequently the validity of a rainfall relationship between the project area and Forecariah is questionable. The weakness of the correlation may be indicated by the wide range of the individual relationships from which average values were derived by COTHA:

| | Range | Average |
|---|---|---|
| Ratio of Koba rainfall to Forecariah rainfall: | 0.76 - 1.48 | 1.14 |
| Ratio of Bakoumpo rainfall to Forecariah rainfall: | 0.75 - 1.28 | 0.96 |

(c) The storm adopted by COTHA as having a five-year recurrence interval was exceeded three times at Bakoumpo during the single year of record, and seven times at Koba during its two years of record, as shown in Table VI-4.

Table VI-4 - Comparison of the COTHA Five-Year Storm with Storms Recorded in the Project Area

| | Date of Storm Beginning | Storm Duration (days) | Precipitation (mm) | Design Storm (mm) |
|---|---|---|---|---|
| a) Koba | July 3, 1954 | 6 | 389 | 378 |
| | July 14, 1954 | 10 | 599 | 490 |
| | August 10, 1954 | 10 | 792 | 490 |
| | August 25, 1954 | 7 | 661 | 405 |
| | July 23, 1955 | 10 | 739 | 490 |
| | August 9, 1955 | 10 | 631 | 490 |
| | July 11, 1955 | 8 | 441 | 436 |
| b) Bakoumpo | July 11, 1955 | 7 | 482 | 342 |
| | July 23, 1955 | 10 | 613 | 412 |
| | August 11, 1955 | 6 | 368 | 320 |

Estimate of a Ten-Year Storm by Correlation with Boffa. The following basic data relative to the project area were available to the Harza Engineering Company for the purpose of their studies:

(a) daily rainfall at Bakoumpo for 1955

(b) daily rainfall at Koba for 1954, 1955, and 1961

(c) monthly rainfall at Koba for 1954 through 1961

(d) monthly rainfall at Boffa for 1950 through 1963

From these records an actual storm was selected to form the basis for a trial design storm of a ten-year frequency. For this purpose, the rainfall records for the Boffa station were first reviewed. The station of Boffa was selected because of its proximity to Koba (25 kilometers) and because of the similarity between the rainfall patterns at the two localities. The ten-year July precipitation at Boffa

was calculated to be 1230 millimeters. The average July precipitation at Boffa for the 1954-61 period was found to be 950 millimeters. It was concluded therefrom that the ten-year July precipitation at Boffa would be approximately 30 percent larger than the average July precipitation at Boffa for the period 1954-61 (concurrent with the period of record at Koba).

It was assumed that the same relationship would apply to Koba, where the average rainfall for the months of July from 1954 through 1961 was 1404 millimeters. The ten-year monthly rainfall at Koba would, therefore, amount to 1.3 x 1404, or approximately 1825 millimeters. The rainfall recorded at Koba in July, 1961 was 2096 millimeters. It was thus concluded that this precipitation, reduced by about ten percent, would be representative of a ten-year event.

Consequently, the storm of July 4, 1961 for which daily data at Koba were available, was used to arrive at an estimated ten-year intensity. The corresponding rainfall-duration data are indicated in Table VI-5. It may be noted that the six-day cumulative precipitation is about 70 percent greater than that selected by COTHA for Koba, which was shown in Table VI-3.

The short duration of the period of record involved cast some doubt on the accuracy of this approach. Moreover, there is some question as to whether the intense precipitation that has occurred in July could reasonably be expected to occur after August 1, which is the approximate date of transplanting rice from the seed beds into the paddies. Consequently, this approach was supplemented by another study to develop a design storm applicable to the project area.

Table VI-5 - Storm of July 4, 1961 at Koba

| Duration (days) | Cumulative Precipitation, in mm: As Recorded at Koba | Cumulative Precipitation, in mm: Reduced by 10% to Represent a 10-Year Storm |
|---|---|---|
| 1 | 344 | 310 |
| 2 | 398 | 358 |
| 3 | 473 | 426 |
| 4 | 499 | 449 |
| 5 | 598 | 538 |
| 6 | 719 | 647 |
| 7 | 820 | 738 |
| 8 | 937 | 843 |
| 9 | 990 | 891 |
| 10 | 1066 | 959 |
| 15 | 1273 | 1145 |

Analysis of Storms Over the Project Area. An examination of the Koba records revealed that two intense storms were recorded in August and September, 1954. These storms began on August 10, 1954 and August 24, 1954 respectively. In the three years 1954, 1955, and 1961 they were second only to the July 4, 1961 storm. It was decided to use these two storms as a basis for developing a design storm over the project area, regardless of their frequency.

An examination of the 1955 records for Koba and Bakoumpo indicated that precipitation at Bakoumpo was generally 15 percent smaller than at Koba. Accordingly, the Koba precipitation was reduced by 15 percent to obtain the rainfall considered representative of conditions in the Koba plains.

The rainfall recorded during the storm of August 10, 1954 at Koba, reduced to the Koba plains, is presented on Table VI-6.

Table VI-6 - Estimated 15-Day Precipitation, in the Koba Plains, Obtained from August 10, 1954 Koba Storm Pattern

| Number of Consecutive Days | Cumulative Precipitation in Consecutive Days (mm) | Incremental Precipitation (mm) |
|---|---|---|
| 1 | 200 | 200 |
| 2 | 309 | 109 |
| 3 | 377 | 68 |
| 4 | 420 | 43 |
| 5 | 459 | 39 |
| 6 | 480 | 21 |
| 7 | 562 | 82 |
| 8 | 618 | 56 |
| 9 | 661 | 43 |
| 10 | 674 | 13 |
| 11 | 681 | 7 |
| 12 | 699 | 18 |
| 13 | 767 | 68 |
| 14 | 833 | 66 |
| 15 | 950 | 117 |

It should be noted that the incremental daily values given in this tabulation are not necessarily in chronological sequence, although the cumulative values correspond to consecutive days.

The rainfall recorded during the 15-day period from August 24, 1954 through September 7, 1954 reduced to the Koba plains, is presented on Table VI-7. Also presented in this table for comparative purposes are the data corresponding to the August 10, 1954 storm.

Table VI-7 - Comparison of the Storm of August 24, 1954 as Adjusted to the Koba Plains, with the August 10, 1954 Storm Pattern

| Number of Consecutive Days | Precipitation of Storm from Aug. 24 - Sept. 7, 1954 (mm) | | August 10, 1954 Storm Pattern |
|---|---|---|---|
| | Daily Precipitation, in Chronological Order | Maximum Cumulative Precipitation for Consecutive Days | Cumulative Precipitation for Consecutive Days (mm) |
| 1 | 119 | 173 | 200 |
| 2 | 60 | 185 | 309 |
| 3 | 27 | 251 | 377 |
| 4 | 105 | 356 | 420 |
| 5 | 66 | 383 | 459 |
| 6 | 12 | 443 | 480 |
| 7 | 173 | 562 | 562 |
| 8 | 5 | 567 | 618 |
| 9 | 1 | 568 | 661 |
| 10 | 3 | 571 | 674 |
| 11 | 1 | 572 | 681 |
| 12 | 8 | 580 | 699 |
| 13 | 25 | 605 | 767 |
| 14 | 2 | 607 | 833 |
| 15 | 2 | 609 | 950 |

An examination of the last two columns of Table VI-4 reveals that he storms of August 10, 1954 and of August 24, 1954 have the ame seven-day precipitation of 562 millimeters. A seven-day intensity f 482 millimeters was recorded in 1955 at Bakoumpo considered repre- entative of the Koba plains. A comparison of the three storms is shown n Table VI-8.

Table VI-8 - Comparison of Three Storms for Koba Plains

(in millimeters)

| Number of Consecutive Days | Maximum Cumulative Precipitation for Consecutive Days | | |
|---|---|---|---|
| | August 10, 1954 | August 24, 1954 | July 11, 1955 |
| 1 | 200 | 173 | 107 |
| 2 | 309 | 185 | 202 |
| 3 | 377 | 251 | 279 |
| 4 | 420 | 356 | 331 |
| 5 | 459 | 383 | 351 |
| 6 | 480 | 443 | 430 |
| 7 | 562 | 562 | 482 |

## Design Storm for Koba Plains

On the basis of the above analysis, it was concluded that a storm pattern similar to that of the storm of August 24, 1954 should be the minimum for which the project would be designed. The values shown in Table VI-8 were adopted as those applying to the first seven days. This intensity appears to have been equalled once and exceeded another time in August, 1954. An intensity smaller by only about 15 percent was actually recorded in July, 1955. Although the frequency of these events are not known, their order of magnitude could be obtained by reducing by 15 percent the seven-day precipitation of 738 millimeters for Koba, as shown in Table VI-5, to obtain the corresponding value at Bakoumpo. This would yield 627 millimeters, as compared with 562 millimeters for the selected design storm. This gives further support to the August, 1954 pattern as the minimum for which the project should be designed.

After the seventh day, the following uniform daily rainfall values were adopted, on the basis of those shown in Table VI-6:

40 millimeters per day for days 8 through 11

50 millimeters per day for days 12 and 13

60 millimeters per day for days 14 and 15

No further adjustments were made to the values adopted for Bakoumpo, although part of the drainage area, represented by Koba station, would have higher rainfall. However, this difference would have a small effect on the average precipitation over the drainage area.

The storm pattern thus obtained is believed to reflect realistic meteorological conditions typical of a 15-day storm suitable for design purposes. The total cumulative rainfall would be about 950 millimeters. The distribution of this storm is shown graphically on Exhibit 5.

Excess Rainfall

Excess rainfall is defined as that portion of the rainfall that is not lost through evaporation or percolation. It corresponds to the amount of water that must be drained om the land or temporarily stored in the fields to be drained later.

An estimate of the evaporation that can be expected during the design storm was made on the basis of observations made by the National Meteorologic Service at Koba in August, 1961. The evaporation recorded at Koba in August, 1961 on a Piche evaporation gage was approximately 25 millimeters for the month. This amount was increased to 41 millimeters per month after comparing the maximum evaporation at Conakry Airport in August, over the period 1949-1962 to the value for August, 1961.

On the basis of the results of permeability tests made in the Koba area, percolation was estimated to be approximately 60 millimeters per

month. This amount may appear too low, particularly in view of the relatively pervious nature of the soils in the project area. On the other hand, the ground water table during the wet season is generally very close to the ground surface. In any event, no further refinement of estimated percolation losses was made because of the small magnitude of these losses relative to the rainfall itself. A nominal loss of 30 millimeters per month was assigned to plant use during submergence.

On the basis of these estimates the total losses would be about 130 millimeters per month. This was arbitrarily increased to 150 millimeters for design purposes. A total of 75 millimeters, uniformly distributed, was subtracted from the 15-day rainfall to obtain the excess rainfall. This is indicated graphically on Exhibit 5.

## Main Canal Design

### Water Level in the Paddies

The Koba plains lie between 1.3 and 2.4 meters above mean sea level, or between elevations 3.4 and 4.5 above the COTHA datum of reference. (The COTHA system of reference has been used exclusively in the design studies.) Detailed topography of the project area is shown on Exhibit B by contours at vertical intervals of 50 centimeters. This topographic map shows that, with the exception of small areas in the center and in the northwestern parts of the project area, all lands are at an elevation of 3.6 or higher.

The flooding criteria established in Chapter V, applied to fields located at an elevation of 3.6 meters, require that the water surface in these fields not exceed elevation 3.9 for more than four days, and that

thereafter it be brought back to a maximum elevation of 3.75 within five days, for a period of at least four days. In the fields located at a higher elevation, the flooding criteria can be satisfied if the head loss in the secondary and lower order canals does not exceed the difference in elevation between the ground elevation of the fields and elevation 3.6. The small areas located below elevation 3.6 may not benefit from the drainage facilities to the same degree as the remainder of the plains in the event of occurrence of a severe and prolonged storm. These areas must be accepted as being marginal for the sake of overall economy.

The main canal was designed to operate with a water surface at its upstream end varying between elevations 3.70 and 3.85. This condition corresponds to a water surface elevation in the nearby paddies varying between 3.75 and 3.90 allowing a head loss of five centimeters between the paddies and the main canal.

Tide Criteria

The capacity of the main drainage canal will be influenced by the elevation of the water surface in the Marigot de Kabelea, at the outlet of the main canal. Observations made in 1955 by COTHA led to the conclusion that the level of the Kabelea is practically not affected by the discharge of fresh water from runoff, but is dependent mainly upon the amplitude of ocean tides. This is confirmed by our observations at the proposed structure site. Where low tide elevation is below the stage of normal fresh water flow in the Kabelea, the amplitude is reduced. The results presented in Table III-3 illustrate these characteristics.

Because of close agreement between our observations in spot checks of tidal variations and those of COTHA, their records were

accepted as reliable. Neap tidal variations and elevations were averaged for the 1955 wet season. With the average high tide, low tide and amplitude known, the tidal cycle was plotted assuming a sinusoidal variation. Spring tides were similarly analyzed. The results are shown in Exhibit 5. The salient characteristics of the tidal cycles used for design purposes are summarized in Table VI-9.

Table VI-9 - Average Tidal Cycles at Proposed Control Structure

| | Spring Tides | Neap Tides |
|---|---|---|
| Average high water elevation | 4.3 | 3.4 |
| Average low water elevation | 1.5 | 1.8 |
| Average amplitude, in meters | 2.8 | 1.6 |

Since in about seven days spring tide amplitudes give way to those of neap tides, this variation was taken into account when determining the fresh water discharge through the gated control structure. Spring tide amplitudes were assumed to occur on the first day of the design storm. This chronological coincidence is considered to be a sound criterion for the method of design used, which is described later in this chapter.

## Gated Control Structure

As mentioned in Chapter II, a control structure provided with automatic flap gates, located across the main canal near the Marigot de Kabelea, was included as part of the plan of reclamation developed by COTHA in 1955-57.



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This structure is considered essential for the following reasons:

(a) It prevents refilling of the main canal with water from the Kabelea during high tides. This results in a larger average discharge capacity of the canal, appreciable in this case because of the flat topography.

(b) It controls salt water intrusion into the canal system during the dry season. As explained in Chapter V, this will result in an increased rice production, found to justify largely the cost of the control structure.

Although we agree in broad principle with the COTHA design, several details were modified in order to reduce the cost of the structure. In the COTHA design, the concrete structure was to be founded on steel sheet piles resting on bedrock. This necessitated the use of heavily reinforced floor slabs. Moreover, no bedrock was encountered during the subsurface investigation conducted by COTHA at the structure site. Our design involves wooden friction piles whose number can be reduced if rock is encountered. The savings in steel reinforcement to the floor slab will be appreciable. Furthermore, structural steelwork was replaced by reinforced concrete members. The erosion protection provided by COTHA, although effective, is not the most economical. We propose the use of precast concrete elements in wingwalls to the structure.

From the viewpoint of operation and maintenance COTHA's gates would present difficulties. They were to be located directly under the axis of the structure, and would not be accessible from the structure's deck. Moreover, any obstruction lodged in the gate opening would be difficult to remove from this position.

Under our proposed design the control structure will be provided with timber flap gates at the tidal side. Hydraulic investigations were

conducted to determine the size and number of gates that would result in an acceptable loss of head. It was found that seven gates each 2.5 meters wide by 4.0 meters high would cause head losses smaller than 0.2 meters. In addition, the flap gates would be able to close almost instantaneously upon reversal of flow, thus allowing only negligible amounts of salt water to enter the canal system.

Hydraulic Design of Main Canal

The discharge capacity of the main canal is increased from COTHA's requirement by virtue of the more severe design storm now developed. COTHA's analysis permitted the ponding of water in three basins along the route of the canal,at kilometers 0, 4 and 7. In their plan the discharge between and from these basins was calculated taking into consideration the fluctuation of a tidal cycle at Kabelea of coefficient 70. The water surface in the basin at kilometer 0 would vary during a tidal cycle between elevations 4.11 and 4.13, which would permit the effective drainage of the paddies located above elevation 4.0. About 500 hectares of land lie below elevation 4.0 in the vicinity of Kibassa and Kindiadi.

To afford a more efficient discharge from the area near Kibassa, it is proposed to abandon the scheme of three basins being allowed to form in the plains. The design presented in this report is based on effective drainage of all paddies above elevation 3.6. This insures adequate drainage of the 500 hectares that lie below elevation 4.0, as mentioned above. Using the same horizontal alignment as COTHA, the main canal will have a length of about 10,500 meters, a depth varying from 3.5 to 1.5 meters, and a bottom width varying from 48 meters near the control structure to 12 meters at the upstream end. Side slopes will be 2 horizontal to 1 vertical. The hydraulic characteristics of this canal

were determined, taking into account an expected sloughing of the banks to a stable slope of 4:1, as shown on the cross-section of the main canal presented on Exhibit 6. The invert of the canal at the gated structure was fixed at elevation 0.6 and a bottom slope of 0.133 meters per kilometer was adopted.

Water Surface Elevation in the Paddies

Hydraulic calculations were made to determine the performance, in the event of occurrence of the design storm of a canal having these dimensions. A table of canal bottom widths by station is given in Exhibit 6. The hydraulic characteristics of each reach of the canal were determined and the loss of head in the canal was estimated using a Manning friction coefficient of 0.030.

Backwater calculations were made to determine the discharge capacity of the canal as a function of (a) the water surface elevation in the Kabelea taking into account the head loss through the gated structure, and (b) the water surface elevation at the upstream end of the canal. The average canal discharge capacity was determined for two tidal cycles: the first corresponding to average spring tides; the second corresponding to average neap tides. The results are presented graphically on Exhibit 5, where the average canal discharge for each tide condition was plotted versus various upstream water surface elevations.

Using the discharge capacity curves shown on Exhibit 5, the variations of the water surface elevation in the paddies were calculated. The analyses were made for the critical case of the 15-day design storm occurring while water was ponded to elevation 3.75 in the paddies at the upstream end of the main canal. It was assumed that during the first day

of the storm, tides in the Kabelea would have average spring tide amplitudes, and that during the seventh day of the storm, they would have average neap tide amplitudes. The approximation that one-quarter of a lunar sycle is equal to seven days is deemed to be inconsequential in its effect on the accuracy of the analysis. The average canal discharges for tidal cycles between the first and seventh day amplitudes were interpolated from the graphs shown on Exhibit 5.

The variations of the water surface in the paddies, as found from the calculations, are presented graphically on Exhibit 5. Also shown on the same graph is the submergence criterion. A comparison of the two graphs indicates that in the event of occurrence of the design storm, the water surface in the paddies will rise to the top of the lowest rice plants after the end of the seventh day. Submergence will not occur. The level of the water surface in the paddies drops uniformly to about five centimeters above its normal operating elevation at the end of the eleventh day. It remains at about this elevation during the remaining four days of the storm. The calculations showed that should a similar storm occur with about 50 millimeters more rainfall on the first day the submergence criterion would still be met. However, any practical diminution of canal sections would result in submergence and the period of submergence would not be tolerable. This was demonstrated by analyses of alternative designs. Therefore, it was concluded that the proposed canal dimensions will be satisfactory for the purpose of maintaining flood levels in the paddies within safe limits during intense storms.

The maximum flow in the canal during discharge of the ponded volume was found to be about 48 cubic meters per second.

The resulting canal dimensions differ from those proposed by COTHA in bottom width, side slope, average depths of section and bed slope.

Comparative design criteria presented in Table VI-10 show the main reasons for the larger canal obtained from our design.

Table VI-10 - Summary of Criteria Affecting Main Canal Design

| Criterion | COTHA | Harza |
|---|---|---|
| 10-day design storm at Bakoumpo, in millimeters | 412 | 682 |
| Average tidal cycle: | | |
| high tide elevation | 3.80 | 3.44 (neap)<br>4.29 (spring) |
| low tide elevation | 1.65 | 1.79 (neap)<br>1.50 (spring) |
| Minimum ground elevation of paddies to which effective drainage will be provided | 4.0 | 3.6 |

The volume of excavation required for construction of the main canal will be about 35 percent greater than that of the canal proposed by COTHA.

## Design of the Secondary and Other Canals

### Layout in Plan

Drainage areas were laid out in accordance with natural boundaries as defined by the dunes, dikes, and drainage patterns of the project topography. Secondary and tertiary canals within these areas were located

to take maximum advantage of natural drainage. Secondary canals join the main canal at 800-meter spacings. A 300-meter spacing of tertiaries and a 200-meter spacing of quaternaries was adopted and was used where appropriate throughout the project. The layout of proposed drainage canals is shown on Exhibit B.

## Canal Sections

The design storm was applied to the several areas served by quaternary, tertiary, and secondary canals. The maximum runoff to be discharged by the canals was found to be 1230 liters per second per square kilometer and the canals were sized accordingly. Quaternaries are considered to be nominal field ditches to receive only single paddy runoff. Tertiaries extend generally at right angles with both quaternaries and secondaries. Maximum runoff for tertiaries was determined as 37 liters per second for each 100 meters of length. Secondary canals were designed to accept tertiary runoff yield at various points along their lengths. Small water surface slopes permitted use of approximate back water methods to properly adjust water surface levels throughout the system and prevent excess heading up in the paddies during the critical design storm period. Geometric elements of the channels were selected to sustain low flow velocities above silting values for self-maintenance and provide for subsidence of excavated side slopes. Exhibit 6 shows typical canal sections.

## Miscellaneous Hydraulic Structures

As mentioned in Chapter III, minor rehabilitation of the dike and structure at the northern boundary of the project area is necessary. A rectangular wooden gate with metal skin plate must be provided at the

structure to permit the exchange of water between the project area and the Koba station. A lifting device will also be installed.

A culvert is required at the junction of the secondary canal and the road passing north of Makinsi. The area drained is about 150 hectares and the maximum discharge through the culvert in the event of the design storm will be about 1.8 cubic meters per second. Two corrugated metal pipes with a diameter of 1.0 meter will provide the necessary opening.

## Chapter VII

# PROJECT CONSTRUCTION

### Introduction

The various features of the Koba Project are relatively simple, and no unusual difficulties are expected during construction. However, because of the present shortage in heavy construction equipment and skilled labor in Guinea, it is believed that the services of a foreign contractor will be required.

Past experience in the project area has shown that the local residents will be capable of performing, both collectively and individually, only small scale work within the limits of their own lands. Consequently, it will be most advantageous to have the contractor perform as much of the civil works as is economically feasible. This will consist of the main, secondary, and tertiary canals, the dikes, the control structure, and the bridges. Land preparation, consisting of levelling and planing operations, will be best accomplished with the mechanical equipment presently available to the Center of Rural Mechanization (C.M.R.). Installation of the new paddies and rehabilitation of existing ones will be left to the individual farmers.

Completion of the work is estimated to require about three years. A schedule of construction is presented on Exhibit 7. This schedule permits the harvesting of a partial crop at the end of the second construction year.

## Access to the Project Site

The project site is readily accessible to wheeled vehicles. About 40 kilometers southeast of Boffa, on the main north-south unpaved road between Conakry and Boke, a branch road to the west leads to Koba, about 30 kilometers away. The nearest commercial airport is located at Conakry, about 65 kilometers from the project area by unpaved roads. The nearest port is that of Taboria, a minor trading post about ten kilometers north of the project boundary. Access by boat from Conakry to the southern area of the Koba plains is easily practicable by way of the ocean and the Marigot de Kabelea. The distance by ocean and marigot is about 45 kilometers.

## Construction of the Dikes

One of the main items of work will be construction of the dikes. About 170,000 cubic meters of earthfill will be required for this item. Materials for the dikes will be excavated by power shovels from borrow areas along the western and eastern sides of the project. Dump trucks will haul the material to the location of the dikes. The material will be spread by graders and rolled by sheeps foot rollers. It is estimated that two 3/4 cubic yard power shovels and about ten dump trucks will permit completion of the dikes within the time shown on the construction schedule. D-8 type bulldozers and other miscellaneous earth-moving equipment will also be necessary on the project.

## Excavation of the Canals

The main item of work for construction of the project consists of channel excavation. Although final selection of the construction method

will be left to the contractor's option, it appears from a comparative study that a combination of floating dredge and crawling draglines will yield the most economical results. The cost estimates are based on this solution.

It is expected that shortly after award of the construction contract the contractor will move a floating dredge to the project site. This dredge would be of the suction type, with cutterhead and about ten-inch suction and discharge pipes. The average excavating capacity of a ten-inch dredge would be about 100 cubic meters per hour. This capacity would be sufficient to perform the work within economic time limits. The dredge would be shipped to Guinea in a knocked-down condition, and partly reassembled at Conakry. The dredge would be moved to the outlet of the main canal by towing or by self-propulsion. Assembly would be completed at the project site.

Excavation of the main canal by the dredge is expected to be started at the downstream end, and the dredge would proceed upstream as the canal is excavated to the specified dimensions. About 1,000,000 cubic meters will be dredged from the main canal.

The draft of a ten-inch dredge is about 0.75 meters. In order for the dredge to be operated during the lowest tides, it may be necessary during the dry season to construct a low cofferday across the canal, provided with a gated conduit. This temporary cofferdam would permit a sufficient depth of water to be maintained in the excavated section.

Dredging during the wet season will be advantageous since most of the fine material put in suspension by operation of the cutterhead will be transported by the flow. The material sucked by the dredge would

be pumped through the discharge pipe and deposited in settling basins along the canal on one or both sides. These spoil areas will be located far enough from the bank's edge so as to allow for sloughing of the banks without excavated material being brought back into the canal. A maintenance road will be located on the spoil bank.

The secondary and tertiary canals would be excavated by draglines concurrently with the main canal dredging, but only during the dry seasons. It is estimated that two draglines with 3/4 cubic yard buckets will be used by the contractor, together with one D-8 type bulldozer and one hauling truck. The total amount of material to be excavated by the draglines is estimated to be about 172,000 cubic meters. The draglines would first be used to excavate the canals located in the southern part of the project area so as to put part of the reclaimable area under production after two years of construction.

## Structures

The project includes a gated control structure across the main canal at about 100 meters from its confluence with the Marigot de Kabelea, five suspension-type foot-bridges across the main canal, and a culvert near Makinsi. A gate must be furnished to rehabilitate the existing structure at the northern boundary of the project area.

Construction of at least three of the seven bays of the gated control structure can be started during the first dry season, without necessity for a cofferdam. Wooden piles will be driven in the foundations and reinforced concrete placed in the dry for the slab and the piers. Construction of the other bays will require temporary cofferdams enclosing the work area during the second dry season. The deck and gates

will then be installed and the temporary cofferdams removed. The foot-bridges over the main canal will be constructed in the dry season of the third construction year. The elevation of the bridge decks as proposed will provide sufficient clearance for passage of the dredge.

A small, portable, concrete batching plant will be required on the project. Materials for concrete aggregates are not available in the immediate vicinity of the project and will have to be hauled from a quarry. Cement to be used in the concrete structures will be Type V cement, or Type II mixed with pozzolan admixtures, so as to give the concrete a better resistance to the action of salt water.

Precast concrete elements for cribs will be cast near the batching plant, to be transported and used for construction of wingwalls at the gated control structure. Materials for the bridges, such as creosoted timber, steel cable, structural steel and miscellaneous metal parts will be brought to each site, and the bridges erected.

## Land Preparation

Preparation of the lands for project operation will consist of minor levelling and smoothing over a small portion of the reclaimed project area. Paddies will be made level to permit dikes to be spaced at reasonable intervals and provide operating room for machinery. Local surface irregularities will be removed at the same time.

This work will be best performed by the C.M.R. Coordination of the land preparation with the civil works construction will be effected by the resident engineer and the project agronomist. Preparation of a portion of the project lands can thus be completed before the entire project.

Each area to be leveled will be surveyed and appropriately marked to indicate cut and fill areas. Rubber-tired tractors developing about 60 horsepower, with self-loading scrapers having a capacity of about two cubic meters, will be required to perform the leveling. The same equipment can also be used to construct and maintain the levees in the paddies.

## Quaternary Canals and Levees

Quaternary canals will be small ditches excavated along the paddies. It is estimated that about 180 meters of such canals will be excavated for each hectare of land. This excavation will be performed by hand by each farmer and his family. The material excavated from the ditches will be spoiled on the sides to form the levees surrounding the paddies. This work has been estimated to involve about 70,000 cubic meters of land excavation.

Chapter VIII

# PROJECT ECONOMICS

## Scope and Procedure

This chapter presents details of the economic appraisal of the Koba Project. The principal objectives sought were: (1) to determine if increases in production anticipated from the project are sufficient to justify the estimated costs, and (2) to estimate the ability of the farmers to pay the costs of operation, maintenance, replacement, and amortizing the project investment.

The analyses follow general principles used by international financing institutions and most United States government agencies in determining economic and financial feasibility of resource development projects. Some modifications of standard procedures were necessary because of lack of data required to complete a rigorous analysis, and because of unique conditions of a non-private land tenure system, nomad and "shifting" cultivation, subsistence farming, and a non-market economy.

The validity of the estimates of increased income due to the drainage and reclamation programs is dependent upon a careful analysis of benefits resulting from anticipated land use under conditions with and without project development. This was accomplished by farm budgeting which provided for systematic outlining of the organization and operation of agricultural enterprises in the area, and included the anticipated income and expenditures for a normal cropping season.

(3) installation of quaternary canals connecting to the tertiary and other canals.

Table VIII-1 - Farm and Retail Prices for Farm Products in Guinea, 1961-1963

(Guinean Francs)

| Products | Unit | 1961 | | 1962 | | 1963 | |
|---|---|---|---|---|---|---|---|
| | | Farm | Retail | Farm | Retail | Farm | Retail |
| Palm nuts | kg | 15-20 | 32-40 | 25 | 37-40 | 25 | 37-40 |
| Palm oil | liter | 60 | 80 | 68 | 125 | 70 | 125 |
| White rice, polished | kg | 30-40 | 50 | 45 | 55 | 45 | 50 |
| Red rice, polished | kg | 25-30 | 40 | 40 | 50 | 40 | 45 |
| Rice paddy | kg | 17-50 | 25 | 25 | 30 | 27 | 30 |
| Peanuts, non-shelled | kg | 20 | 35-40 | 25 | 35 | 25 | 40 |
| Millet | kg | 20 | 25 | 20 | 25 | 20 | 25 |
| Coconuts | each | 5 | 10 | 7 | 15 | 7 | 15 |
| Fonio, cleaned | kg | 15 | 25 | 30 | 40 | 30 | 40 |
| Fonio, paddy | kg | 10 | 20 | 20 | 25 | 20 | 25 |
| Sweet potatoes | kg | 10 | 15 | 10 | 15 | 10 | 15 |
| Bananas | kg | 23 | 30 | 23 | 30 | 23 | 30 |
| Pineapples | kg | - | 90 | - | 90 | - | 90 |
| Meat: beef | kg | - | - | - | - | - | 180-225 |
| mutton | kg | - | - | - | - | - | 250-350 |
| pork | kg | - | - | - | - | - | 500-800 |
| Poultry | each | - | - | - | - | - | 200-500 |
| Eggs | each | - | - | - | - | - | 15-20 |
| Fish | kg | - | - | - | - | 72-90 | 80-115 |

The cost of leveling and grading has been included in the project investment. Quaternary canals and levees within each farm land will be constructed by hand by the farmers. The spoil material from the canals will be used for construction of the levees surrounding the paddies. It is expected that a nominal amount of cash outlay for simple tools will be required for performance of this work. The value of this work, however, has been estimated to be about GF 44,500 per farm unit of 6 hectares, including grading at a unit price of GF 4625 per hectare and surface drains at a unit price of about GF 2,780 per hectare.

over the economic life of the project. Because prices are arbitrarily set by the Government, projected prices based on anticipated supply and demand relationships would not be realistic. Prices for major farm products at the farm and retail levels for 1961, 1962, and 1963, as shown in Table VIII-1, were used in the study.

Inspection of Table VIII-1 indicates that the relation between farm and retail prices of white rice (polished) was 90 percent of the retail price in 1963, but only 75 percent in 1961. For some products, the farm price is only 60 percent of the retail price. This variation in spread presumably reflects the costs of marketing. However, according to estimates by some government officials, this difference is unrealistic for many products.

## Farm Expense

Investment in Land. There is little private capital, in the form of cash outlay, invested in the project lands. An exclusive "de facto" right to use land is established by each cultivator when he settles on it, but neither the land nor improvements made during occupancy may be sold or transferred. Existing improvements including clearing, leveling, drainage and diking have been accomplished by individual cultivators almost entirely by hand without cash expenditures. Although these improvements increase the value of land for production, they do not represent an increased equity for the land users. Therefore, the present private capital investment in land has been assigned no value.

Additional land development necessary for proper cultivation and drainage of individual farm units will consist of one or more of the following operations; (1) land leveling and grading, (2) renovation of levees,

Table VIII-4 - Estimated Amount, Original Cost, and Annual Costs of Equipment Per Subsistence Farm

| Item | Number | Original Cost (GF) | Estimated Life (years) | Annual Depre-ciation (GF) | Cost Repairs (GF) |
|---|---|---|---|---|---|
| Grubbing hoes | 3 | 650 | 10 | 52 | 13 |
| Axes | 2 | 600 | 10 | 48 | 12 |
| Machette - Sickles | 4 | 1,000 | 10 | 80 | 20 |
| Flails | 3 | 600 | 2 | 293 | 12 |
| Shovels | 2 | 800 | 5 | 145 | 16 |
| Rice sacks | 10/ton | 1,000 | 3 | 317 | 20 |
| Storage container | 1 | 1,250 | 10 | 100 | 25 |
| Screens for cleaning | - | 600 | 5 | 108 | 12 |
| Wheel barrel 1/ | 1 | 7,150 | 10 | 560 | 153 |
| Polishing container | 1 | 500 | 5 | 90 | 10 |
| Miscellaneous | | 1,450 | - | 115 | 29 |
| Total | | 15,600 | | 1,908 | 322 |

1/ Assumed owned only at later stages of development.

Mechanization of rice production is expected to develop very slowly. Government officials stated that the services of the CMR will eventually be extended to private cultivators, although cooperatives and force account enterprises have first choice on existing machinery at the present time. Some small plows, suited to pulling by animals, have been imported but none were being used at present.

It was assumed that little change from present hand cultivation methods will occur during an initial five-year development period. For subsequent periods, it is assumed that machinery and equipment for plowing and for harvesting will be available on a rental basis. Estimated

It is expected that some technical services will be required to supervise the installation of these facilities. Costs for these services are not included in the farm expenses, since they are included in the project operating costs.

Investment in Buildings. The amount of investment in farm buildings is very small. Existing buildings consist primarily of a mud-thatched house for the family, and a small wooden-thatched structure to provide protection for a few sheep, goats, or chickens. Additional buildings per farm are not expected with the project, although some improvements in the type of house will gradually be made, and new units will be established.

A typical house consists of dried mud walls on a lathing of wood branches, and roofed with grass thatching. The floors are mud and in some cases, the front step is dried mud blocks with a thin covering of cement plaster. The house can be built in approximately three months by two men and three women. The men do most of the actual construction, with the women helping by transporting materials. Most of the materials are gathered by the family. Total cost of the house and other structures is estimated to be GF 100,000 including all materials and the value of labor. The breakdown of this estimate is shown in Table VIII-2.

Table VIII-2 - Estimated Cost of Typical Farm Family Dwelling

| Item | Unit Costs (GF) | Total Costs (GF) |
|---|---|---|
| Thatch grass | 2,000 | 2,000 |
| Wall lathing | 1,500 | 1,500 |
| Roof timber | 1,500 | 1,500 |
| Mason | 12 days at 1000 | 12,000 |
| Family labor | 15 man-months at GF 5,333 | 80,000 |
| Nails, wire, etc. | | 3,000 |
| | Total | 100,000 |

Taxes. All agricultural enterprises are exempt from taxation. There is at present a head tax of GF 500 which must be paid on all persons of working age, except indigents. There are no real estate taxes on agricultural land.

Improvements in education, medical and transportation facilities, contemplated for the future will require additional taxes. Although it is not known how taxes for improvements will be assessed it was assumed that taxes will be increased to GF 1000 per person by the fifth year of operation of the project, seven persons being taxable on a farm.

Interest. There has been little need for credit facilities for agricultural purposes by subsistence farmers. Provisions are being made by the government to establish credit for plantation and cooperative-type farming for export crops. Current interest rates for these enterprises and for non-agricultural businesses are adopted for this analysis, and amount to the following:

| Length of Loan | | | Interest Rates |
|---|---|---|---|
| Short-term | - | up to 9 months | 4% |
| Medium-term | - | up to 5 years | 5% |
| Long-term | - | 5 years and up | 6% |

Other Crop and Livestock Expenses. The annual requirements and estimated costs for commercial fertilizer, seed, plant protection, and miscellaneous livestock expenses are presented in Tables VIII-7 through 10. These data were obtained mostly from local sources but with some adjustments to assure adequate requirements for the levels of production assumed for the study.

It is assumed that seed for planting would be home-grown, exceptions being for pasture crops and specialty crops, such as grain sorghum.

total cost for farm buildings will increase proportionately with increases in crop and livestock production.

For analytical purposes, one-half of the investment cost for the family dwelling and all of the other farm buildings are charged as a farm investment. Annual costs for depreciation are based on a five percent sinking fund extended over the estimated useful life of the house at 100 percent of the original cost. This assumes an accumulation of funds to replace the buildings at the end of their useful life. Cost of repairs are calculated at three percent of the original cost.

Other Improvements. There are few other farm improvements present or considered necessary. Farm fences are non-existent. Domestic water is carried, usually by the women on their heads, from nearby stream or shallow village wells. Public utilities such as telephones and electricity are not available. Machine sheds and repair shops are not needed because there is little, if any, machinery except as owned and operated by the CMR. Minor repairs on equipment is done mostly by the cultivator, but in some instances, facilities for building and repairing crude tools are available in the nearby village centers. For the most part, significant changes in these types of improvements are not anticipated within the foreseeable future.

Machinery and Equipment. At the present time, most rice is produced by hand methods. The average inventory and estimated cost of equipment used by the typical farm family are presented in Table VIII-4.

For the minor equipment listed in Table VIII-4, annual repair costs, excluding labor, are computed as two percent of the initial cost. Depreciation is based on a five percent sinking fund over the useful life, and calculated on 90 percent of first cost, with ten percent allowed for salvage value.

Table VIII-9 - Cost of Seed Treatment, Pest and Weed Control[1/] Per Hectare

| Crops | Costs Per Measure (GF) | | | | |
|---|---|---|---|---|---|
| | Pests | Diseases | Weed Control[2/] | Seed Treatment | Total Costs |
| Rice | 500 | 445 | - | 275 | 1220 |
| Legume clover (Lespedeza) | 500 | - | - | 250 | 750 |
| Grain sorghum | 500 | 250 | - | - | 750 |
| Maize | 500 | 250 | - | - | 750 |

1/ Rates of application and costs for full protection program.

2/ Assumed to be accomplished by hand labor which is included in labor requirements.

Table VIII-10 - Miscellaneous Costs for Livestock Expenses Per Head

| | GF |
|---|---|
| Beef and dairy cattle: | |
| Vaccinations | 125 |
| Minerals, salt, etc. (2 kg. at GF 75) | 150 |
| Miscellaneous equipment and supplies | 125 |
| Total per Head | 400 |
| Sheep: | |
| Dippings, parasite control, etc. | 60 |
| Miscellaneous equipment and supplies | 75 |
| Total per Head | 135 |

Miscellaneous Farm Expenses. Miscellaneous expenses, estimated at five percent of total itemized farm expenses, are included in the budgets to cover unforeseen contingencies and minor expenses normally incurred but not specifically identified with a specific crop enterprise.

rental charges for machinery to perform various operations are presented in Table VIII-5. For machinery assumed to be rented, annual costs are included in the rental charge.

Table VIII-5 - Rental Charges for Farming Operations

| Item | Unit | Total Costs (GF) |
|---|---|---|
| Plowing | hectare | 3000 1/ |
| Discing, harrowing, etc. | hectare | 2000 1/ |
| Combining | hectare | 3500 1/ |
| Drying rice | 100 kg. | 150 |
| Cleaning or hulling rice | 100 kg. | 125 |

1/ Includes cost of fuel at GF 500 per hectare.

Fuel and oil for operation of a tractor was based on local costs. The price for gasoline varies from GF 41 to GF 45 per liter. Diesel fuel is sold at GF 28 per liter, and oil from GF 250 to GF 300 per liter.

Inventory Value of Livestock. The inventory value of livestock is presented in Table VIII-6. These data were used in the analysis to represent future conditions that may be expected with integrated crop and livestock enterprises, 10 to 20 years after the project is in operation.

Table VIII-6 - Inventory Value of Livestock

| Item | Value (GF) |
|---|---|
| Milk cow | 20-25,000 |
| Beef steer | 15-25,000 |
| Sheep | 4- 5,000 |
| Goat | 2,000 |
| Pig | 20-30,000 |
| Chicken | 200 |
| Eggs (dozen) | 60 |

On most subsistence farms much of the available labor is under-employed and alternative employment opportunities offering greater economic returns are practically nil. Assuming this represents future conditions throughout the period of analysis the cost of family labor could justifiably be excluded as a production cost in computing project benefits. Because of the uncertainty of this situation and because present cultivators do sustain themselves economically, the input value of family labor has been considered as an economic cost and it has been included in computing net returns to the drainage and reclamation program.

Table VIII-11 - Estimated Man Labor Requirements, and Equivalent Costs for Rice Production Under Present Cultural Methods

| Operation | Unit | Annual Man-hour Requirement per Hectare 1/ | Equivalent Labor Costs per Hectare (GF) |
|---|---|---|---|
| Preparing seed bed | Plot | 20 | 450 |
| Seeding primary bed | Plot | 10 | 225 |
| Preparing land in paddy | Hectare | 100 | 2,250 |
| Transplanting rice 2/ | Hectare | 60 | 1,350 |
| Weed control | Hectare | 200 | 4,500 |
| Harvesting | Hectare | 200 | 4,500 |
| Threshing and cleaning | Hectare | 200 | 4,500 |
| Total | | 790 | 17,775 |

1/ Does not include time of one man hour per four kilograms of rice estimated for hulling and preparation for cooking and cleaning for sale.

2/ Assumed to continue to be done manually in the future.

Table VIII-7 - Fertilizer Requirements and Annual Cost per Hectare[1/]

| Crop | Portion of Area Fertilized Each Year (%) | Amount of Fertilizer Per Hectare (kg) | Annual Costs Per Hectare (GF) |
|---|---|---|---|
| Rice and grain Sorghum[4/] | 80 | 134[2/] | 8300[3/] |
| Legume grass | 40 | 56 | 2740[3/] |

1/ Recommended rates for full production potential.

2/ Based on 78 kgs. of nitrogen and 56 kgs. of phosphates per hectare.

3/ Based on cost of nitrogen at GF 71 per kilogram and phosphate at GF 49 per kilogram. Phosphate applied to legume grass (Lespedeza) only.

4/ Portion of area fertilized upon completion (one-year) estimated at 25%.

Table VIII-8 - Seeding Rates and Annual Costs per Hectare

| Crop | Seed Required (kg) | Cost per Kilogram (GF) | Seeding Interval (years) | Annual Costs (GF) |
|---|---|---|---|---|
| Rice | 57.27 | 32 | Annual | Farm |
| Legume clover | 15 | 400 | 3 | 2000 |
| Maize | 33 | 35 | Annual | 1155 |
| Sorghum | 10 | 300 | Annual | 3000 |

progessively thereafter to reach six hectares about the twentieth year of operation. This increase in intensity of cultivation with crops that are complementary to rice is considered practical, and within the limits of the future possibilities of the farmers.

Owing to the increase in total area available for cultivation, the total number of families that could be maintained by the project would be increased from 243 to 553 in the first year of operation, and to 618 after five years of operation.

Results of the analysis show that net income, after a five-year development period, will increase from GF 32,340,000 to GF 130,100,000 or by an average of approximately GF 26,000 per hectare for the net reclaimed area of 3710 hectares. Most of this increase is attributable to production from 2700 hectares of new land which is now essentially non-productive because of inadequate drainage conditions and, to a certain extent, because of salt water intrusions. The total increase includes the value of farm privileges, composed of non-cash allowances for the equivalent rental value of the farm dwelling, and the market value of the rice and other products consumed by the farm family.

The results for conditions anticipated after 10 and 20 years of operation show that large increases in production and income are possible with moderate applications of fertilizers, insecticides, improved plant varieties, and better cultural practices. It is estimated that net income after 10 and 20 years of operation could be increased by about 25 and 75 percent, respectively, above that estimated after five years without these improvements.

Labor Requirements and Wage Rates. Few statistical data are available on the amount of labor expended in producing rice or other crops on subsistence farms. Estimates obtained from cultivators and government officials varied considerably. It was generally agreed that a typical family of one man with two wives plus their children, could cultivate about four hectares of rice plus sufficient other land to provide their own food requirements, and have a small portion of the production for sale. In most instances some additional labor, usually exchange labor with neighbors, is required during the peak work load seasons.

The man labor requirements for rice was estimated at 800 man-hours per hectare, or 100 eight-hour days, excluding time spent in hulling and preparation for cooking. An increase of approximately ten percent for each additional increase in yield of 1.0 ton per hectare was used in projecting future requirements without mechanization, most of which is assumed to be hired or exchange labor. Use of tractors and powered machinery for plowing, harvesting, and threshing would reduce labor requirements by more than one-half. Estimates for labor requirements and equivalent costs in producing rice are presented in Table VIII-11.

Wage rates, set by the government, are GF 28 per hour for farm labor and GF 32 for non-farm labor, primarily in Conakry. This amounts to about GF 225 or about $0.90 per day. Work contributed by women in producing crops is considered equally productive as for men.

Although wage rates may appear low, there is evidence that they are high relative to the marginal value productivity of labor. Because labor comprises the major portion of total costs an inbalance in its pricing tends to affect adversely the economic feasibility of the project.

Table VIII-13 Budget No. 2 - Estimated Income and Expenses From Subsistence Rice Farm Upon Completion of the Reclamation Project

(In Guinean Francs)

| Crop | Production and Value | | | | | | Disposition of Production | | |
|---|---|---|---|---|---|---|---|---|---|
| | Hectares | Unit | Yield | Total | Price | Value | Seed | Consumed | Sales 1/ |
| Rice | 4 | Kg | 1,700 | 6,800 | GF 32 | 217,600 | 7,360 | 48,000 | 159,750 |
| Idle | 2 | | | | | | | - | |
| Total | | | | 6,800 | | 217,600 | 7,360 | 48,000 | 159,750 |

**Farm Investment**

| Item | Value |
|---|---|
| Land Development | GF 44,500 |
| Dwelling (Farm share) | 50,000 |
| Other Improvements | 20,000 |
| Equipment and Supplies | 15,600 |
| Other | 6,500 |
| Total | GF 136,600 |

**Farm Expenses**

| Item | Value |
|---|---|
| Interest on Investment | GF 8,200 |
| Taxes | 3,500 |
| Depreciation and Repairs: | |
| a. Buildings and Improve. | 7,665 |
| b. Equipment | 2,230 |
| Cleaning at GF 3/kg | 19,710 |
| Hired Labor 2/ | 11,000 |
| Marketing at GF 2.5/kg | 8,875 |
| Fertilizer | 5,025 |
| Miscellaneous | 3,310 |
| Total | GF 69,515 |

**Financial Summary**

| Item | Value |
|---|---|
| Cash Sales | GF 159,750 |
| Farm Privileges: | |
| a. Consumed by family | 48,000 |
| b. Rental value of dwelling | 5,475 |
| Total Income | 213,225 |
| Total Expenses | 69,515 |
| Net Income | GF 143,710 |
| Family Labor and Management | 138,000 |
| Residual income available for profit and repayment | 5,710 |

1/ 5,070 kg paddy or 3550 kg polished at GF 45.

2/ Equivalent value of hired or exchange labor.

## Farm Budgets

The five farm budgets established for conditions without the project and for conditions anticipated upon completion of the construction and after five, ten, and 20 years of operation are presented in summary form on Tables VIII-12 through 16. The net income found in each of the five farm budgets were used to determine the increase in net income as shown in Table VIII-17 for each farm unit.

For conditions without the project, it has been assumed that each family of cultivators would continue to cultivate the four hectares which it is now cultivating, year after year. The production, as calculated, represents average conditions.

For conditions after the project has been constructed, it has been assumed that the cultivators could be persuaded to establish a systematic crop rotation of two-thirds rice annually. One-third of the land would be idle initially with gradual introduction of crops complementary to rice production as improved cultural practices are introduced.

The cultivated area of rice in the Koba region averages about four hectares per family. We have assumed that the total area per farm unit would be increased to six hectares after construction of the drainage facilities. However, it also has been assumed that the average land in production during the initial years would be only four hectares per farm unit. This will provide each family the same cultivated area of rice as at present and allow for implementing the recommended crop rotation of two-thirds rice and one-third for other uses.

It has been assumed that the total cultivated area by each family would remain equal to four hectares in the first five years and increase

## Table VIII-15 Budget No. 4 - Estimated Income and Expenses From Subsistence Rice Farm

10 Years After Completion of the Reclamation Project

(In Guinean Francs)

| Crop | Production and Value | | | | | | Disposition of Production | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Hectares | Unit | Yield | Total | Price | Value | Seed | Consumed | Sales | Feed |
| Rice | 4.0 | kg | 3,000 | 12,000 | GF 32 | 384,000 | 7,360 | 48,000 | 323,550 | |
| Maize | .15 | kg | 2,000 | 300 | 35 | 10,500 | 175 | 1,925 | 8,400 | |
| Lespedeza | .9 | kg | 10,000 | 9,000 | 3.7 | 33,300 | | 9,200 | 9,200 | (33,300) |
| Idle | .95 | | | | | | | | | |
| Total | 6.00 | | | | | 427,800 | 7,535 | 59,125 | 341,150 | 33,300 |

### Farm Investment

| Item | Value |
|---|---|
| Land Development | GF 44,500 |
| Dwelling (Farm Share) | 87,500 |
| Other Improvements | 30,250 |
| Equipment and Supplies | 25,250 |
| Livestock | 22,500 |
| Miscellaneous | 10,500 |
| Total | GF 220,500 |

### Farm Expenses

| Item | Value |
|---|---|
| Interest on Investments | GF 13,230 |
| Taxes | 7,000 |
| Depreciation & Repairs: | |
| a. Building & Improv. | 12,895 |
| b. Equipment | 4,185 |
| Equipment Rental | 15,300 |
| Marketing | 17,975 |
| Crop Seed | 1,500 |
| Cleaning Rice | 35,310 |
| Fertilizer | 13,150 |
| Plant Protection | 2,500 |
| Hired Labor | 15,000 |
| Livestock Expenses | 400 |
| Miscellaneous | 6,920 |
| Total | GF 145,365 |

### Financial Summary

| Item | Value |
|---|---|
| Crop Sales: | |
| a. Rice | GF 323,550 |
| b. Other Crops | 17,600 |
| Farm Privileges: | |
| a. Rice Consumed | 48,000 |
| b. Other Products | 11,125 |
| c. Rental value dwelling | 9,375 |
| Total Farm Income | 409,650 |
| Total Expenses | 145,365 |
| Net Income | 264,285 |
| Family Labor & Management | 158,000 |
| Residual Income Available for Profit & Repayment | 106,285 |

## Table VIII-12 - Farm Budget No. 1 - Estimated Income and Expenses From Subsistence Rice Farm Under Present Conditions

(In Guinean Francs)

| Crop | Production and Value | | | | | | Disposition of Production | | |
|---|---|---|---|---|---|---|---|---|---|
| | Hectares | Unit | Yield | Total | Price | Value | Seed | Consumed | Sales |
| Rice | 4.0 | kg | 1,500 | 6,000 | GF 32 | 192,000 | 5,760 | 38,400 | 145,350 |
| Idle | - | | - | - | | - | - | - | - |
| Total | 4.0 | | | | | 192,000 | 5,760 | 38,400 | 145,350 |

### Farm Investment

| Item | Value |
|---|---|
| Land Development | GF - |
| Dwelling (Farm Share) | 50,000 |
| Other Improvements | 15,000 |
| Equipment and Supplies | 15,600 |
| Miscellaneous | 4,030 |
| Total | GF 84,630 |

### Farm Expenses

| Item | Value |
|---|---|
| Interest on Investment | GF 5,080 |
| Taxes | 3,500 |
| Depreciation and Repairs: | |
| a. Buildings and Improv. | 7,120 |
| b. Equipment | 2,230 |
| Cleaning at GF 3/kg. | 17,460 |
| Hired Labor 1/ | 10,000 |
| Marketing at GF 2.5/kg. | 8,075 |
| Miscellaneous (5%) | 2,675 |
| Total | GF 56,140 |

### Financial Summary

| Item | Value |
|---|---|
| Cash Sales | GF 145,350 |
| Farm Privileges: | |
| a. Consumed by Family | 38,400 |
| b. Rental Value of Dwelling | 5,475 |
| Total Income | 189,225 |
| Total Expenses | 56,140 |
| Net Income | GF 133,085 |
| Family Labor and Management | 133,085 |

1/ Equivalent value of hired or exchange labor.

Table VIII-17 - Summary of Increased Net Crop Income With Drainage and Reclamation, Koba Project

| Item | Unit | Under Present Conditions | With Project: Upon Completion | With Project: Five Years After Completion | With Project: Ten Years After Completion | With Project: Twenty Years After Completion |
|---|---|---|---|---|---|---|
| Rice | Hectare | 972 | 2,212 | 2,472 | 2,472 | 2,472 |
| Other Crops | Hectare | - | - | 309 | 649 | 1,236 |
| Idle | Hectare | - | 1,106 | 927 | 587 | - |
| Total | | 972 | 3,318 | 3,708 | 3,708 | 3,708 |
| Gross Income | GF 1000 | 45,982 | 117,914 | 194,995 | 253,164 | 349,574 |
| Farm Expenses | GF 1000 | 13,642 | 38,442 | 64,899 | 89,836 | 113,962 |
| Net Income | GF 1000 | 32,340 | 79,472 | 130,096 | 163,328 | 235,612 |
| Per Hectare | GF | - | 24,000 | 35,000 | 44,000 | 62,000 |
| Net Increased Income | GF 1000 | - | 47,132 | 97,756 | 130,988 | 203,272 |
| Per Hectare | GF | - | 14,000 | 26,000 | 35,000 | 55,000 |

Table VIII-14 Budget No. 3 - Estimated Income and Expenses From Subsistence Rice Farm

5 Years After Completion of the Reclamation Project

(In Guinean Francs)

| Crop | Production and Value | | | | | | Disposition of Production | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Hectares | Unit | Yield | Total | Price | Value | Seed | Consumed | Sales 1/ | Feed |
| Rice | 4.0 | kg | 2,400 | 9,600 | GF 32 | 307,200 | 7,360 | 48,000 | 247,950 | |
| Lespedeza | 0.5 | kg | 10,000 | 5,000 | GF 3.7 | 18,500 | | 5,100 | 5,100 | (18,500) |
| Idle | 1.5 | | | | | | | | | |
| Total | 6.0 | | | | | 325,700 | | 53,100 | 253,050 | (18,500) |

Farm Investment

| Item | Value |
|---|---|
| Land Development | GF 44,500 |
| Dwelling (Farm Share) | 87,500 |
| Other Improvements | 25,000 |
| Equipment and Supplies | 19,700 |
| Livestock | - |
| Miscellaneous | 8,800 |
| Total | 185,500 |

Farm Expenses

| Item | Value |
|---|---|
| Interest on Investment | GF 11,130 |
| Taxes | 7,000 |
| Depreciation and Repairs: | |
| a. Buildings and Improv. | 12,320 |
| b. Equipment | 3,630 |
| Marketing | 13,775 |
| Crop Seed | 1,000 |
| Cleaning Rice | 28,110 |
| Fertilizer | 10,050 |
| Hired Labor 2/ | 13,000 |
| Miscellaneous | 5,000 |
| Total | GF 105,015 |

Financial Summary

| Item | Value |
|---|---|
| Crop Sales: | |
| a. Rice | GF 247,950 |
| b. Other Crops | 5,100 |
| Farm Privileges: | |
| a. Rice consumed | 48,000 |
| b. Other products | 5,100 |
| c. Rental value of dwelling | 9,375 |
| Total Farm Income | 315,525 |
| Total Expenses | 105,015 |
| Net Income | 210,510 |
| Family Labor and Management | 148,000 |
| Residual Income Available for Profit and Repayment | 62,510 |

1/ Rice sold 5510 kg. at GF 45.

2/ Assumed hired labor or equivalent value of exchange labor.

The detailed estimate of the project construction cost is presented on Exhibit 8. At an interest rate of six percent, the interest during construction amounts to about GF 95 million. The project investment is GF 900 million. Amortized over a period of 50 years at six percent per annum, the project investment is equivalent to GF 57 million. Annual charges for operation, maintenance and replacement, estimated to be GF 10 million, were added to obtain the annual equivalent cost of the project, GF 67 million.

## Direct Benefits

Direct benefits are the increases in net income anticipated for the entire project area after completion of the reclamation project. The net project income for conditions without the project and for each stage of development was derived from the net farm income and the corresponding number of farm units. The increases in total net income for each level of development from the net income accruing to the Koba area were thus calculated. These values are the direct benefits corresponding to each stage of development. They are shown in Table VIII-18.

Table VIII-18 - Determination of Direct Project Benefits

(Amounts in GF 1000)

| | Under Present Conditions | Upon Completion of Project | After 5 Years of Operation | After 10 Years of Operation | After 20 Years of Operation |
|---|---|---|---|---|---|
| Net income per farm | 133,085 | 143,710 | 210,510 | 264,285 | 381,249 |
| Number of farms | 243 | 553 | 618 | 618 | 618 |
| Net project income | 32,340 | 79,472 | 130,096 | 163,328 | 235,612 |
| Increase in net income (direct benefits) | - | 47,132 | 97,754 | 130,988 | 203,272 |
| Use, GF 1000 | - | 47,000 | 98,000 | 131,000 | 203,500 |

## Table VIII-16 Budget No. 5 - Estimated Income and Expenses From Subsistence Rice Farm 20 Years After Completion of the Reclamation Project

(In Guinean Francs)

| Crop | Production and Values: Hectares | Unit | Yield | Total | Price | Value | Disposition of Production: Seed | Consumed | Sales | Feed |
|---|---|---|---|---|---|---|---|---|---|---|
| Rice | 4.0 | kg | 3,700 | 14,800 | GF 32 | 473,600 | 7,360 | 48,000 | 411,750 | |
| Maize | .5 | kg | 2,500 | 1,250 | 35 | 43,750 | 525 | 1,925 | 41,300 | |
| Lespedeza | 1.2 | kg | 12,000 | 14,400 | 3.7 | 53,280 | - | 14,652 | 14,652 | 53,280 |
| Grain Sorghum | .3 | kg | 2,000 | 600 | 40 | 24,000 | - | - | 24,000 | |
| Idle | 0.0 | | | - | - | - | - | - | - | - |
| Total | 6.0 | | | | | 573,030 | 7,885 | 64,577 | 491,702 | 53,280 |

### Farm Investment

| Item | Value |
|---|---|
| Land Development | GF 44,500 |
| Dwelling (Farm Share) | 87,500 |
| Other Improvements | 35,500 |
| Equipment and Supplies | 32,000 |
| Livestock | 45,000 |
| Miscellaneous | 12,200 |
| Total | GF 256,700 |

### Farm Expenses

| Item | Value |
|---|---|
| Interest on Investment | GF 15,400 |
| Taxes | 7,000 |
| Depreciation and Repairs: | - |
| a. Buildings & Improv. | 13,500 |
| b. Equipment | 4,740 |
| Equipment Rental | 18,000 |
| Marketing | 22,875 |
| Crop Seed | 3,900 |
| Cleaning Rice | 43,710 |
| Fertilizer | 19,000 |
| Plant Protection | 6,500 |
| Hired Labor | 20,000 |
| Livestock Expenses | 1,000 |
| Miscellaneous | 87,800 |
| Total | GF 184,405 |

### Financial Summary

| Item | Value |
|---|---|
| Crop Sales: | |
| a. Rice | GF 411,750 |
| b. Other Crops | 79,952 |
| Farm Privileges: | |
| a. Rice Consumed | 48,000 |
| b. Other Products | 16,577 |
| c. Rental value of home | 9,375 |
| Total Farm Income | 565,654 |
| Total Expenses | 184,405 |
| Net Income | GF 381,249 |
| Family Labor & Management | 170,000 |
| Residual Income Available for Profit and Repayment | 211,249 |

## Public Benefits

Public benefits are defined as the value of achieving national objectives other than those included in direct and indirect benefits. Their evaluation represents a judgement estimate, more than a rigourous determination. The following benefits have been estimated.

(1) Employment Opportunities. This consists of benefits resulting from the contribution of the project to stabilization of income, employment, and investment opportunities outside of the project area. Although there is no accurate criteria for estimating these benefits, experience in the United States show such benefits to be at least five percent of direct project benefits. It is believed that these benefits would not be less for Guinea.

In addition, employment will be afforded during the construction and development period. It is estimated that no less than GF 120,000,000 of the construction costs will be spent in purchase of local goods and services. Depending on actual contracting arrangements, at least 70 percent of this, or about GF 84,000,000 would be paid to local laborers. This would result in employment and training for many local workers, and in stimulating the national economy. At six percent annual interest, this benefit would amount to an equivalent of GF 5,000,000 annually.

The combined public benefits from increased employment and economic stimulation of the region are shown in Table VIII-20. They are the only public benefits for which we have made a monetary evaluation.

Table VIII-20 - Determination of Public Benefits

(GF 1000)

| | Upon Completion of Project | After 5 Years of Operation | After 10 Years of Operation | After 20 Years of Operation |
|---|---|---|---|---|
| Employment outside of project | 2,360 | 5,040 | 6,500 | 10,165 |
| Employment during construction | 5,000 | 5,000 | 5,000 | 5,000 |
| Total Public Benefits | 7,360 | 10,040 | 11,550 | 15,165 |
| Use, GF 1000 | 7,500 | 10,000 | 11,500 | 15,000 |

(2) Settlement Opportunities. Reclamation of the project lands will provide opportunities for the establishment of additional subsistence farms, or enlargement of existing farms and creation of cooperative enterprises. At six hectares per subsistence farm, about 375 new subsistence units could be established. Public benefits from providing settlement opportunities would result, equivalent to at least the alternative earnings of the new cultivators. Although these benefits have not been evaluated in monetary terms, they would be very significant to the economy of the region and to Guinea. The magnitude of these benefits will increase as the population continues unless equal alternative economic opportunities are provided.

(3) Reduction in Foreign Currency Expenditures. The additional production anticipated from the project will contribute to a reduction of import requirements and, in turn, a reduction in expenditures of Guinea's scarce foreign currency. The value of additional production to the nation would, therefore, be equal to the alternative cost of imported rice. The

value of rice imported from the United States in 1962 was about $140 per metric ton, including shipping costs. Increased production of rice to offset this expenditure for import rice would be extremely important in bolstering the economy of Guinea. Although this has not been included in the evaluation of public benefits, the importance of this factor can be easily illustrated. The foreign currency component of the project investment is $2,130,000, which corresponds to the cost of about 15,000 tons of rice. These foreign currency expenditures can be recovered by the project through reductions in imports in the first six years of operation, on the basis of present worth at an annual rate of six percent.

## Equivalent Annual Benefits

Benefits will start accruing at the beginning of project operation and will increase gradually, to reach their full value 20 years after completion of the project, as shown in summary form on Table VIII-21.

Table VIII-21 - Summary of Project Benefits
(GF 1000)

| Annual Benefits | Upon Completion of Project | After 5 Years of Operation | After 10 Years of Operation | After 20 Years of Operation |
|---|---|---|---|---|
| Direct Benefits | 47,000 | 98,000 | 131,000 | 203,500 |
| Indirect Benefits | 10,000 | 19,500 | 26,500 | 34,000 |
| Public Benefits | 7,500 | 10,000 | 11,500 | 15,000 |
| Total Annual Benefits | 64,500 | 127,500 | 169,000 | 252,500 |

For the purpose of economic studies, the equivalent annual benefits were calculated as follows. The net annual benefits that are expected to accrue after one, five, ten, and twenty years of project

operation were plotted on a chart, and the values corresponding to intermediate years were interpolated. These values are tabulated on Table VIII-22. Also listed in this table are the single payment - present worth factors for an annual rate of six percent. These were used to obtain the present worth of the benefits accruing each year of the period of analysis, listed in Column (4). The present worth of future annual benefits accruing over a 50-year period was found equal to GF 2,868 million. By amortizing this amount over 50 years at a rate of six percent, the equivalent annual benefits were determined as GF 181,813,000.

A similar calculation of the equivalent annual direct benefits - excluding indirect and public benefits - yielded GF 141,294,000.

### Benefit-Cost Ratios

The ratios of total benefits to total costs and direct benefits to total costs were determined as follows:

| | |
|---|---|
| With direct benefits only: | 2.1 to 1.0 |
| With total benefits: | 2.7 to 1.0 |

## Financial Analysis

### Financing Terms

Construction of the Koba Project will require funds in the amount of $1,900,000 and GF 330 million, to be expended over a period of about three years. These amounts will probably be secured through an international lending institution. Since the terms of such financing are not known, it has been assumed that the entire project investment would be financed, to be repaid over a period of 40 years with an interest rate of

Table VIII-22 - Determination of the Equivalent Annual Benefits

| Year | Total Benefits (GF 1000) | Present Worth Factor | Present Worth of Benefits (GF 1000) |
|---|---|---|---|
| 1 | 64,500 | 0.9434 | 60,849 |
| 2 | 80,000 | .8900 | 71,200 |
| 3 | 96,000 | .8396 | 80,[illegible]02 |
| 4 | 112,000 | .7921 | [illegible]715 |
| 5 | 127,500 | .7473 | 95,281 |
| 6 | 136,000 | .7050 | 95,880 |
| 7 | 144,000 | .6651 | 95,774 |
| 8 | 152,000 | .6274 | 95,365 |
| 9 | 161,000 | .5919 | 95,296 |
| 10 | 169,000 | .5584 | 94,370 |
| 11 | 180,000 | .5268 | 94,824 |
| 12 | 192,000 | .4970 | 95,424 |
| 13 | 208,000 | .4688 | 97,510 |
| 14 | 220,000 | .4423 | 97,306 |
| 15 | 229,000 | .4173 | 95,562 |
| 16 | 236,000 | .3936 | 92,890 |
| 17 | 242,000 | .3714 | 89,879 |
| 18 | 246,000 | .3503 | 86,174 |
| 19 | 249,000 | .3305 | 82,295 |
| 20 | 252,500 | | |
| | ↕ | 4.604 | 1,162,510 |
| 50 | 252,500 | | |
| Total | | | 2,867,706 |

Equivalent annual benefits:

GF 1000 x 2,867,706 x 0.0634 = GF 181,813,000

0.75 percent per annum. The first payment would be deferred to the eleventh year after beginning of operation. These terms are those currently offered by international lending institutions such as the International Development Association (IDA), an affiliate of the International Bank for Reconstruction and Development (IBRD, World Bank), and by the Agency for International Development (AID), an agency of the United States, Department of State.

## Annual Costs

Such financing terms would require repayments at an annual rate of $25,000 for the first ten years, and $95,000 for the following 40 years, equivalent to GF 6 million and GF 24 million, respectively.

The annual costs of operating the project, including operation, maintenance, replacements, and the support of an agricultural extension program have been estimated to be GF 13 million for the first three years of operation, and GF 10 million thereafter.

## Repayment Ability

The repayment ability of the farmers has been evaluated by determining the amounts available annually to them after all farm expenses are met. The net farm incomes calculated in the farm budgets were reduced by amounts corresponding to the values of the family labor utilized in operating the farm unit. These amounts, shown on Tables VIII-12 through 16, were estimated on the basis of current wages for farm labor. The remaining amounts, multiplied by the number of farms to be operated in the project area, are the residual amounts available for profit of the farm enterprises and for repayment of the project. They are indicated on Table VIII-23. Also shown in the table are the project annual costs.

Inspection of Table VIII-23 indicates that only during the first three years of project operation will residual income of the farmers be less than the total annual costs of the project. From then afterward, income becomes substantially greater than project costs.

Table VIII-23 - Financial Analysis

(Amounts in GF Million)

| Years After Completion | Residual Income for Profit and Repayment | Annual Costs | | | |
|---|---|---|---|---|---|
| | | Interest and Amortization | Operating Costs | Extension Services | Total |
| 1 | 3 | 6 | 8 | 5 | 19 |
| 2 | 10 | 6 | 8 | 5 | 19 |
| 3 | 20 | 6 | 8 | 5 | 19 |
| 4 | 30 | 6 | 8 | 2 | 16 |
| 5 | 39 | 6 | 8 | 2 | 16 |
| 6 | 45 | 6 | 8 | 2 | 16 |
| 7 | 51 | 6 | 8 | 2 | 16 |
| 8 | 57 | 6 | 8 | 2 | 16 |
| 9 | 61 | 6 | 8 | 2 | 16 |
| 10 | 66 | 24 | 8 | 2 | 34 |
| 15 | 105 | 24 | 8 | 2 | 34 |
| 20 | 131 | 24 | 8 | 2 | 34 |

Chapter IX

# PROJECT OPERATION AND DEVELOPMENT

## Introduction

Ultimate success of the proposed project is contingent upon the following essentials: (1) bringing the reclaimed land into production as early as possible; (2) increasing yields through improvements of research and production techniques; (3) effective operation and maintenance of the project facilities; (4) effective transportation, storage, processing and marketing facilities for the rice. These elements are interrelated and must be attacked simultaneously which will require joint and well-coordinated efforts between the farmers and a designated administrative authority from the very beginning of construction.

## Administrative Authority

The responsibility for project operation and development must be firmly established at the start of construction. It is not know at present what type of organization will be implemented to carry out the project.

It is recommended that responsibility be vested in an administrative and supervisory authority at the project level. This responsibility should include overall coordinating functions covering all technical, educational, and operational matters pertinent to the success of the new venture.

It is recommended that an experienced rice agronomist be employed full time to direct this agency for several years beginning at the time of construction. Because of the present shortage of experienced Guinean



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technicians, this agronomist may have to be an expatriate. Guinean assistants should be assigned to work with him with the objective of ultimately assuming full responsibility after sufficient experience is gained.

The agronomist would also be assigned the technical direction of the CMR or such organization created specifically for the purpose of controlling the available mechanized equipment, acquiring and distributing farm supplies, and maintenance operation. He would be responsible also for conducting research and experiments on test plots, and extension activities to extend results to the farmers.

The Koba Project could serve as a pilot project for demonstration purposes and for training personnel for projects contemplated in other areas of Lower Guinea. Several trainees could be assigned to the project, under the technical direction of the agronomist, for subsequent assignment to other projects.

Land and Soil Preparation

Proper coordination between the land preparation and the contractors' operations is an absolute essential for integration of the drainage and reclamation scheme. Considerable reorganization and consolidation of presently cultivated lands will be necessary. Farm units of proper size and shape, and surface drains to be installed by the farmers must be laid out in proper patterns at the time the primary drainage channels are constructed. The spoils from these channels may be used for dikes and farm borders. Also the construction and land preparation must proceed systematically to permit as much land being brought into production as rapidly as possible. This will enable partial production during the

construction period without serious disruption of current farming operations.

The technical services of the agronomist, and other specialists as required, must be available during construction to assist farmers with proper land preparation, and operation of the drainage facilities.

## Agricultural Development Programs

The primary goal of the administering authority will be to assist the farmers in achieving and sustaining substantial increases in rice production. Substantial improvements are possible from a technological standpoint but realistic objectives must fit within the present patterns of land holdings and cultural methods. There are severe limitations to the range of improved practices that can be introduced. A rapid enlistment of peasant and nomad farmers in a change from traditional practices to intensive and modern practices is not expected. Short and long range programs should be initiated simultaneously with emphasis on those factors which will bring immediate results with least cost and management.

Short Range Programs. The immediate steps must deal with proper drainage and control of the fresh water supply, reduction of salinity in the surface soils, seed bed preparation, and adoption of varieties most suitable to the changed soil conditions. These improvements can be accomplished with practically no cash expenditures or changes in use of available hand implements.

The use of fertilizers, particularly phosphorus, and plant protection measures should be introduced at the start of the project. Initially this may require government assistance under communal rather than

individual programs. It is expected that several years will be required to inform the farmers of the factors of utility, availability, use, supply, and planning necessary to secure substantial universal application of inorganic fertilizers. However, adaption will have to be more rapid in certain fields. For instance, water levels within the paddies will be altered with drainage from those to which the farmers are accustomed. Proper timing in seed bed preparation, transplanting, spacing of plants,etc. are expected to be changed. Rapid adjustment to these new conditions is necessary to obtain the production levels anticipated.

Long-Range Programs. It is essential to introduce programs concerned with the primary factors of production at the beginning, even though the results may not be realized for several years. These include research for improvement of seed, introduction of complementary crops to be used in rotation with rice, test plots for fertilization trials with various combinations of plant food elements, soil testing and drainage studies, and a training program.

It is likely that at least five years will be needed before the first seeds from the research programs may be available for widespread distribution. However, the potential for increased yields from this source justifies this endeavor. Extensive plant protection measures are required for effective disease and pest control. These activities fall logically under the purview of the project area and can best be employed where substantial contiguous areas are planted to the same crop.

The long-range program should include integrated studies and analysis of the soils and corrective measures necessary to improve their fertility. This will involve fertilization trials, crop rotations with green manure and other crops, and chemical analysis. This

program would be integrated also with drainage studies for reduction and control of salinity, and control of water tables.

With the exception of plowing and threshing, mechanization is not expected to be a significant goal in improving rice production. These operations could be handled through machinery pools or the operating agency. Much improvement in production techniques, however, is possible with adoption and use of improved simple tools and equipment. For instance, hand plows pulled by animals would do much to lighten the burden of the farmer.

The success of the project will stand or fall with the success of contact with the farmers. Technical information must be transferred to the farmers which requires communication skills and methods. Also, the farmers must be motivated to change traditional methods and to intensify production.

We recommend that extension services be established through locally trained field agents in getting the farmers to accept and adopt new practices and materials. As the Koba Project is small only one or two agents may be required. The beginning technical tasks should be relatively simple, but growing more complex as the project develops. The agents can be trained through short courses, field demonstration, and working with the technical director.

Reactivation of the Koba Experiment Station. In their reports[1/], the two experts of the Food and Agriculture Organization of the United Nations recommended the reactivation of the Koba Experiment Station. Many of the short-term and long-term improvements mentioned in this

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1/ Reference 14 and 15, pages II-9 and II-10.

chapter can be brought about as a result of the activities of a rice experiment station. The facilities already existing at the Koba Center will provide an excellent start to such a program. The station is well located relative to the geographic position of the marsh ricelands in Lower Guinea.

However, it must be emphasized, as stated by the FAO experts, that the Koba Station reactivation can be useful only if its direction is entrusted to competent agronomists. One of them could also serve as extension officer in charge of the Koba Project, thus achieving economies and coordination.

The cost of reactivating the station is not included in our economic analysis of the project.

Maintenance and Operation

The maintenance and operation program will be one of the most important responsibilities of the technical director. The drainage channels, the tide control gates, and the other structures must be kept in a good state of repair. This will include constant cleaning to keep them free of debris, dredging to maintain grades, and other miscellaneous operations.

The responsibility for these operations must be with the technical director to enforce strict discipline throughout the project. Close cooperation and understanding from the farmers must be obtained for continued success. It is recommended that a farmers' committee be appointed to work with the director on these and other functions of the project. This arrangement frequently creates interest in the farmers

for maintaining the project because of understanding the problems and recognizing the benefits to them.

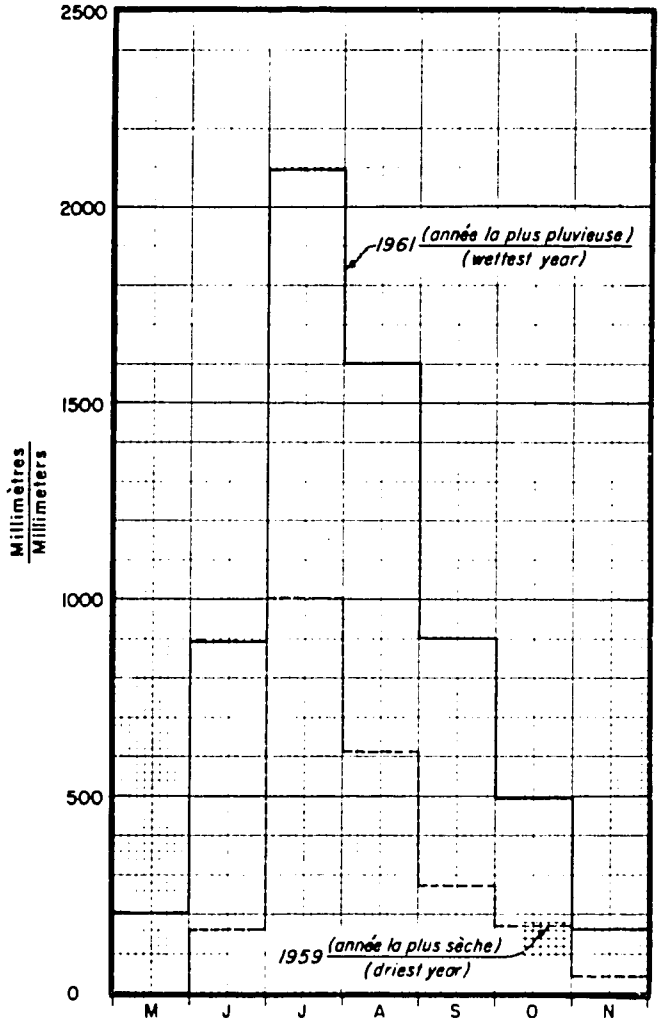
## Financial Arrangements

To carry out the duties and services recommended for the project the agency responsible will need a budget sufficient to enable an effective operation. This budget should be earmarked for this specific purpose by the government of Guinea and allocated to the administrative agency directly or through the Boffa regional executive government.

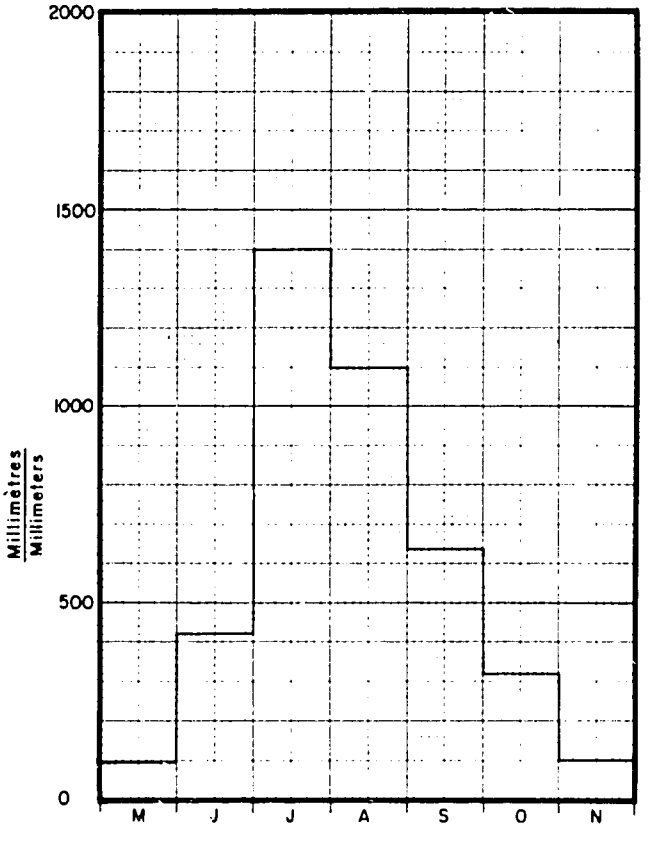
It is expected that costs for services involving training of field agents to be used elsewhere would not be charged to the Koba Project. It is recommended that the regional budget be allocated additional funds for these services, if provided. Financing arrangements and sources of revenue for costs of services for the Koba Project were discussed in Part One. A well-managed Koba Project will ultimately yield sufficient returns to the Republic of Guinea to justify the programs necessary for assuring its success.

## THE EXHIBITS

Exhibit 1. Climatological and Hydraulic Data
2. Land Use Map
3. Logs of Auger Holes
4. Results of Laboratory Tests
5. Results of Hydraulic Analyses
6. Details of Structures
7. Construction Schedule
8. Estimate of Project Construction Cost

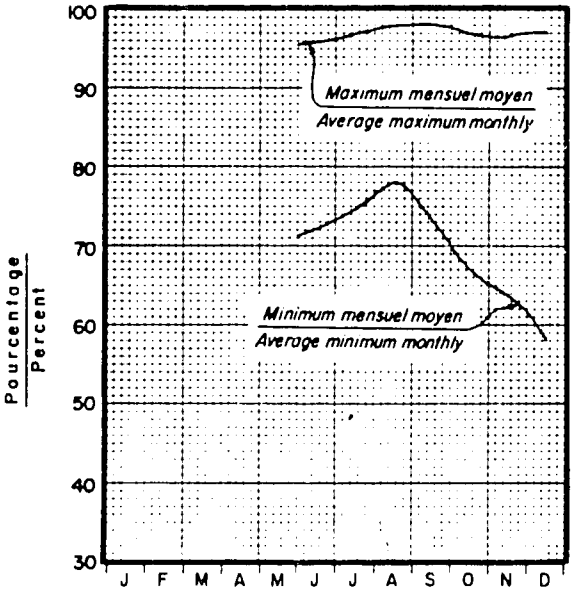



ANNEES EXTREMES / EXTREME YEARS

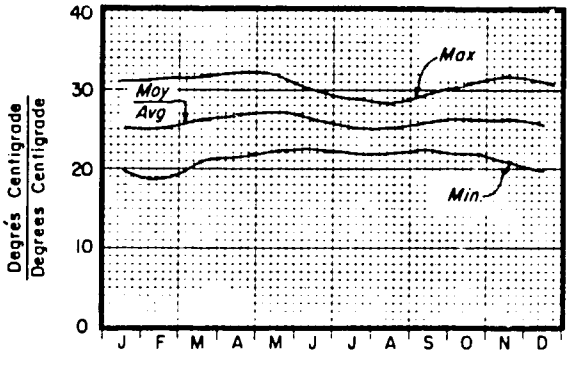



ANNEE MOYENNE / AVERAGE YEAR (1953-1961)

PLUVIOMETRIE MENSUELLE A KOBA / MONTHLY RAINFALL AT KOBA




HUMIDITE A BAKOUMPO (PLAINES DU KOBA) / HUMIDITY FOR BAKOUMPO (KOBA PLAINS) (1955)




TEMPERATURES A KOBA / TEMPERATURES FOR KOBA (1955)

NOTE

Données sur la pluviométrie, la température, et l'humidité à Koba et à Bakoumpo provenaient des archives du Service Météorologique National et du rapport COTHA "Plaines du Koba - Etudes préliminaires", 1956

Precipitations, temperatures and humidity at Koba and Bakoumpo were obtained from the files of the National Meteorologic Service and from COTHA'S "Plaines du Koba - Etudes préliminaires", 1956

DONNEES CLIMATOLOGIQUES ET HYDRAULIQUES

CLIMATOLOGICAL AND HYDRAULIC DATA

PLANCHE 2
EXHIBIT

LEGENDE
LEGEND

- Piste / Unpaved road
- Village
- Cours d'eau / Streams
- Dunes
- Limite de la région du projet / Limits of Project Area
- ● 22 Point de prélèvement d'échantillons de sol / Soil sampling site
- [B] Point de mesure du coefficient de perméabilité / Permeability test site

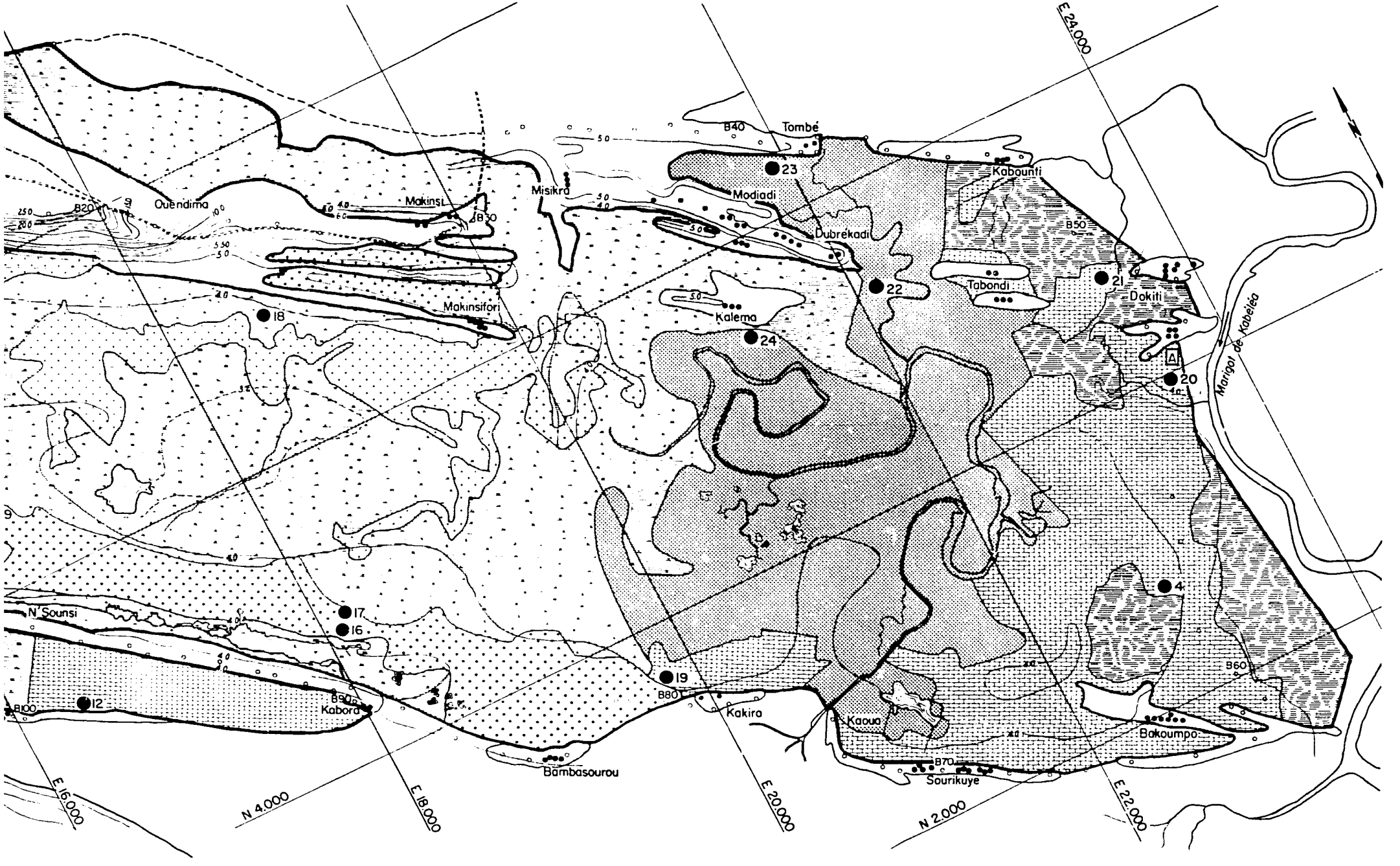
| | | |
|---|---|---|
| Terres catégorie I / Group I lands | (620 ha.) | Terres actuellement cultivées mais sujettes à des inondations par eau de ruissellement de façon intermittente. / Lands presently under cultivation but subject to intermittent fresh water flooding. |
| Terres catégories II / Group II lands | (1790 ha.) | Terres non cultivées sujettes à des inondations par eau douce en période d'hivernage. / Areas subject to fresh water ponding during wet season. Lands not cultivated. |
| Terres catégories III / Group III lands | (205 ha.) | Terres couvertes d'arbres. 23 pour cent de la superficie est sujette à des inondations par eau de ruissellement. / Lands with tree cover 23 percent of area subject to fresh water ponding. |
| Terres catégories IV / Group IV lands | (455 ha.) | Zones basses affectées par des intrusions salines. 88 pour cent de la superficie est actuellement cultivée. / Low areas - subject to salt water intrusion. 88 percent of lands under cultivation. |
| Terres catégories V / Group V lands | (630 ha.) | Zones basses inondées en période d'hivernage, mais affectées par des intrusions salines en saison sèche. Terres non cultivées. / Low areas flooded during the wet season but subject to salt water intrusion during the dry season. Lands not cultivated. |
| Terres catégories VI / Group VI lands | (200 ha.) | Zones soumises aux intrusions salines. Terres couvertes par la mangrove ou par des souches de palétuviers. / Areas subject to salt water intrusion. Lands have mangrove or mangrove stump cover. |

NOTE:
Les détails topographiques et courbes de niveau sont basés sur les cartes topographiques COTHA préparées en 1954.

NOTE:
Topographic details and contours are based on 1954 COTHA topographic maps.

Echelle / Scale 0 — 500 Mètres / Meters

CARTE DES CULTIVATIONS
LAND USE MAP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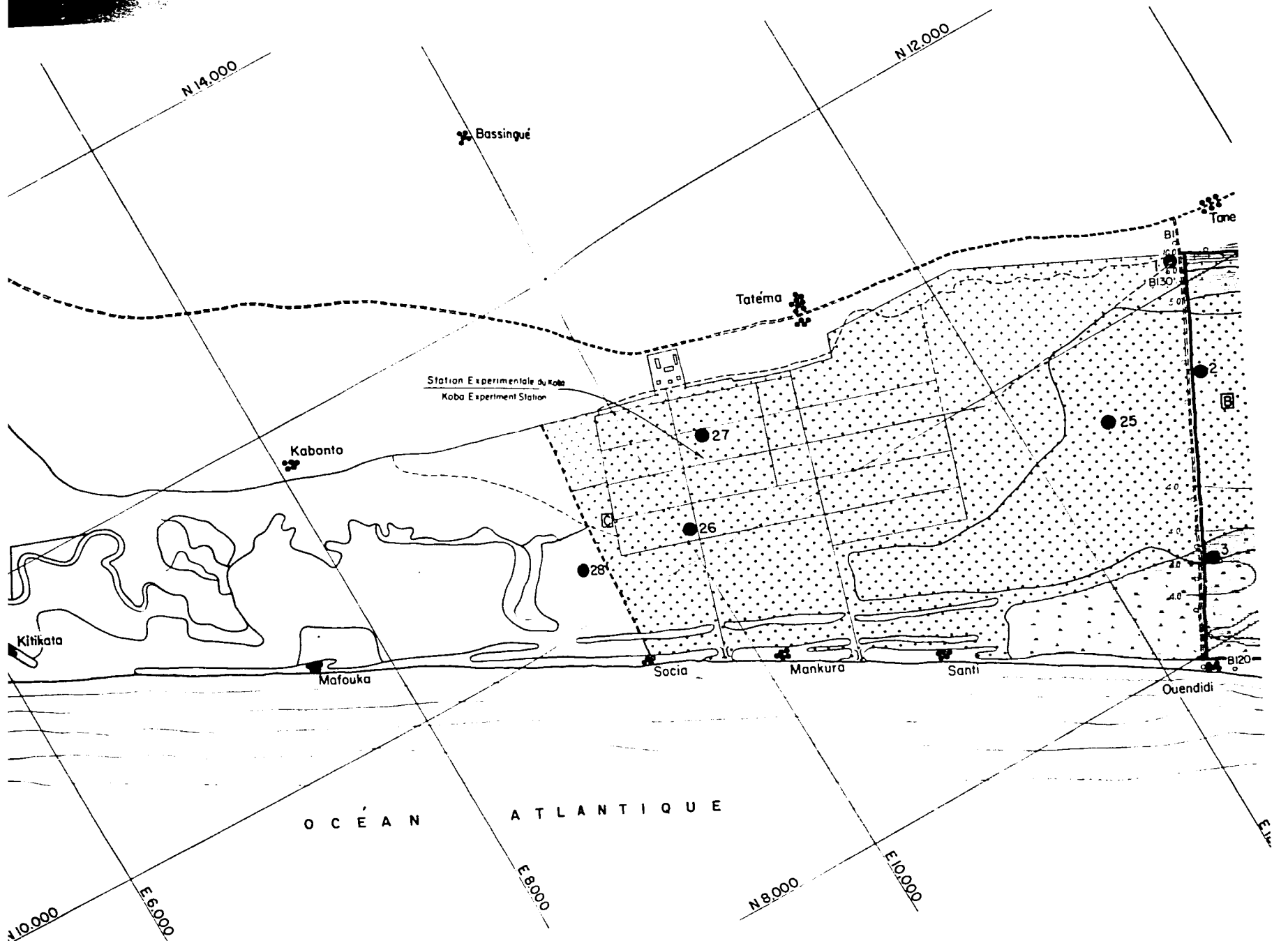
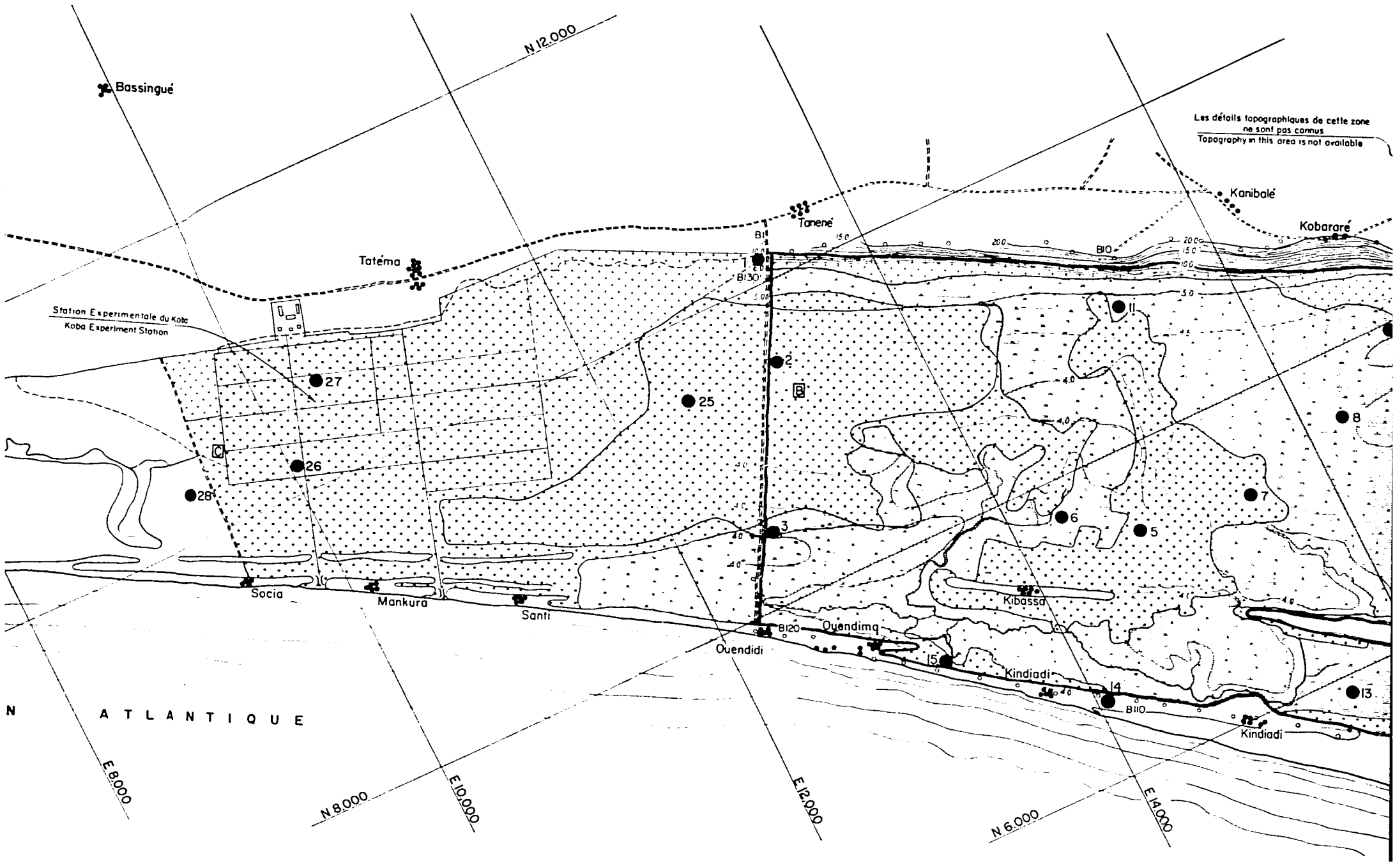
B40
23
Kabounti
Modiadi
Misikrá
Dubrékadi
B50
Ouendima
B20
Makinsi
B30
Tabondi
21
Dokiti
22
Makinsifori
18
Kalema
24
Marigot de Kabeléa
20
4
N'Sounsi
17
16
19
B60
B100
12
B90
Kabora
B80
Kakira
Kaoua
Bakoumpo
B70
Sourikuye
Bambasourou
E.16.000
N 4.000
E.18.000
E.20.000
N 2.000
E.22.000
E.24.000


N 14.000
N 12.000
N 10.000
N 8.000
E 6.000
E 8.000
E 10.000
Bassinqué
Tane
Tatéma
Station Expérimentale du Koba
Koba Experiment Station
Kabonta
Kitikata
Mafouka
Socia
Mankura
Santi
Ouendidi
B130
B120
1
2
3
25
26
27
28
OCÉAN ATLANTIQUE


Bassingué
N 12.000
Les détails topographiques de cette zone ne sont pas connus
Topography in this area is not available
Kanibalé
Kobararé
Tanené
Tatéma
Station Experimentale du Koba
Koba Experiment Station
B1
B130
B10
B120
B110
1
2
3
5
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7
8
11
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15
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C
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Socia
Mankura
Santi
Ouendidi
Ouendimq
Kibassa
Kindiadi
Kindiadi
A T L A N T I Q U E
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N 8.000
E 10.000
E 12.000
N 6.000
E 14.000

PLANCHE 2
EXHIBIT

LEGENDE
LEGEND

Piste
Unpaved road

Village

Cours d'eau
Streams

Dunes

Limite de la région du projet
Limits of Project Area

22 Point de prélèvement d'échantillons de sol
Soil sampling site

B Point de mesure du coefficient de perméabilité
Permeability test site

Terres catégorie I (620 ha.)
Group I lands
Terres actuellement cultivées mais sujettes à des inondations par eau de ruissellement de façon intermittente.
Lands presently under cultivation but subject to intermittent fresh water flooding.

Terres catégories II (1790 ha.)
Group II lands
Terres non cultivées sujettes à des inondations par eau douce en période d'hivernage.
Areas subject to fresh water ponding during wet season. Lands not cultivated.

Terres catégories III (205 ha.)
Group III lands
Terres couvertes d'arbres. 23 pour cent de la superficie est sujette à des inondations par eau de ruissellement.
Lands with tree cover. 23 percent of area subject to fresh water ponding.

Terres catégories IV (455 ha.)
Group IV lands
Zones basses affectées par des intrusions salines. 88 pour cent de la superficie est actuellement cultivée.
Low areas - subject to salt water intrusion. 88 percent of lands under cultivation.

Terres catégories V (630 ha.)
Group V lands
Zones basses inondées en période d'hivernage, mais affectées par des intrusions salines en saison sèche. Terres non cultivées.
Low areas flooded during the wet season but subject to salt water intrusion during the dry season. Lands not cultivated.

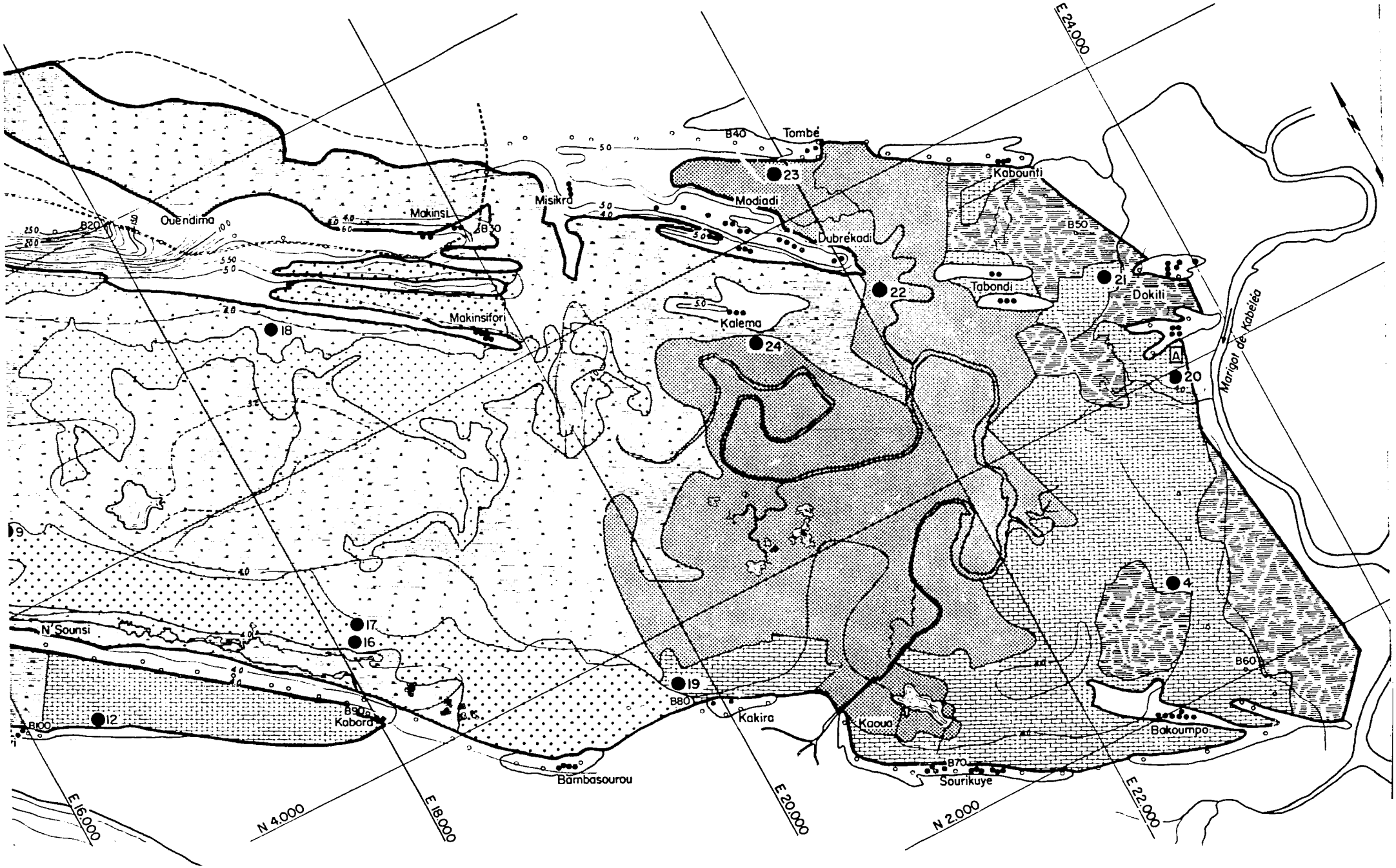
Terres catégories VI (200 ha.)
Group VI lands
Zones soumises aux intrusions salines. Terres couvertes par la mangrove ou par des souches de palétuviers.
Areas subject to salt water intrusion. Lands have mangrove or mangrove stump cover.

NOTE:
Les détails topographiques et courbes de niveau sont basés sur les cartes topographiques COTHA préparées en 1954.

NOTE:
Topographic details and contours are based on 1954 COTHA topographic maps.

Echelle / Scale 0 500 Mètres / Meters

CARTE DES CULTIVATIONS
LAND USE MAP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B40
Kabounti
Modiadi
Misikra
Makinsi
B30
B20
Ouendima
Dubrekadi
B50
Tabondi
Dokiti
Kalema
Makinsifori
Marigot de Kabéléa
N'Sounsi
Kabora
B90
B100
Kakira
B80
Kaoua
Bakoumpo
B60
B70
Sourikuye
Bambasourou
E 16.000
N 4.000
E 18.000
E 20.000
N 2.000
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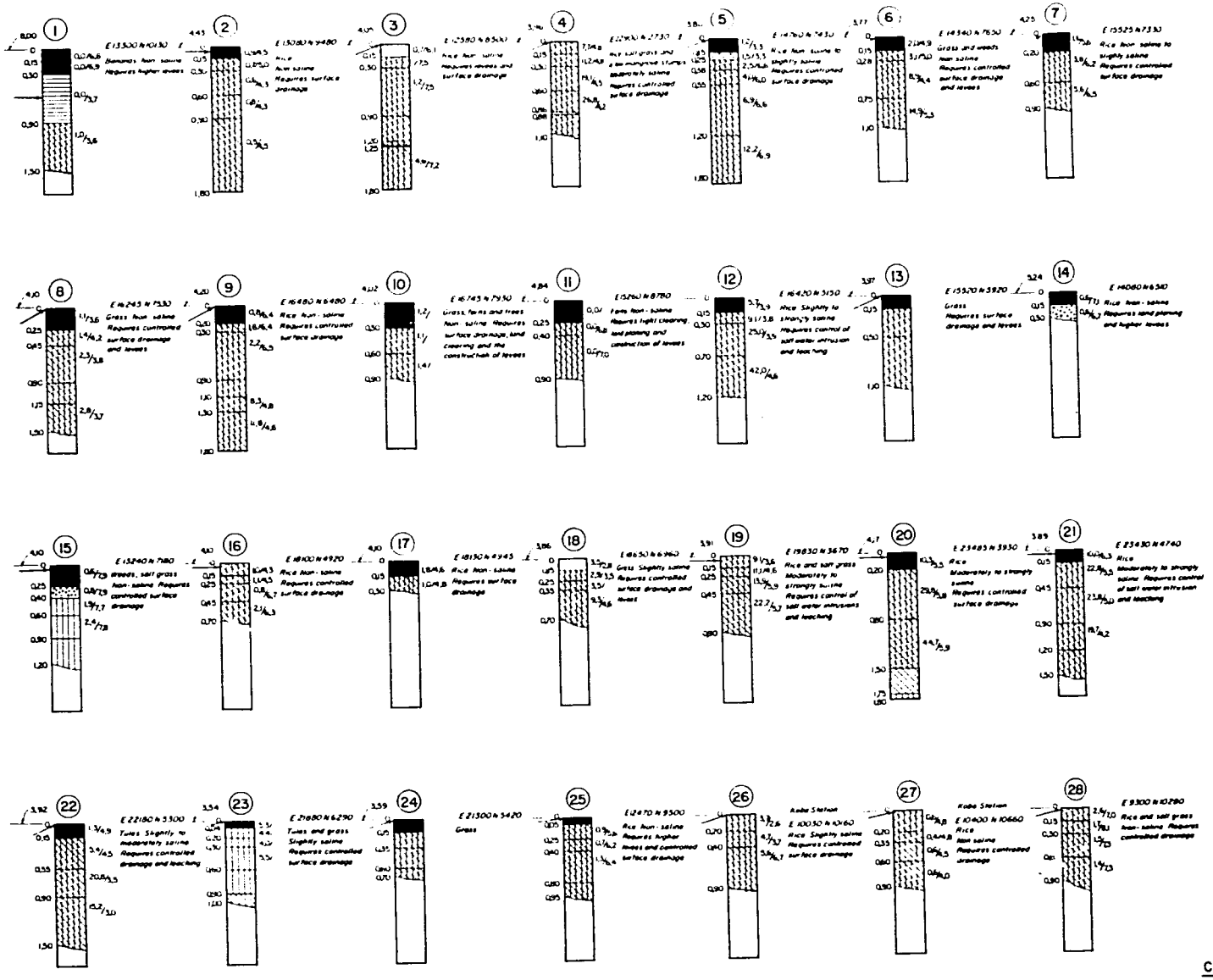
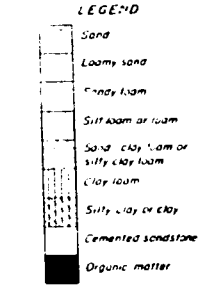
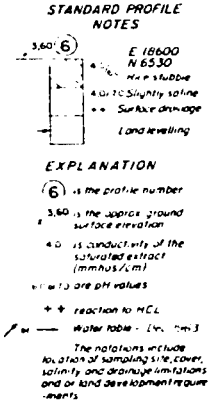





## COUPES VERTICALES DES TERRAINS
## SOIL PROFILES

Exhibit 4

# CHEMICAL & PHYSICAL ANALYSES OF SOIL SAMPLES

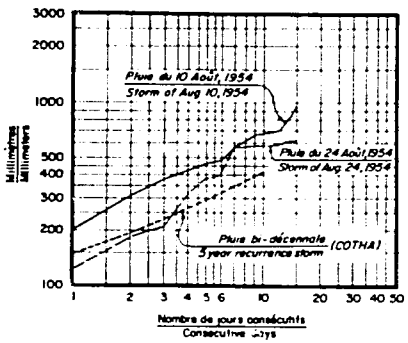
## KOBA - 1963

| LOCATION | HOLE No. | DEPTH | WATER AT SATURATION | pH SATURATED PASTE | pH SATURATED EXTRACT | CATION EXCHANGE CAPACITY (NAOAC) | EXTRACTABLE CATIONS me/100 grams K | Ca | Mg | Na | H* | TOTAL | ORGANIC MATTER | AVAILABLE P | $P_2O_5$ | MECHANICAL ANALYSIS SAND | SILT | CLAY | SOIL TEXTURE | FREE IRON | EXTRACTABLE ALUMINUM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cms | % | | | me/100 g | | | | | | | % | kg/ha | kg/ha | % | % | % | | % | me/100 g |
| N9480-E13080 | 2 | 0-15 | 108 | 4.5 | 5.3 | 40.0 | 0.17 | 0.38 | 0.94 | 0.28 | 42.19 | 43.96 | 14.4 | 57 | 130 | 4.0 | 44.0 | 52.0 | SiC | 2.5 | 35.6 |
| | | 15-30 | 105 | 5.0 | 5.7 | 38.9 | 0.10 | 0.38 | 0.94 | 0.10 | 34.61 | 36.13 | 17.0 | 82 | 188 | 4.9 | 48.1 | 47.0 | SiC | 1.4 | 39.4 |
| | | 30-60 | 86 | 4.3 | 6.0 | 21.6 | 0.09 | 0.50 | 2.08 | 0.09 | 31.18 | 33.94 | 2.6 | 65 | 149 | 2.3 | 30.6 | 67.1 | C | 3.4 | 46.1 |
| | | 60-90 | 85 | 4.3 | 5.8 | 17.6 | 0.14 | 0.63 | 2.60 | 0.79 | 25.30 | 28.96 | 2.3 | 100 | 229 | 1.5 | 22.2 | 76.3 | C | 4.4 | 46.1 |
| | | 90-150 | 92 | 4.5 | 7.1 | 20.2 | 0.22 | 1.13 | 7.91 | 0.14 | 16.92 | 26.32 | 0.6 | 23 | 53 | 0.9 | 27.0 | 77.1 | C | 3.3 | 28.3 |
| N2730-E22900 | 4 | 0-15 | 86 | 4.8 | 6.5 | 26.0 | 0.90 | 1.00 | 7.29 | 9.90 | 12.37 | 31.46 | 7.3 | 10 | 23 | 4.2 | 24.9 | 70.9 | C | 4.2 | 1.6 |
| | | 15-30 | 88 | 4.8 | 6.9 | 19.6 | 1.14 | 1.13 | 7.29 | 10.74[1] | 10.78 | 31.08 | 2.7 | 17 | 39 | 3.8 | 22.7 | 73.5 | C | 3.6 | 2.2 |
| | | 30-60 | 86 | 4.5 | 6.9 | 20.2 | 1.26 | 1.75 | 10.42 | 2.93 | 11.54 | 27.90 | 1.8 | 25 | 57 | 3.8 | 28.4 | 67.8 | C | 5.8 | 6.1 |
| | | 60-80 | 94 | 4.2 | 6.4 | 19.6 | 1.28 | 2.00 | 10.00 | 3.91 | 11.87 | 29.06 | 1.0 | 15 | 34 | 3.6 | 20.7 | 75.7 | C | 5.7 | 8.3 |
| N7650-E14340 | 6 | 0-15 | 82 | 4.9 | 7.1 | 25.4 | 0.66 | 1.50 | 6.25 | 2.88 | 17.06 | 28.35 | 9.2 | 63 | 144 | 1.4 | 19.1 | 79.5 | C | 2.0 | 9.4 |
| | | 15-28 | 124 | 5.0 | 6.5 | 28.9 | 0.85 | 2.25 | 6.25 | 3.97 | 16.01 | 29.33 | 3.9 | 22 | 50 | 0.7 | 12.5 | 86.8 | C | 4.8 | 5.0 |
| | | 28-75 | 89 | 4.4 | 6.8 | 24.8 | 0.94 | 2.50 | 7.92 | 6.85 | 14.97 | 33.18 | 1.0 | 6 | 14 | 1.3 | 21.8 | 76.9 | C | 25.4 | 7.8 |
| | | 75-110 | 114 | 5.3 | 6.2 | 26.1 | 1.24 | 4.75 | 7.29 | 13.26 | 9.54 | 36.09 | 0.5 | 20 | 46 | 0.9 | 14.3 | 84.8 | C | 1.9 | 1.7 |
| N4920-E18100 | 16 | 0-15 | 75 | 4.3 | 6.5 | - | 0.33 | 1.13 | 4.69 | 0.58 | 18.15 | 24.88 | 1.6 | 6 | 14 | - | - | - | | 5.7 | - |
| | | 15-25 | 72 | 4.5 | 6.8 | - | 0.21 | 1.13 | 5.83 | 0.79 | 17.86 | 25.82 | 2.4 | 11 | 25 | - | - | - | | 3.8 | - |
| N4945-E18130 | 17 | 0-15 | 77 | 4.6 | 4.1 | - | 0.21 | 1.00 | 5.21 | 0.88 | 22.54 | 29.80 | 3.6 | 26 | 60 | - | - | - | | 3.0 | - |
| | | 15-25 | 86 | 4.8 | 6.2 | - | 0.23 | 1.00 | 3.65 | 2.01 | 21.27 | 28.16 | 3.9 | 23 | 53 | - | - | - | | 2.6 | - |
| N3930-E23485 | 20 | 0-20 | 80 | 5.5 | 7.2 | 20.9 | 1.22 | 1.00 | 5.21 | 5.79 | 9.45 | 23.67 | 2.3 | 10 | 23 | 10.3 | 33.0 | 55.7 | C | 5.1 | 0.6 |
| | | 20-80 | 102 | 5.8 | 6.4 | 21.5 | 1.89 | 3.25 | 8.33 | 33.04 | 6.56 | 53.07 | 1.0 | 10 | 23 | 5.7 | 26.6 | 67.7 | C | 15.2 | 0.0 |
| | | 80-150 | 100 | 5.9 | 6.0 | 16.7 | 2.29 | 4.88 | 12.50 | 26.52 | 5.35 | 51.54 | 1.8 | 21 | 48 | 24.9 | 18.9 | 56.2 | C | 3.9 | 1.7 |
| N10660-E10400 | 27 | 0-20 | 77 | 4.8 | 6.5 | 24.1 | 0.12 | 4.25 | 1.15 | 0.25 | 17.14 | 22.91 | 2.6 | 67 | 153 | 1.1 | 14.6 | 84.3 | C | 5.4 | 10.6 |
| | | 20-35 | 79 | 5.8 | 6.5 | 19.0 | 0.09 | 4.25 | 1.04 | 0.09 | 15.41 | 20.88 | 1.8 | 77 | 176 | 1.0 | 28.4 | 70.6 | C | 15.7 | 9.4 |
| | | 35-60 | 95 | 4.5 | 5.8 | 15.6 | 0.13 | 2.50 | 1.56 | 0.08 | 16.59 | 20.86 | 1.0 | 8 | 18 | 0.4 | 14.1 | 85.5 | C | 27.7 | 21.1 |
| | | 60-90 | 82 | 4.0 | 6.8 | 16.7 | 0.17 | 1.75 | 3.13 | 0.08 | 18.75 | 23.88 | 1.3 | 2 | 5 | 0.4 | 15.8 | 83.8 | C | 5.1 | 23.9 |

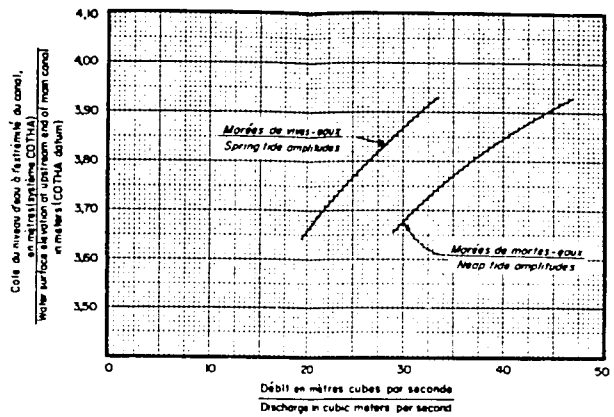
| LOCATION | HOLE No. | DEPTH | ELECTRICAL CONDUCTIVITY | CATIONS me/liter Ca | Mg | Na | K | TOTAL | ANIONS me/liter $CO_3$ | $HCO_3$ | $SO_4$ | Cl | TOTAL | SODIUM ADSORPTION RATIO (SAR) | TOTAL S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cms | mmhos/cm | | | | | | | | | | | | % |
| N9480-E13080 | 2 | 0-15 | 0.9 | 0.1 | 2.3 | 7.4 | 0.3 | 10.1 | NIL | 0.0 | 2.1 | 5.0 | 7.1 | 7 | |
| | | 15-30 | 0.7 | 0.1 | 1.4 | 7.6 | 0.1 | 9.2 | NIL | 2.5 | 2.6 | 2.5 | 7.6 | | 0.24 |
| | | 30-60 | 0.6 | 0.7 | 1.4 | 5.6 | 0.1 | 7.8 | NIL | 2.5 | 1.6 | 2.5 | 6.6 | | |
| | | 60-90 | 0.8 | 0.2 | 1.9 | 8.4 | 0.1 | 10.6 | NIL | 2.0 | 3.1 | 4.0 | 9.1 | | |
| | | 90-150 | 0.5 | 0.1 | 1.8 | 5.6 | 0.1 | 7.6 | NIL | 1.0 | 1.6 | 2.0 | 4.6 | | |
| N2730-E22900 | 4 | 0-15 | 7.7 | 1.2 | 16.8 | 49.0 | 3.1 | 70.1 | NIL | 2.5 | 4.0 | 65.0 | 71.5 | 16 | 0.09 |
| | | 15-30 | 11.2 | 1.7 | 23.7 | 78.7 | 3.6 | 107.7 | NIL | 2.0 | 2.0 | 103.0 | 107.0 | 22 | 0.21 |
| | | 30-60 | 19.1 | 4.8 | 47.7 | 105.7 | 4.8 | 163.0 | NIL | 0.0 | 44.3 | 201.5 | 245.8 | | |
| | | 60-80 | 26.8 | 8.2 | 79.8 | 168.4 | 5.4 | 261.8 | NIL | 1.0 | 41.7 | 279.6 | 322.3 | | |
| N7650-E14340 | 6 | 0-15 | 2.0 | 0.4 | 3.6 | 16.1 | 0.4 | 20.5 | NIL | 0.0 | 1.6 | 10.0 | 11.6 | 11 | 0.27 |
| | | 15-28 | 3.1 | 0.3 | 4.5 | 31.1 | 0.6 | 36.5 | NIL | 2.0 | 1.0 | 17.5 | 20.5 | 20 | 0.90 |
| | | 28-75 | 8.9 | 2.4 | 20.8 | 52.1 | 1.2 | 76.5 | NIL | 5.0 | 21.9 | 71.0 | 97.9 | | |
| | | 75-110 | 14.9 | 0.6 | 30.3 | 90.9 | 4.5 | 126.3 | NIL | 5.0 | 52.1 | 115.0 | 172.1 | | |
| N4920-E18100 | 16 | 0-15 | 1.0 | | | | | | | | 2.0 | 10.0 | | | |
| | | 15-25 | 1.1 | | | | | | | | 2.6 | | | | |
| N4945-E18130 | 17 | 0-15 | 1.8 | | | | | | | | 1.5 | | | | |
| | | 15-25 | 1.0 | | | | | | | | 2.0 | | | | |
| N3930-E23485 | 20 | 0-20 | 10.3 | 2.0 | 12.8 | 55.5 | 4.8 | 75.1 | NIL | 2.5 | 1.6 | 101.0 | 105.1 | 20 | 0.09 |
| | | 20-80 | 29.8 | 13.5 | 73.1 | 256.0[1] | 9.0 | 351.6[1] | NIL | 1.5 | 27.7 | 327.5 | 356.7 | 28 | 0.97 |
| | | 80-150 | 44.7 | 21.6 | 164.5 | 350.1 | 1.2 | 537.4 | NIL | 2.5 | 72.9 | 623.0 | 698.4 | | |
| N10660-E10400 | 27 | 0-20 | 0.5 | Neg. | 0.8 | 4.2 | 0.1 | 5.1 | NIL | 2.5 | 2.0 | < 0.5 | 4.5[1] | | 0.62 |
| | | 20-35 | 0.4 | Neg. | 0.7 | 4.8 | 0.1 | 5.6 | NIL | 2.5 | 1.6 | < 0.5 | 4.1[1] | | 0.86 |
| | | 35-60 | 0.6 | Neg. | 0.7 | 5.0 | 0.1 | 5.8 | NIL | 2.0 | 2.6 | < 0.5 | 4.6[1] | | |
| | | 60-90 | 0.6 | 0.0 | 1.2 | 6.4 | 0.1 | 7.7 | NIL | 2.5[1] | 4.2 | < 0.5 | 7.7[1] | | |

1 Estimated

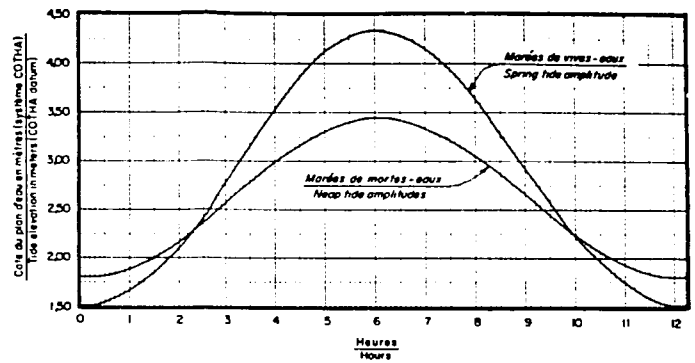
* Exchange-Acidity



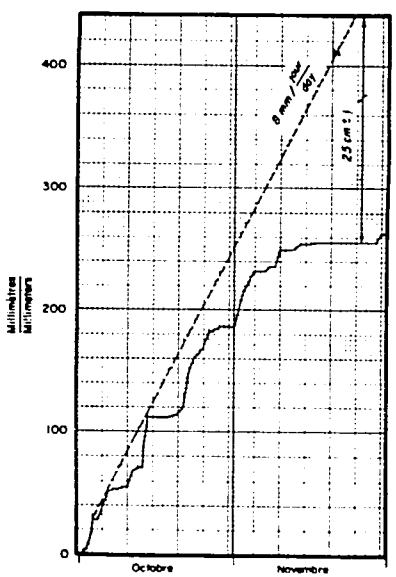

PLUVIOMETRIE CUMULEE A BAKOUMPO PENDANT LE NOMBRE DE JOURS CONSECUTIFS INDIQUE EN ABSCISSES
CUMULATIVE RAINFALL AT BAKOUMPO FOR CONSECUTIVE DAYS



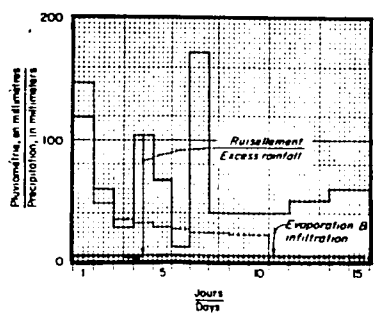

DEBIT MOYEN DU CANAL PRINCIPAL PENDANT UN CYCLE DE MAREE
MAIN CANAL AVERAGE DISCHARGE FOR ONE TIDE CYCLE



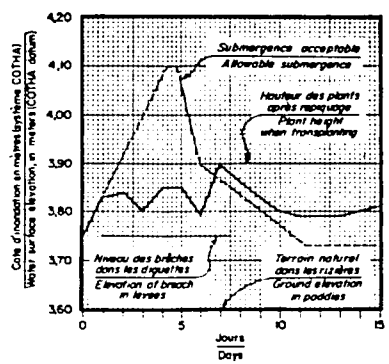

VARIATIONS DU PLAN D'EAU AU MARIGOT DE KABELEA
AVERAGE TIDAL CYCLES AT KABELEA MARIGOT




PLUVIOMETRIE CUMULEE DU 1er OCTOBRE AU 30 NOVEMBRE 1955 A BAKOUMPO
CUMULATIVE RAINFALL AT BAKOUMPO FROM OCTOBER 1st TO NOVEMBER 30, 1955



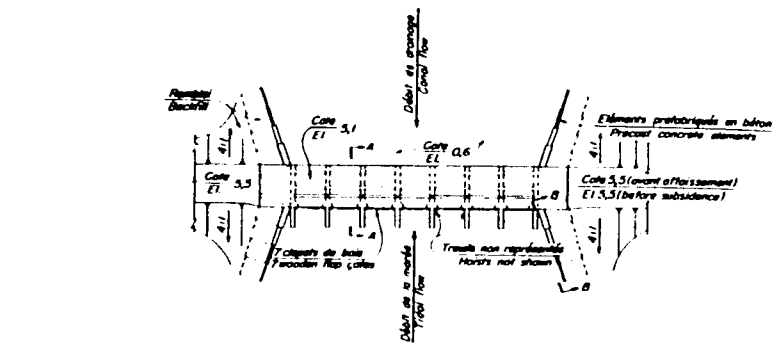

AVERSE-TYPE DE 15 JOURS
15-DAY DESIGN STORM

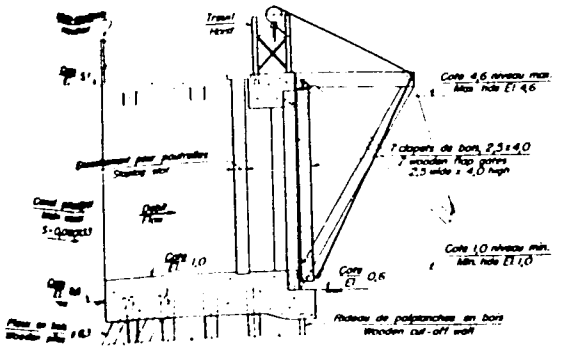


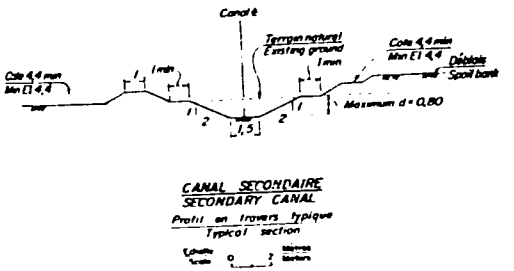

NIVEAU D'EAU DANS LES RIZIERES PENDANT L'AVERSE-TYPE DE 15 JOURS
WATER SURFACE IN PADDIES DURING DESIGN 15-DAY STORM

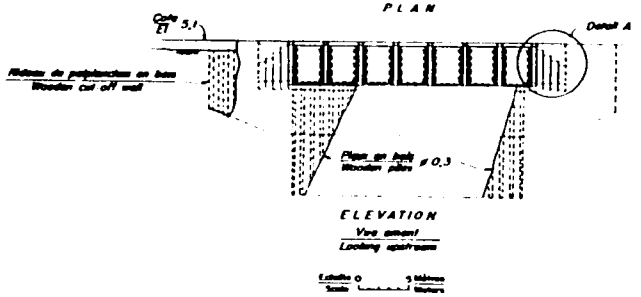
RESULTATS DES ETUDES HYDRAULIQUES
RESULTS OF HYDRAULIC ANALYSES

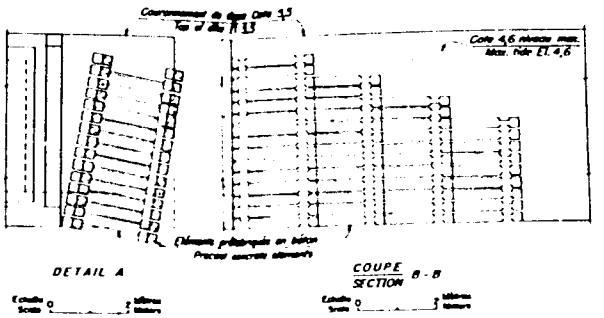
PLANCHE
EXHIBIT 6

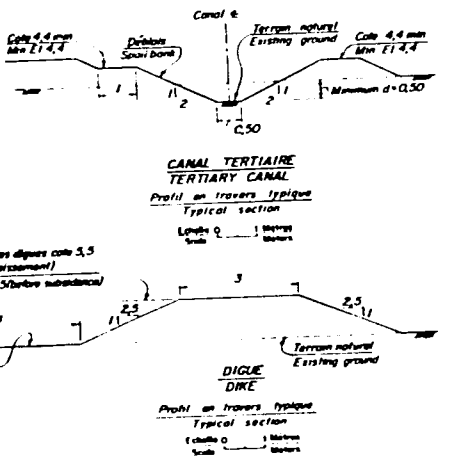


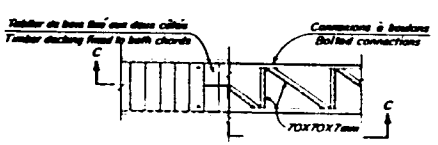



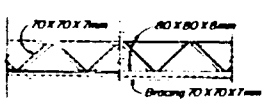




OUVRAGE DE VANNAGE
CONTROL STRUCTURE




| De kilomètre From kilometer | à kilomètre to kilometer | B Mètres Meters |
|---|---|---|
| 0,0 | 1,8 | 12 |
| 1,8 | 3,3 | 17 |
| 3,3 | 6,6 | 27 |
| 6,6 | 12,0 | 32 |
| 12,0 | 32,0 | 40 |
| 32,0 | 46,0 | 46 |

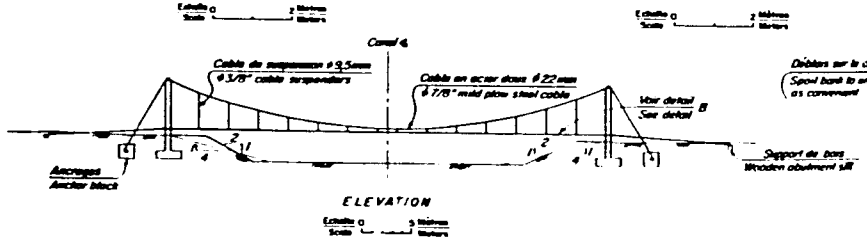
LARGEUR AU PLAFOND DES CANAUX
CANAL BOTTOM WIDTHS

NOTES

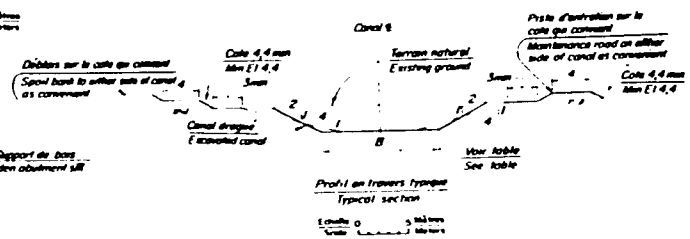
1. Toutes les cotes altimétriques se rapportent au nivellement COTHA
2. Toutes les dimensions sont en mètres sauf indications spécifiques contraires
3. Pour tous les ponts et passerelles le bord des rideaux sera à la cote 4,0 minimum
4. Les passerelles sont calculées pour une charge de 700 kg/mètre carré uniformément répartie

NOTES

1. All elevations are referred to the COTHA system
2. All dimensions are in meters except as noted
3. Minimum level for all bridges to be not less than EI 4,0
4. Foot bridges are designed for uniform distributed load of 700 kg per square meter

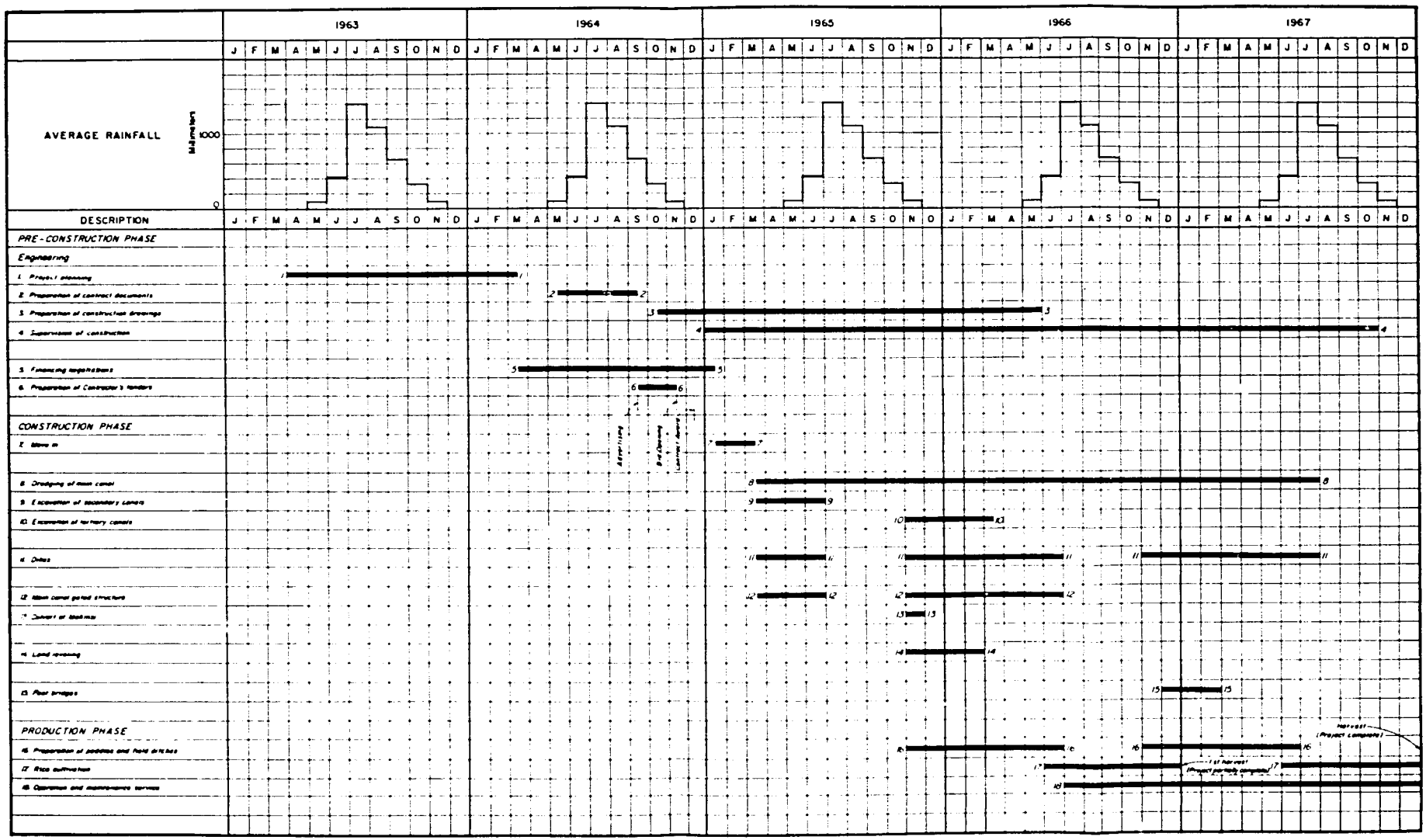



PONCEAU SUR CANAL PRINCIPAL
FOOT BRIDGE SPANNING MAIN CANAL




CANAL PRINCIPAL
MAIN CANAL

VUES DETAILLEES DES OUVRAGES
DETAILS OF STRUCTURES




CONSTRUCTION SCHEDULE

**ESTIMATE** **HARZA ENGINEERING COMPANY INTERNATIONAL** Exhibit 8

Project Number 309

Project Koba Date 2.2.64 Page 1 of 2 Pages

Structure Project Construction Cost Estimated by JAT/MB Checked by JJM

| Item No. | ITEM | Quantity | Unit Price GF (Local) | Unit Price U.S. Dollars | Amount GF (Local) | Amount U.S. Dollars |
|---|---|---|---|---|---|---|
| 1 | Canal Excavation | | | | | |
| | Main Canal | 1,012,000m³ | 160 | 0.80 | 161,920,000 | 809,600 |
| | Secondary Canals | 74,000m³ | 95 | 1.05 | 7,030,000 | 77,700 |
| | Tertiary Canals | 98,000m³ | 95 | 1.05 | 9,310,000 | 102,900 |
| | | | | | | |
| 2 | Dikes | | | | | |
| | New Dikes | 161,000m³ | 125 | 1.35 | 20,125,000 | 217,350 |
| | Dike Improvement | 10,000m³ | 100 | 1.00 | 1,000,000 | 10,000 |
| | | | | | | |
| 3 | Control Structure | | Lump | Sum 1/ | 28,242,000 | 58,500 |
| | | | | | | |
| 4 | Culvert at Makinsi | | Lump | Sum 1/ | 309,060 | 206 |
| | | | | | | |
| 5 | Gate at Ouendidi | 1 each | 55,000 | 1,000.00 | 55,000 | 1,000 |
| | | | | | | |
| 6 | Land Leveling | 45,000m³ | 125 | 1.00 | 5,625,000 | 45,000 |
| | | | | | | |
| 7 | Foot-Bridges | 5 each | 1,750,000 | 4,000.00 | 8,750,000 | 20,000 |
| | | | | | | |
| 8 | Clearing | 85 hectares | 50,000 | 10.00 | 4,250,000 | 850 |
| | | | | | | |
| | Subtotal Direct Cost | | | | 246,616,060 | 1,343,103 |
| | Contingencies | (15% ±) | | | 23,383,940 | 206,897 |
| | | | | | | |
| | Total, Direct Cost | | | | 270,000,000 | 1,550,000 |
| | Engineering & Supervision of Construction | (15% ±) | | | 20,000,000 | 300,000 |
| | | | | | | |
| | Construction Cost of Civil Works | | | | 290,000,000 | 1,850,000 |
| | Cost of Land Preparation | | | | 40,000,000 | 50,000 |
| | | | | | | |
| | Total Project Construction Cost | | | | 330,000,000 | 1,900,000 |
| | | | | | | |
| | 1/ See page 2 for detailed estimate | | | | | |

**ESTIMATE** **HARZA ENGINEERING COMPANY INTERNATIONAL** Exhibit 8

Project Number 309

Project Koba Date 2.2.64 Page 2 of 2 Pages

Structure Items 3 & 4 (detailed estimate) Estimated by JAT/MB Checked by JJM

| Item No. | ITEM | Quantity | Unit Price | | Amount | |
|---|---|---|---|---|---|---|
| | | | GF (Local) | U.S. Dollars | GF (Local) | U.S. Dollars |
| 3 | Control Structure | | | | | |
| | Diversion Cofferdam | 15,000m$^3$ | 200 | 2.00 | 3,000,000 | 30,000 |
| | Excavation, Structural | 2,800m$^3$ | 165 | 1.80 | 462,000 | 5,040 |
| | Pile Foundation, Timber | 1,800 lm | 3,300 | 2.70 | 5,940,000 | 4,860 |
| | Cut off Wall, Timber | 25m$^3$ | 7,590 | 8.00 | 189,750 | 200 |
| | Concrete, Structural | 300m$^3$ | 17,600 | - | 5,280,000 | - |
| | Formwork | 800m$^2$ | 2,530 | 3.20 | 2,024,000 | 2,560 |
| | Concrete, Precast (Cribs) | 74m$^3$ | 35,200 | - | 2,604,800 | - |
| | Steel Reinforcement | 24,000 kg | 198 | - | 4,752,000 | - |
| | Flap Gates with Hoists | 7 each | 340,000 | 1,500.00 | 2,380,000 | 10,500 |
| | Earthfill, Cribs | 200m$^3$ | 693 | 4.60 | 138,600 | 920 |
| | Backfill, Structural | 1,000m$^3$ | 125 | 1.40 | 125,000 | 1,400 |
| | Misc. Items | | | | 1,345,850 | 3,020 |
| | | | | | | |
| | Subtotal Control Structure | | | | 28,242,000 | 58,500 |
| | | | | | | |
| 4 | Culvert at Makinsi | | | | | |
| | Excavation, Structural | 100m$^3$ | 165 | 1.80 | 16,500 | 180 |
| | Corrugated Metal Pipe | 20 lm | 10,800 | 1.30 | 216,000 | 26 |
| | Concrete, Structural | 3m$^3$ | 17,600 | - | 52 52,800 | - |
| | Steel Reinforcement | 120 kg | 198 | - | 23,760 | - |
| | | | | | | |
| | Subtotal Culvert at Makinsi | | | | 309,060 | 206 |