FIGURE V-1 PROPOSED CROPPING PATTERN

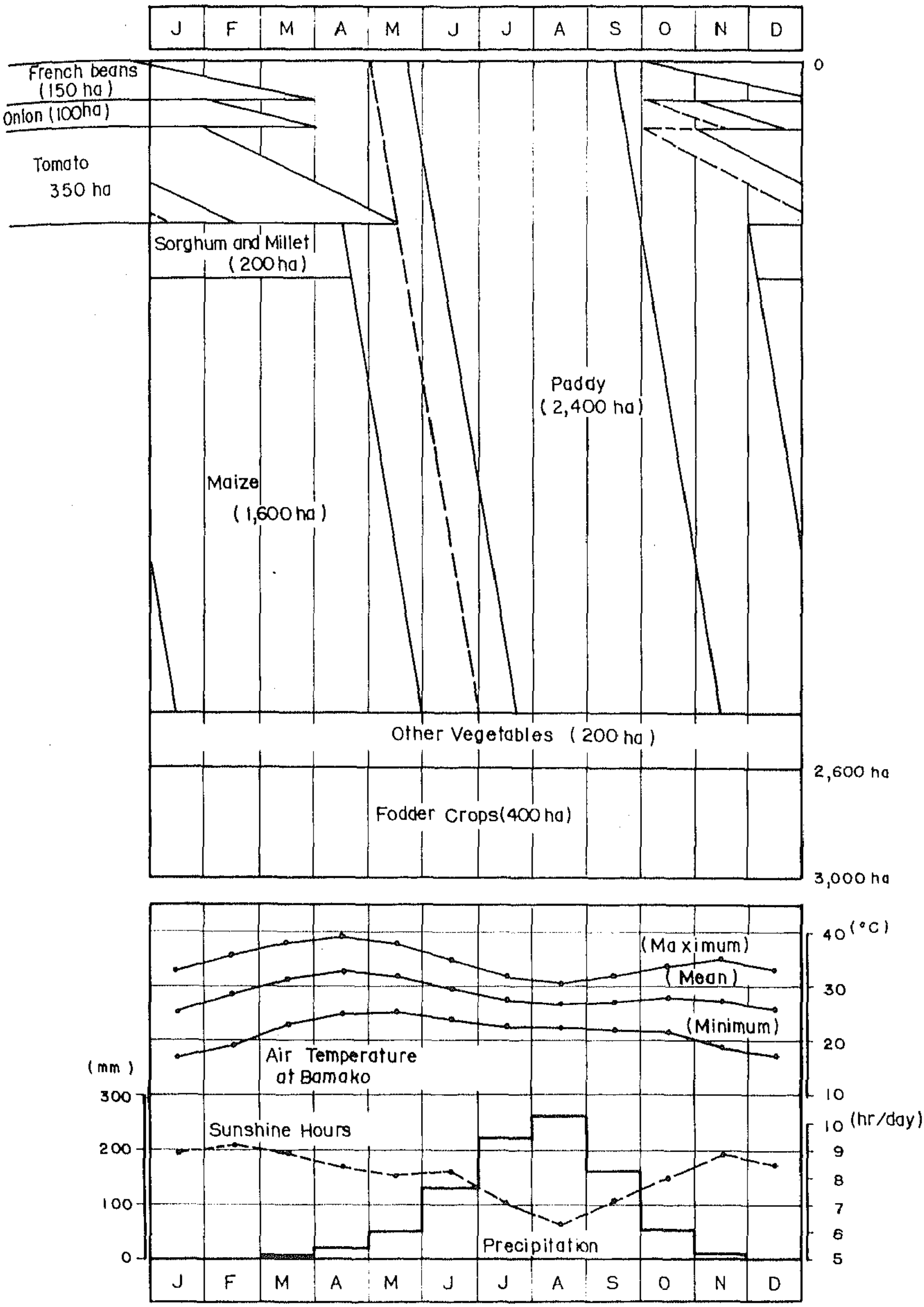


FIGURE Ⅴ-2 TYPICAL LAYOUT OF RICEMILL

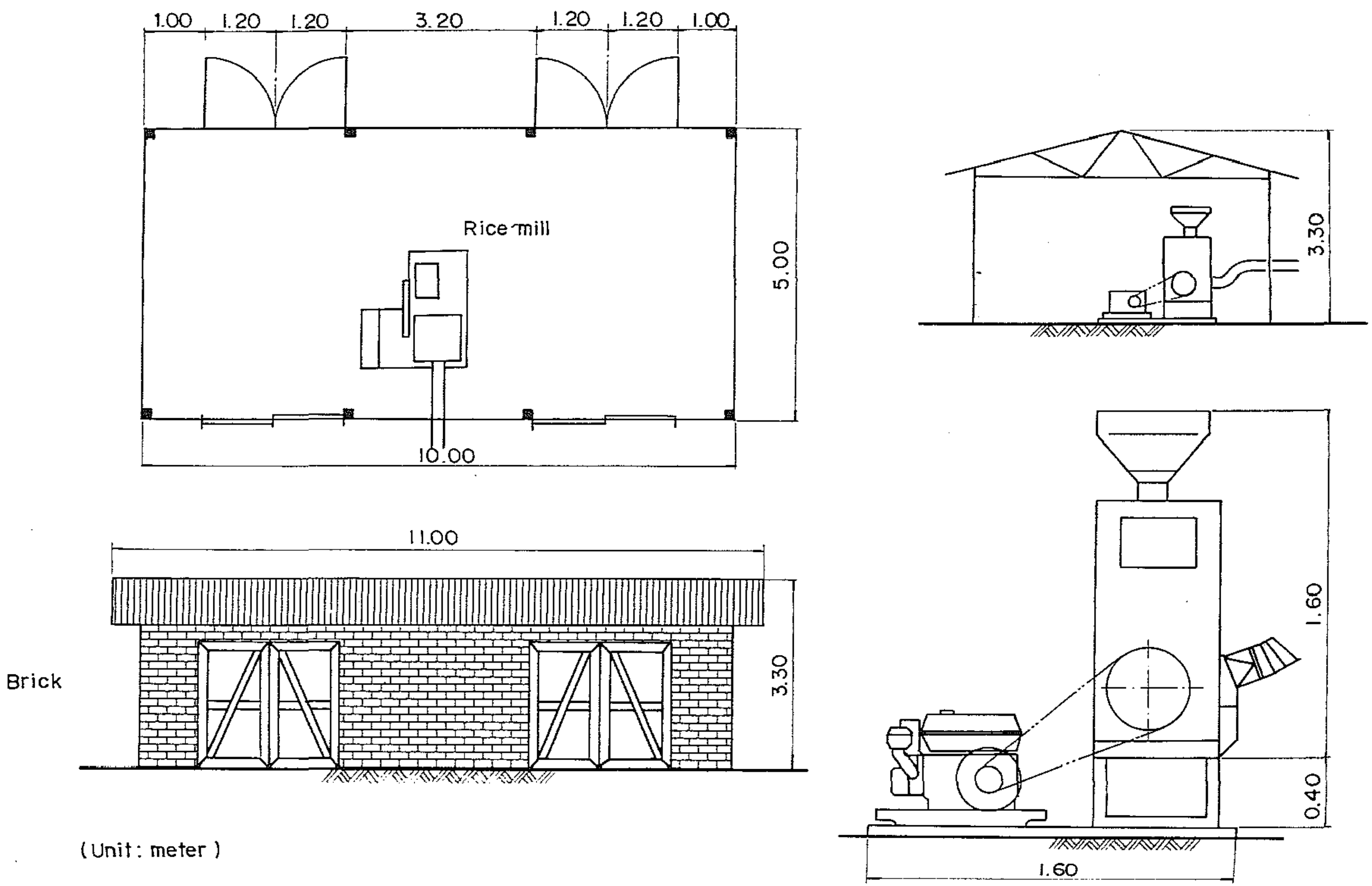
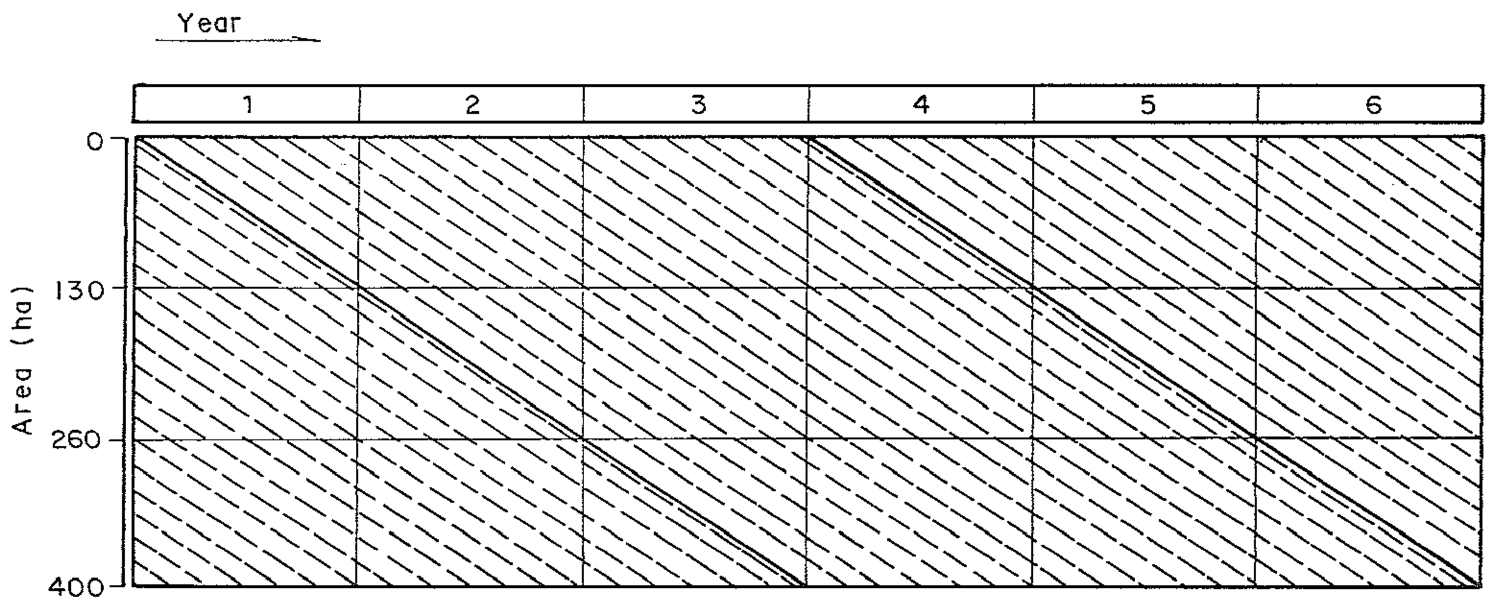


FIGURE V-3 FODDER CROPPING PATTERN

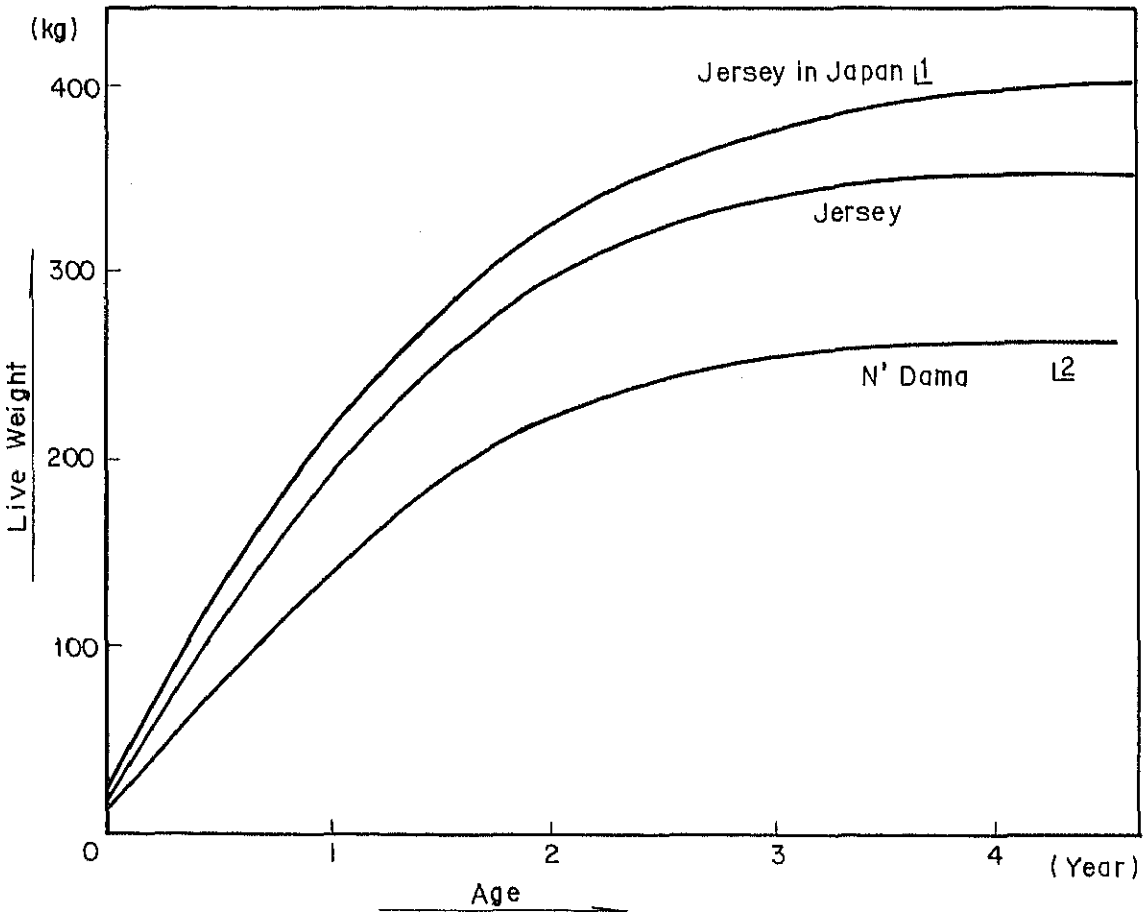


REMARKS

——— Soil preparation and seeding

– – – Harvesting

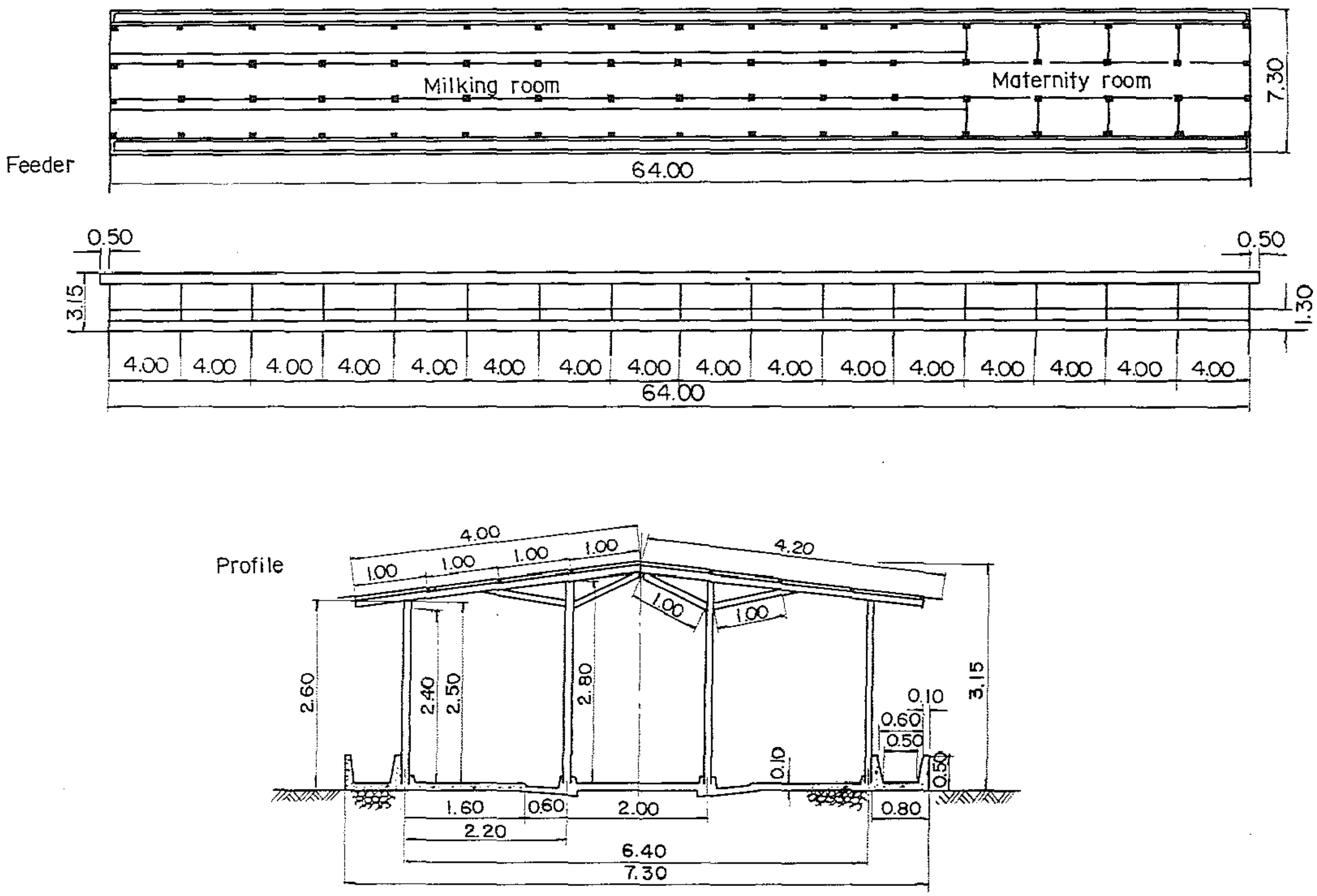
FIGURE V-4 STANDARD GROWTH CURVE OF MILKING COW



Source : L1 Technical Handbook of Agriculture, Agricultural Extension Association, Japan, 1980.

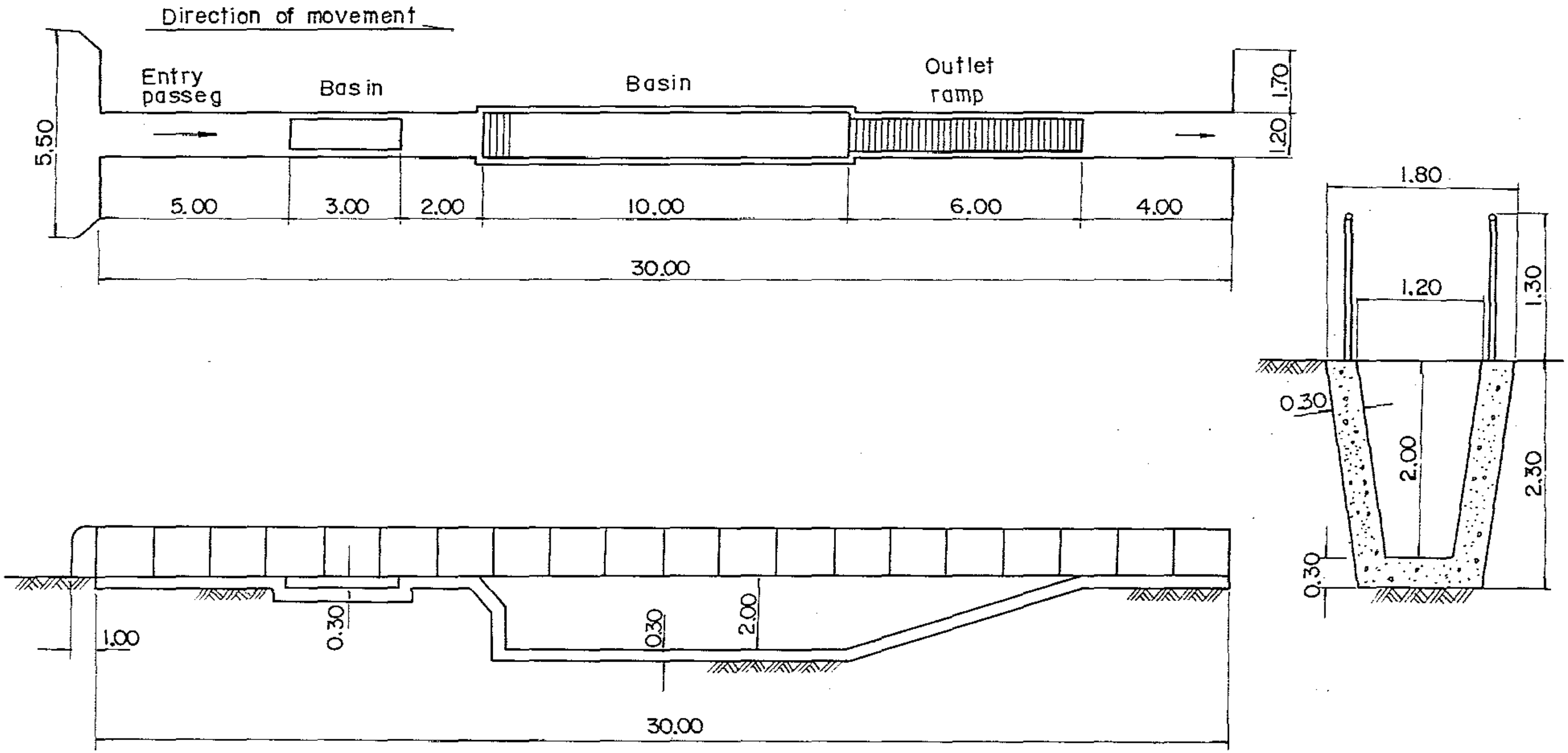
L2 Field survey results.

FIGURE V - 5 GENERAL PLAN OF COWSHED



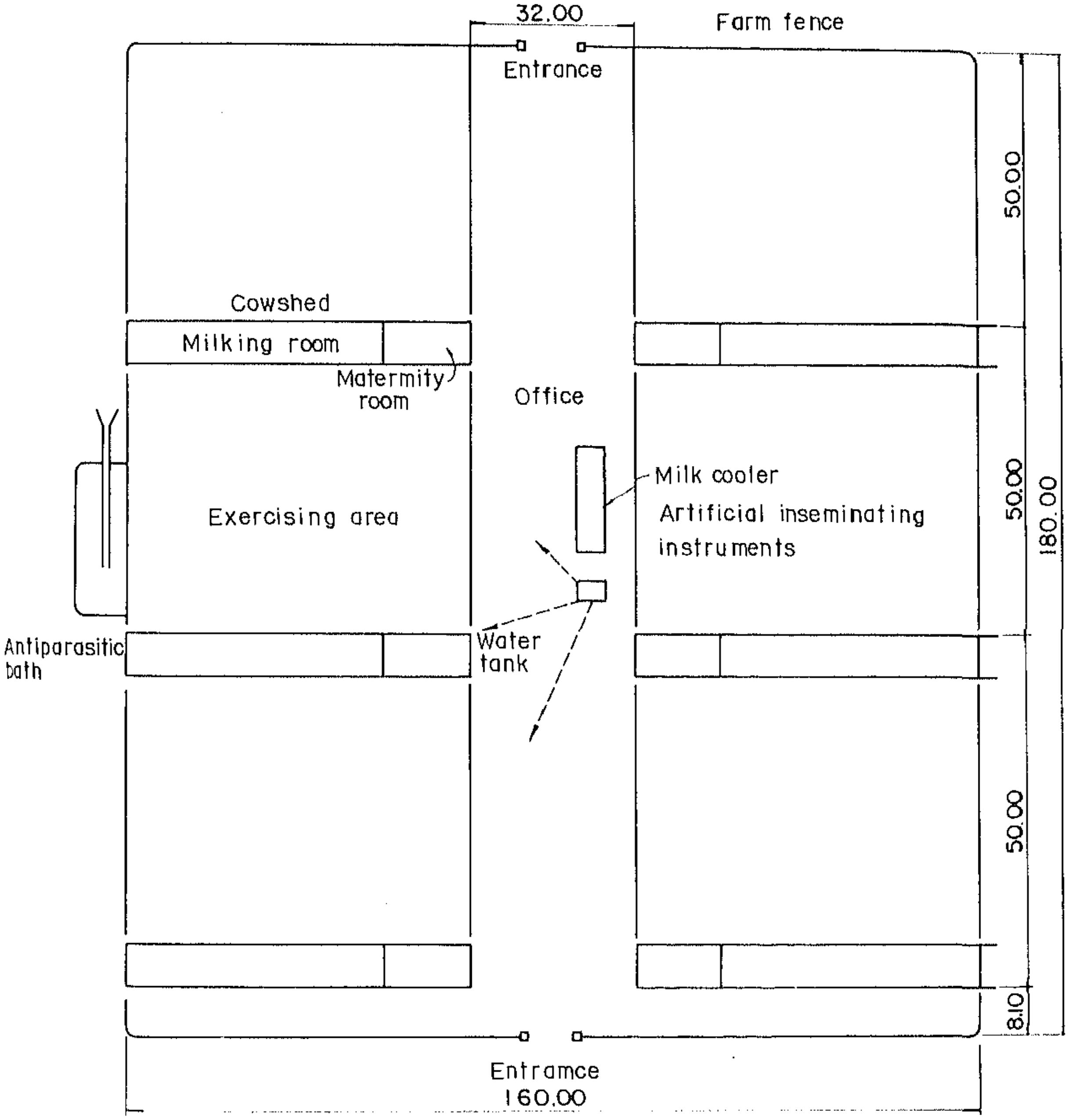
(Unit : meter)

FIGURE V-6 ANTIPARASITIC CATTLE - DIP



(Unit : metre)

FIGURE V-7 GENERAL LAYOUT OF MILK PRODUCTION FARM



(Unit : meter)

ANNEX VI

IRRIGATION AND DRAINAGE PLAN

ANNEX VI

IRRIGATION AND DRAINAGE PLAN

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IRRIGATION AND DRAINAGE PLAN

VI.1 Irrigation Plan

VI.1.1 Delineation of the project area

The Baguineda Area covering about 5,000 ha of land is located on the right bank of Niger river. The area was envisaged to be developed for a rice farm of about 4,000 ha established by the Government of Mali 50 years ago. This farm is being operated by the Baguineda Operation.

After deducting 500 ha of uncultivable land and 500 ha for construction of irrigation and drainage system, road network and on-farm facilities, the total net irrigable area retained in the Project is 3,000 ha.

The whole project area would be divided into 4 irrigation sectors. The net areas of these sectors and their main supply canals are as follows:

	Sectors	Irrigation Canals	Net Area (ha)
I	Koba	Sotuba	557
II	Baguineda	Baguineda	1,979
	- Upper		555
	- Lower		1,424
III	Tanima	Tanima	304
IV	Sienkoro	Sienkoro	160
	Total		3,000

VI.1.2 Proposed irrigation system

The existing irrigation system in the project area would be incorporated as far as possible into the new system. The present Sotuba and Baguineda main canals would be used for irrigation of Koba and Baguineda Sectors, and two new main canals would be constructed for water supply to Tanima and Sienkoro Sectors.

Most of the existing secondary canals would be improved and used as new secondary canals. In addition, new secondary canals would be constructed for rational distribution of irrigation water.

(1) Water intakes

As explained in Section IV.2, the existing water intakes are still in good condition. Therefore, no restoration works would be required.

(2) Koba sector and Sotuba main canal

Irrigation water would be taken at the Sotuba water intake some 120 m upstream of Sotuba hydropower station and conveyed to the project area through the Sotuba main canal. The first secondary canal No. CSK-1 would be branched off from the main canal at about 9 km downstream of the Sotuba water intake.

A total of 17 secondary canals would be provided in Koba Sector. These would include 10 existing canals to be restored and 7 new canals. The interval between two canals would be 800 m on an average. The discharge of the canals would vary from 0.03 to 0.26 m^3/sec and their length from 300 to 2,000 m.

(3) Baguineda Sector and Baguineda main canal

The Baguineda main canal would start from the Baguineda water-gate near the old pump station and run towards Farakan village.

In order to irrigate this sector with an area of about 2,000 ha, it was planned to provide 26 secondary canals which would be branched off from the Baguineda main canal and run in the direction of Niger river. Six of these would be restored canals and the remainder would be new ones. They would be aligned at the intervals of 1,000 m, and would have a discharge ranging from 0.01 to 0.52 m^3/sec and a length from 300 to 2,900 m.

(4) Tanima and Sienkoro sectors, Tanima main canal and Sienkoro canal

The Tanima canal, located in southern part of the area and running along the Baguineda main canal, is seriously worn out and no more usable. This canal would be reconstructed following a completely modified route in order to ensure year-round irrigation of Tanima Sector. The Sienkoro canal is also worn out and cannot convey water adequately. A new canal would be provided for irrigation of this sector.

The new Tanima canal would start from the end of the Baguineda main canal and runs northward. The new Sienkoro canal would be connected to the Baguineda main canal at a point near the Palasso village.

The Sienkoro canal would divert water into 5 secondary canals, all of which would be newly constructed. The discharge of these canals would range from 0.07 to 0.10 m^3/sec and their length from 500 to 1,500 m. The new Tanima canal would deliver water to 7 secondary canals, including 2 existing canals and 5 new canals.

The above canals would be aligned at intervals of about 700 m from each other. Their discharge would be within the range of 0.09 to 0.21 m^3/sec and their respective length would be from about 500 to 1,700 m.

(5) Tertiary canals

The tertiary canals would be required for irrigation purpose. Their typical layout is as shown in Fig. VI.1. In principle, the tertiary canals would be branched off at intervals of 120 m from each side of the secondary canals. A tertiary of 500 m long on an average would supply irrigation water to 5 farm units.

VI.2 Irrigation Water Requirement

VI.2.1 General

For the estimation of crop water requirement, meteorological data at the Bamako station were used since data for the study of other meteorological stations are not available. Rainfall data of the Baguineda station is employed for the estimation of effective rainfall based on the analysis of areal rainfall stated in Chapter I.

Mean monthly meteorological values observed at Bamako station are as follows:

Item		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Temperature	°C	25.0	27.9	30.5	32.1	31.5	29.3	27.0	26.4
Relative humidity	%	32.7	28.1	30.5	39.7	54.3	67.1	76.8	80.4
Sunshine hours	h/day	8.9	9.2	8.8	8.4	8.0	8.0	7.0	6.4
Wind velocity	m/sec	2.5	2.6	2.8	2.7	2.8	2.6	2.3	2.1

Item		Sep.	Oct.	Nov.	Dec.	Average
Temperature	°C	26.8	27.8	26.4	25.5	28.0
Relative humidity	%	78.3	67.9	50.4	38.7	53.7
Sunshine hours	h/day	7.3	8.1	8.7	8.4	8.1
Wind velocity	m/sec	1.7	1.7	2.0	2.3	2.3

VI.2.2 Potential evapotranspiration

In order to determine an appropriate method for estimation of the potential evapotranspiration in the project area, Blaney - Criadle, Modified Penman and Radiation method were applied based on the climatic data obtained in Bamako station. Fig. VI.2 shows the values, on the monthly basis, estimated according to these methods and results of measurement by Class A pan. The data obtained by Class A pan seem not so reliable due to the short period of measurement and poor condition of measuring instruments. The values obtained by Modified Penman show higher than those obtained by other method. Accordingly, the Modified Penman method could be considered as most suitable for estimation of potential evapotranspiration in the project area. Summary of estimated ETo values by Modified Penman method is as follows and details are shown in Table VI.1

(Unit: mm)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
6.5	7.5	8.4	8.7	7.7	7.2	5.6	5.3	5.7	6.1	6.3	6.2	6.8

VI.2.3 Crop coefficient

The crop coefficients adopted for this study are shown in Table VI.2, which is established by FAO since there are no experimental data on the crop coefficients in the project area.

VI.2.4 Consumptive use of water

The consumptive use of water is estimated by multiplying the calculated ETo values by the crop coefficients (Kc) which express the relation between potential and actual evapotranspiration during distinct vegetative stage of the crop. Ten days consumptive use of water by crops are shown in Table VI.3.

VI.2.5 Percoration rate

Water loss due to percoration in paddy field is taken into account the calculation of irrigation water requirement. Percoration rates were measured at the site using the cilinder type infiltrometer. Based on the results and the texture of soils observed in the project area, it was assumed that the percoration rate on the 10-day basis would be 12 mm in the colluvial soil layer and 5 mm in alluvial soil layer.

VI.2.6 Other water requirement

(1) Plowing water requirement

Considering the soil texture in the project area, ponding of the paddy fields would be necessary before plowing. Ponding water depth of 50 mm for a period of 3 days would be enough.

(2) Puddling water requirement

The water amount required for puddling work can be estimated based on the soil depth to be saturated moisture contents and porosity of soils. The puddling water requirement was estimated according to the following formula and assumptions:

$$Pw = Ps + Ws$$

where, Pw: puddling water (mm)

Ps: water depth above soil surface after Ac puddling (mm)

Ws: difference in soil moisture contents before and after saturation (mm)

Assumptions are as follows:

1) Water depth on soil surface after puddling would be 40 mm,

2) Porosity of a 30 cm thick soil layer was estimated to be 50%,

3) Vapour part in soil after puddling was estimated to be 5%, and

4) Soil moisture content before puddling was estimated to be 15%.

Thus, puddling water amount was estimated as follows:

$$Pw = 40 + 300 \times (0.5 - 0.15 - 0.05) = 130 \text{ mm}$$

Based on this result, the actual puddling water requirements were calculated following equations:

$$Wd = Pw \times Ap$$

where, Wd: actual puddling water requirement in mm for a period of 10 days

Pw: 130 mm as above calculation

Ap: percentage of area under puddling for 10 days in total area.

Water requirement for nursery period was estimated by applying the following formula:

$$Nw = (Kc \times ETo + Pc \times 1.5) \times Ac$$

where,
- Nw: water requirement for nursery period in mm for a period 10-day
- Kc: crop coefficient
- ETo: potential evapotranspiration in mm for a period of 10-day
- Pc: percoration rate
- Ac: percentage of nursery area in total planted area (10%)

VI.2.7 Estimation of crop water requirement

Ten days crop water requirements for each crop were computed based on the proposed cropping pattern taking into account the ETo values, crop coefficient, percoration rate and other water requirements. The results of calculation are shown in Table VI.4.

VI.2.8 Effective rainfall

Rainfall record at the Baguineda station is selected as representative data for estimation of effective rainfall. Criteria of estimating an effective rainfall for paddy and upland cultivation are as follows:

(1) For paddy cultivation

- Effective rainfall for the paddy cultivation is estimated on the 10-day basis in paddy field which will be considered as small pond taking into account rainfall, evapotranspiration, percoration, water depth and irrigation water supply.
- Initial water depth at paddy field is assumed to be 50 mm.
- When water depth at paddy field drop to less than 20 mm, irrigation water is to be supplied up to the required depth.
- In case of the much rainfall can be obtained in the paddy fields, such rainfall can be stored in the field at the maximum depth of 200mm, and the rain water more than 200mm will be drained as not usable for crops.

(2) For upland cultivation

- Effective rainfall for the upland cultivation is also estimated on the 10-day basis taking into account rainfall, total readily available moisture and irrigation water supply.
- When amount of water to be replaced is less than 63.2 mm, irrigation water is supplied. (T.R.A.M = 63.2 mm)
- In case of rainfall can be obtained in the upland fields, such rainfall can be stored up to 63.2 mm, and the rain water more than 63.2 mm will be drained as not usable for crops.

Based on the above assumptions, annual effective rainfall in the period of 33 years are calculated for the proposed crops. Average effective rainfall for each crop is tabulated as follows corresponding with annual average rainfall of 862.4 mm.

Crops	Rice 1	Rice 2	French Beans	Tomato	Sorghum	Maize	Vegetable	Pasture
Effective rainfall	836.6	836.6	25.9	30.8	8.8	62.1	633.0	671.9
Crop consumptive use	1,032.0	960.1	356.5	516.3	782.4	924.4	1,895.0	2,264.2

Summary is shown in Table VI.5.

VI.2.9 Irrigation efficiency

Water losses are unavoidable during the conveyance from intake to the farm. Irrigation water requirement at the head of water source were estimated in consideration of net irrigation water requirement, operation of irrigation system, conveyance by tertiary, secondary and main irrigation canal. Taking into consideration the canal type, related structures and the soils, the gross irrigation efficiency was estimated to be 52% on the basis of the following assumptions:

(1) Application efficiency	90%
(2) Operation efficiency	85%
(3) Conveyance efficiency	
Secondary and tertiary canal	85%
Main canal	80%
Overall irrigation efficiency	52%

VI.3 Characteristics of Soil Moisture and Watering Periods

VI.3.1 Total readily available water quantity

(1) Available water

Water quantity available for irrigation of the fields is represented by the difference between the field capacity (PF. 1.5 - 2.0) and the moisture at initial wilting point (PF. 3.5 - 4.0) retained by the soil at such a depth where the roots absorb water efficiency.

(2) Soil layers favorable for efficient water absorption by plants

Soil layers favourable for efficient water absorption by plants were determined on the condition that the paddy fields will be continuously cultivated with other crops after rice harvesting. According to the results of pedological survey, these layers would have a thickness of not more than 75 cm approximately.

(3) Different types of water absorption by plants

The types of water absorption by crops in the fields can be determined by the "Method of base absorption by crops" established by Sockley in the USA.

(4) Total readily available water quantity

Following procedure would be applied in estimating the total readily available water quantity.

Available moisture of a soil layer was estimated by the following formula:

$$AMI = 1/100 \times (FC - WPF) \times H$$

where, AMI: available moisture in mm of a soil layer

FC: field capacity in percentage

WPF: moisture at initial wilting point in volumetical percentage

H: thickness of a soil layer in mm

The field capacity and the moisture at initial wilting point were determined based on the soil type of the project area.

According to the empirical data established by Tillet and Sounder, the above soil moistures would be assumed as follows:

Soil type: sandy silt	Soil Moisture (%)
Field capacity (PF. 1.5)	26
Initial wilting point (PF. 3.5)	12

The thickness of a soil layer favourable for efficient water absorption by plants was estimated to be 190 mm based on various types of water absorption. Accordingly, the available moisture of a soil layer (AM1) was calculated as follows:

AMI = 1/100 x (26 - 12) x 190 = 26.6 mm

The total moisture efficiently absorbed by plants was estimated by the following formula:

$$WDI = AMI \times \frac{100}{RMEI}$$

where, WDI: moisture absorbed by plants in mm according to soil characteristics

RMEI: ratio of absorbed moisture in each soil layer in percent

The results are summarized below:

Soil Layer	Ratio of Water Absorption (%)	Moisture Absorbed by Plants According to Soil Characteristics (mm)
1st layer	42.1	63.2
2nd layer	28.2	94.3
3rd layer	19.1	193.3
4th layer	10.8	246.3

The total readily available moisture was determined as the minimum value of moisture efficiently absorbed by plants. As shown in the above table, the total readily available moisture would be 63.2 mm.

VI.3.2 Watering periods

The maximum period of waterings was estimated according to the following formula:

Maximum period of waterings per day

$$= \frac{\text{Total readily available moisture in mm}}{\text{Peak water consumption by crops in mm}}$$

The peak water consumption by crops was estimated to be 9 mm per day as shown in Table VI.1. Therefore, the watering period would be 7 days (63.2 mm ÷ 9 mm).

VI.3.3 Rate of water percolation into the soil

(1) Percolation rate measured by infiltrometer

Measurement by infiltrometer was carried out at 5 stations located in general near the secondary canals. The results were obtained by logarithmic graph as shown in Fig. VI.3, based on which the stabilized percolation rates were estimated.

As shown in Fig. VI.3, the stabilized percolation rates are extremely lower than the rates which may be obtained with a similar type of soil. Taking this fact into consideration, the method of irrigation by ditches would be more appropriate for the project area.

(2) Percolation rate measured by ditches

In order to determine the most suitable method of irrigation by ditches, measurement of percolation rate was carried out at the site by digging test furrows. The results were analyzed by logarithmic graph and the following equation was obtained:

$$I = 17.2 \times T^{-0.861}$$

where, I: rate of water percolation into ditches in lit./min/m

T: time in minutes

In view of the canal width, this equation may be transformed as below:

$$I = (1.032.0/B) \times T^{-0.861}$$

where, I: intensity of percolation rate in mm/h

B: width of a ditch

T: period of irrigation in minutes

On the other hand, the cumulative percolation into ditches may be calculated by the following equation.

$$D = (123.7/B) \times T^{0.139}$$

where, D: total cumulative percolation in mm

T: period of irrigation in minutes

B: width of a ditch in meters

The following empirical formula was applied for calculating the time required for the percolation water to reach the ends of the ditches:

$$TA = a \times L^{b}$$

where, TA: time required for percolation water to reach the ends of the ditches in minutes

L: length of a ditch in meters

a,b: coefficients determined according to results of site observation

The result was as follows:

$$TA = 0.06 \times L^{2.257}$$

(3) Irrigation period

The irrigation period consists of the time required for water supply and the time required for irrigation water to reach the ends of the ditches. It was estimated as follows, based on the above formula:

(i) Time required for water supply

$$T = \left(\frac{D \times B}{123.7} \right)^{7.194}$$

where, T: time required for water supply in minutes

B: width of a ditch: 4.5 m

D: cumulative percolation: 63 mm
(9 mm/day x 7 days)

The obtained value was as follows:

$$T = \left(\frac{63 \times 4.5}{123.7} \right)^{7.194} = 390 \text{ minutes} = 6.5 \text{ hours}$$

(ii) Time required for irrigation water to reach the ends of the ditches

Assuming that the ditch length will be 100 m, the time required for irrigation water to reach the ends of the ditches was estimated as follows:

$$TA = 0.006 \times 100^{2.257}$$

$$= 196 \text{ minutes} = 3.3 \text{ hours}$$

Thus, the minimum irrigation period would be about 10 hours.

Considering the conditions of the fields in the project area, an irrigation period of 12 hours would be required in order to facilitate the operation of the irrigation system.

VI.4 Irrigation Water Distribution Method and Layout of Farm Plots

VI.4.1 Method of irrigation water distribution to the upland fields

With a view of minimizing water expenses and taking into consideration the operation of irrigation system, rotational irrigation method would be recommendable. On the basis of site investigation results, it was planned that irrigation intervals will be seven days, and that the irrigation system will be operated 12 hours a day.

Considering the low percolation rate as explained in the previous chapter and the elevation of intake height, the sprinkler irrigation method would not be appropriate. It was recommended to adopt the ditch irrigation method.

VI.4.2 Method of irrigation water distribution to the paddy fields

From the viewpoint of water management, the same irrigation intervals of water supply is favorable. The rotational irrigation method with the seven days of interval would be applied for paddy cultivation. Taking into account the discharges of the proposed irrigation canals and the irrigation water requirement at the farm turnouts, it would be recommended that the irrigation system will be operated 24 hours a day. The ponding irrigation method would be applied for paddy fields considering the proposed farming practices.

VI.4.3 Design water requirements for irrigation canal systems

For planning the design capacity of irrigation canals, diversion water requirements on the 10-day basis were estimated taking into account crop water requirements, irrigation efficiency and method of water distribution.

Peak diversion water requirement at the head of main canal is estimated at 10.31 m^3/sec which occurs in March. Table VI.6 shows estimated results. Consequently, the estimated value in this study is quite similar to the value on previous study of 10.34 m^3/sec. Therefore, the value of design water requirements on previous study is applied for this study.
(See Table VI.6)

For tertiary canal

The design capacity for on-farm facilities is determined considering the maximum water requirements at peak stage.

$$\frac{130\,\text{mm} \times 10^{-3} \times 1.0\,\text{ha} \times 10^{4} \times 10^{3}}{86,400 \times (1 - 0.25) \times 10\ \text{days}} = 2.01\ \text{lit./sec/ha}$$

For secondary canal

The design capacity for secondary canal and its related structures is determined at 2.769 lit./sec/ha which comprises average irrigation water requirements of crops at the peak.

For main canal

The design discharge of main canals and its related structures are estimated based on design discharge at the head of secondary canals divided by irrigation efficiency of 0.80.

Fig. VI.4 shows irrigation diagram of the project area.

VI.5 Drainage Plan

VI.5.1 General

In view of its topographical and geological conditions as explained preceding sections, the project area could be well drained even in rainy season. In principle, a part of existing drainage canals would be repaired by widening and reconditioning of the canal section and be cleaned. Many new related drainage structures would be provided.

VI.5.2 Rainfall intensity

According to the result of analysis of rainfall intensity data obtained at the Baguineda meteorological station, the maximum daily rainfall of a probability of 1/10 was 105 mm. This value was adopted in planning and design of the project drainage facilities. Besides, in order to estimate the mean rainfall of each catchment area to be drained, the Horton coefficient was applied and the results of calculation are shown in Fig. VI.5.

VI.5.3 Water quantity to be drained

(1) Overland runoff from the project area

The overland runoff from the total gross area of 4,500 ha consists of rainfall and seepage from irrigation canals and fields. As the rainfall and seepage do not always occur at the same time and as the seepage is negligible, the water quantity to be drained was estimated on the basis of rainfall only.

Based on the types of overland runoff from the project area and without taking into consideration the water loss due to percolation and evaporation during drainage, it was assumed that an overland runoff from rainfall of a probability of 1/10 would have to be drained from the paddy fields within a period of 48 hours or 2 days. Calculation of the water quantity per hectare per second to be drained was made according to the following formula:

$$QL = H \times K \times S$$

where, QL: water quantity to be drained in m^3/ha/day
H: maximum daily rainfall in mm/day
K: Horton coefficient: 0.83
S: area unit: 10,000 m^2

therefore,

$$QL = 105 \text{ mm/day} \times 0.83 \times 10^{-3} \times 10{,}000 \text{ m}^2$$
$$= 872 \text{ m}^3\text{/ha/day}$$

After conversion, the above volume becomes:

$$Q = 872 \text{ m}^3\text{/ha/day} \times 86{,}400 \text{ sec/2 days} = 5.0 \text{ lit./sec/ha}$$

(2) Flow of Koba and Fara rivers

The Koba and Fara rivers have insignificant or almost no discharge in dry season. But the direct flow of Koba river can be observed immediately after each rainfall and its peak discharge is very important.

The flow of these river was estimated by a "rational" formula as follows:

$$Q = \frac{1}{3.6} f \times \gamma_T \times A$$

where, Q: peak discharge in m^3/sec

f: discharge coefficient

γ_T: rain intensity (mm/hour)

A: catchment area in km^2

Rain intensity is a function of rain concentration time in the given catchment area and characteristics related to duration/intensity of rains. The concentration time was estimated by the following formula.

$$Te = L/W \qquad W = 72 \left(\frac{H}{L}\right)^{0.6}$$

where, Te: concentration time in hours

L: horizontal distance between the upstream limit of the zone to be drained and a given point in km

W: flow velocity in km/hour

H: difference in elevation between the upstream limit of the zone to be drained and a given point in km

The rain intensity was estimated by the following formula:

$$Y_T = R_{24/24} \cdot \left(\frac{24}{Te}\right)^{2/3}$$

where, Y_T: rain intensity in mm/hour

R_{24}: daily rainfall in mm: 105 mm

Te: concentration time in hour

Hydrological factors considered in the estimation of the runoff of each river and the results thereof are summarized below:

	Hydrological Factors and Results	Koba River	Fara River
1)	Catchment area (km^2)	287.7	73.5
2)	Average slope of river	1/350	1/500
3)	River length (km)	20.5	19.0
4)	Rain concentration time (hour)	5.0	10.7
5)	Horton coefficient	0.7	0.75
6)	Peak runoff coefficient	0.2	0.2
7)	Rain intensity during concentration time (mm/hour)	8.8	5.6
8)	Rate of runoff (m^3/sec)	140	23
9)	Specific yield (m^3/sec/km^2)	0.49	0.31

(3) Overland runoff from uncultivated lands

Twenty cross drains have been provided under the main irrigation canals to evacuate the runoff from uncultivated lands on the right bank of these canals. The runoff discharge at the inlet of each cross drain was estimated based on the specific discharge of Koba river, the results are as follows:

Discharges of Overland Runoff from the Lands
Extending on the Right Bank

Syphon Number	Maximum Runoff Discharge (m^3/sec)	Syphon Number	Maximum Runoff Discharge (m^3/sec)
S1	8.1	S11, S12	5.5
S2	1.5	S13	5.7
S3	2.4	S14, S15	4.3
S4	1.0	S17	2.1
S5	4.5	S18	2.7
S6, S7	0.6	S19	8.0
S8	7.9	S20	9.5
S9	0.9		
S10	0.8		

Each of the obtained figure was compared to the discharge evacuated by the drainage syphon under the canal or by the secondary drain connected to the said drainage syphon.

The specific discharge of runoff from the existing mango plantations of 40 ha in the project area was estimated to be 6.4 lit./sec/ha, assuming that the hydrological conditions in these plantations are similar to those in uncultivated lands.

VI.5.4 Proposed drainage system

Most of the existing drainage canals in the project area would be incorporated into the new drainage system after having been partly repaired. The proposed drainage system would comprise 1 principal drain, 53 secondary drains, tertiary drains to be provided in each farm plot and catch drains to be installed along the main irrigation canals. The principal drain would be constructed in Tanima Sector and the secondary drains would be aligned alternately with the secondary irrigation canals in order to drain excess water into the Niger river.

The runoff from uncultivated lands on the right bank of the last section of the Baguineda main canal is at present drained into the Tanima main canal. In order to ensure year-round irrigation, a new catch (carrier) drain would be provided along the proposed new Tanima main canal. This catch drain would evacuate the runoff from the uncultivated lands directly into the Niger river. Besides, another new catch drain would be constructed along the Sienkoro canal in order to drain water from Sienkoro hill. A diagram of the proposed drainage system is given in Fig. VI.6.

Table VI.1 SUMMARY OF ETO VALUES BY MODIFIED PENMAN

	Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
(1)	T mean °C	25.0	27.9	30.5	32.1	31.5	29.3	27.0	26.4	26.8	27.8	26.4	25.5
(2)	RH mean %	32.7	28.1	30.5	39.7	54.3	67.1	76.8	80.4	78.3	69.7	50.4	38.7
(3)	ea mbar	31.7	37.6	43.7	47.9	46.3	40.8	35.7	34.4	35.3	37.4	34.4	32.7
(4)	ed mbar	10.4	10.6	13.3	19.0	25.1	27.4	27.4	27.7	27.6	25.4	17.3	12.7
(5)	ea-ed mbar	21.3	27.0	30.4	28.9	21.2	13.4	8.3	6.7	7.7	12.0	17.1	20.0
(6)	Wind U km/day	216	225	242	233	242	225	199	181	147	147	173	199
(7)	f(u)	0.85	0.88	0.92	0.90	0.92	0.88	0.81	0.76	0.67	0.67	0.74	0.81
(8)	(1 - w)	0.25	0.22	0.21	0.19	0.20	0.21	0.23	0.24	0.23	0.22	0.24	0.24
(9)	w	0.75	0.78	0.79	0.81	0.80	0.79	0.77	0.76	0.77	0.78	0.76	0.76
(10)	Ra mm/day	12.8	13.9	15.1	15.7	15.7	15.5	15.5	15.6	15.2	14.4	13.3	12.5
(11)	N	11.5	11.7	12.0	12.4	12.7	12.8	12.7	12.5	12.1	11.8	11.5	11.4
(12)	n	8.9	9.2	8.8	8.4	8.0	8.0	7.0	6.4	7.3	8.1	8.7	8.4
(13)	n/N ratio	0.77	0.79	0.73	0.68	0.63	0.63	0.55	0.51	0.60	0.69	0.76	0.74
(14)	Rs mm/day	8.1	9.0	9.3	9.3	8.9	8.8	8.1	7.9	8.4	8.6	8.4	7.8
(15)	Rms mm/day	6.1	6.8	7.0	7.0	6.7	6.6	6.1	5.9	6.3	6.5	6.3	5.9
(16)	f(T)	15.7	16.3	16.8	17.2	17.1	16.6	16.1	16.0	16.1	16.3	16.0	15.8
(17)	f(ed)	0.20	0.20	0.18	0.15	0.12	0.11	0.11	0.11	0.11	0.12	0.16	0.18
(18)	f(n/N)	0.79	0.81	0.76	0.71	0.67	0.67	0.60	0.56	0.64	0.72	0.78	0.77
(19)	Rnl	2.5	2.6	2.3	1.8	1.4	1.2	1.1	1.0	1.1	1.4	2.0	2.2
(20)	Rn	3.6	4.2	4.7	5.2	5.3	5.4	5.0	4.9	5.2	5.1	4.3	3.7
(21)	C	0.90	0.88	0.88	0.95	0.94	1.07	1.04	1.08	1.10	1.07	1.00	0.93
(22)	ETo mm/day	6.5	7.5	8.4	8.7	7.7	7.2	5.6	5.3	5.7	6.1	6.3	6.2

ETo = C [w . Rn + (1 - w) · f(u) · (ea - ed)]

Table VI.2 ADOPTED CROP COEFFICIENT (KC)

Month		Rice 1	Rice 2	French Beans	Tomato	Sorghum	Maize	Veget-able	Pasture
Sep.	1	1.05	1.05	-	-	-	-	0.43	0.95
	2	0.97	0.97	-	-	-	-	0.43	0.95
	3	-	-	-	-	-	-	0.69	0.95
Oct.	1	-	-	0.40	-	-	-	0.69	0.95
	2	-	-	0.44	-	-	-	0.69	0.95
	3	-	-	0.63	-	-	-	0.95	0.95
Nov.	1	-	-	0.85	0.41	-	-	0.95	0.95
	2	-	-	0.95	0.46	-	-	0.95	0.95
	3	-	-	0.96	0.69	-	-	0.95	0.95
Dec.	1	-	-	0.63	0.92	0.40	0.39	0.95	0.95
	2	-	-	0.87	1.04	0.42	0.41	0.95	0.95
	3	-	-	-	1.06	0.50	0.45	0.95	0.95
Jan.	1	-	-	-	1.04	0.68	0.61	0.95	0.95
	2	-	-	-	1.00	0.85	0.80	0.95	0.95
	3	-	-	-	0.75	1.02	0.97	0.95	0.95
Feb.	1	-	-	-	-	1.08	1.10	0.95	0.95
	2	-	-	-	-	1.09	1.14	0.87	0.95
	3	-	-	-	-	1.11	1.16	0.87	0.95
Mar.	1	-	-	-	-	1.09	1.14	0.87	0.95
	2	-	-	-	-	1.04	1.12	0.87	0.95
	3	-	-	-	-	0.92	1.05	0.87	0.95
Apr.	1	-	-	-	-	0.73	0.87	0.33	0.95
	2	-	-	-	-	-	0.69	0.33	0.95
	3	-	-	-	-	-	-	0.33	0.95
May	1	1.11	1.11	-	-	-	-	0.64	0.85
	2	1.11	1.11	-	-	-	-	0.64	0.85
	3	1.11	1.11	-	-	-	-	0.64	0.85
Jun.	1	1.13	1.13	-	-	-	-	0.64	0.85
	2	1.14	1.14	-	-	-	-	0.64	0.85
	3	1.16	1.16	-	-	-	-	0.95	0.85
Jul.	1	1.18	1.18	-	-	-	-	0.95	0.85
	2	1.19	1.19	-	-	-	-	0.95	0.85
	3	1.20	1.20	-	-	-	-	0.95	0.85
Aug.	1	1.21	1.21	-	-	-	-	0.87	0.85
	2	1.20	1.20	-	-	-	-	0.87	0.85
	3	1.15	1.15	-	-	-	-	0.87	0.85

Table VI.3 10 DAYS CONSUMPTIVE USE OF WATER

(Unit: mm/10 days)

Month		Rice 1	Rice 2	French Beans	Tomato	Sorghum	Maize	Veget-able	Pasture
Sep.	1	61.08	60.36	-	-	-	-	24.51	54.15
	2	28.06	27.99	-	-	-	-	24.51	54.15
	3	-	-	-	-	-	-	39.33	54.15
Oct.	1	-	-	24.42	-	-	-	42.09	57.95
	2	-	-	26.84	-	-	-	42.09	57.95
	3	-	-	42.24	-	-	-	46.30	63.75
Nov.	1	-	-	53.57	25.85	-	-	59.85	59.85
	2	-	-	59.84	28.93	-	-	59.85	49.85
	3	-	-	60.50	43.45	-	-	59.85	59.85
Dec.	1	-	-	39.05	57.09	24.80	12.10	58.90	58.90
	2	-	-	26.95	64.46	26.04	25.40	58.90	58.90
	3	-	-	-	72.27	34.10	30.70	64.79	64.79
Jan.	1	-	-	-	67.65	44.20	39.65	61.75	61.75
	2	-	-	-	65.01	55.25	52.00	61.75	61.75
	3	-	-	-	53.68	72.93	69.35	67.93	67.93
Feb.	1	-	-	-	-	81.00	82.50	71.25	71.25
	2	-	-	-	-	81.75	85.50	65.25	71.25
	3	-	-	-	-	66.60	69.60	52.20	57.00
Mar.	1	-	-	-	-	91.56	95.75	73.08	79.80
	2	-	-	-	-	87.36	94.10	73.08	79.80
	3	-	-	-	-	85.01	97.00	80.39	87.78
Apr.	1	-	-	-	-	31.76	75.70	28.71	82.65
	2	-	-	-	-	-	60.05	28.71	82.65
	3	-	-	-	-	-	-	28.71	82.65
May	1	118.32	117.30	-	-	-	-	49.28	65.45
	2	10.32	9.30	-	-	-	-	49.28	65.45
	3	95.22	94.50	-	-	-	-	54.21	72.00
Jun.	1	82.56	81.84	-	-	-	-	46.08	61.20
	2	83.28	82.56	-	-	-	-	46.08	61.20
	3	84.72	84.00	-	-	-	-	68.40	61.20
Jul.	1	67.26	66.60	-	-	-	-	53.20	47.60
	2	67.86	67.14	-	-	-	-	53.20	47.60
	3	75.12	74.40	-	-	-	-	58.52	52.36
Aug.	1	65.34	64.62	-	-	-	-	46.11	45.05
	2	64.80	64.08	-	-	-	-	46.11	45.05
	3	68.22	67.56	-	-	-	-	50.72	49.56

Table VI.4 10 DAYS CROP WATER REQUIREMENT

(Unit: mm/10 days)

Month		Rice 1	Rice 2	French Beans	Tomato	Sorghum	Maize	Veget-able	Pasture
Sep.	1	76.70	70.75	-	-	-	-	24.51	54.15
	2	69.90	64.01	-	-	-	-	24.51	54.15
	3	57.40	52.15	-	-	-	-	39.33	54.15
Oct.	1	46.50	42.41	2.22	-	-	-	42.09	57.95
	2	32.30	29.38	4.66	-	-	-	42.09	57.95
	3	20.47	18.54	8.97	-	-	-	46.30	63.75
Nov.	1	6.09	5.51	13.29	2.35	-	-	59.85	59.85
	2	-	-	18.73	4.98	-	-	59.85	59.85
	3	-	-	24.23	8.93	-	-	59.85	59.85
Dec.	1	-	-	27.39	13.98	24.80	2.42	58.90	58.90
	2	-	-	29.84	19.84	26.04	7.50	58.90	58.90
	3	-	-	32.83	28.40	34.10	14.39	64.79	64.79
Jan.	1	-	-	31.29	33.21	44.20	21.65	61.75	61.75
	2	-	-	31.29	39.12	55.25	32.05	61.75	61.75
	3	-	-	31.82	47.91	72.93	46.33	67.93	67.93
Feb.	1	-	-	30.38	47.69	81.00	58.95	71.25	71.25
	2	-	-	26.08	47.69	81.75	69.30	65.25	71.25
	3	-	-	16.23	35.92	66.60	62.04	52.20	57.00
Mar.	1	-	-	15.46	46.77	91.56	92.57	73.08	79.80
	2	-	-	8.13	41.50	87.36	95.09	73.08	79.80
	3	-	-	3.65	37.93	85.01	103.67	80.39	87.78
Apr.	1	-	-	-	27.48	31.76	92.92	28.71	82.65
	2	-	-	-	19.10	-	84.74	28.71	82.65
	3	-	-	-	10.88	-	64.90	28.71	82.65
May	1	19.72	19.55	-	2.63	-	40.19	49.28	65.45
	2	21.45	21.10	-	-	-	24.02	49.28	65.45
	3	36.03	35.53	-	-	-	11.69	54.21	72.00
Jun.	1	50.34	48.71	-	-	-	-	46.08	61.20
	2	66.02	63.22	-	-	-	-	46.08	61.20
	3	81.94	77.98	-	-	-	-	68.40	61.20
Jul.	1	62.92	57.96	-	-	-	-	53.20	47.60
	2	74.69	68.74	-	-	-	-	53.20	47.60
	3	83.07	76.53	-	-	-	-	58.52	52.36
Aug.	1	72.74	66.79	-	-	-	-	46.11	45.05
	2	73.27	67.32	-	-	-	-	46.11	45.05
	3	80.48	73.95	-	-	-	-	50.72	49.56

Table VI.5 EFFECTIVE RAINFALL
(USING MEAN 10 DAYS RAINFALL)

Month 10 Days	Rain-fall	Rice 1	Rice 2	French Beans	Tomato	Sorghum	Maize	Veget-able	Pasture
Jan. 1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.3	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Feb. 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Mar. 1	1.3	0.0	0.0	1.3	1.3	1.3	1.3	1.3	1.3
2	0.7	0.0	0.0	0.7	0.7	0.7	0.7	0.7	0.7
3	1.8	0.0	0.0	1.8	1.8	1.8	1.8	1.8	1.8
Apr. 1	4.0	0.0	0.0	0.0	4.0	4.0	4.0	4.0	4.0
2	5.2	0.0	0.0	0.0	5.2	0.0	5.2	5.2	5.2
3	9.7	0.0	0.0	0.0	9.7	0.0	9.7	9.7	9.7
May 1	12.8	12.8	12.8	0.0	2.6	0.0	12.8	12.8	12.8
2	14.0	14.0	14.0	0.0	0.0	0.0	14.0	14.0	14.0
3	17.6	17.6	17.6	0.0	0.0	0.0	11.7	17.6	17.6
Jun. 1	34.5	34.5	34.5	0.0	0.0	0.0	0.0	34.5	34.5
2	44.6	44.6	44.6	0.0	0.0	0.0	0.0	44.6	44.6
3	38.6	38.6	38.6	0.0	0.0	0.0	0.0	38.6	38.6
Jul. 1	54.3	54.3	54.3	0.0	0.0	0.0	0.0	53.2	47.6
2	71.3	71.3	71.3	0.0	0.0	0.0	0.0	53.2	47.6
3	82.9	82.9	82.9	0.0	0.0	0.0	0.0	58.5	52.4
Aug. 1	85.2	85.2	85.2	0.0	0.0	0.0	0.0	46.1	45.1
2	87.1	87.1	87.1	0.0	0.0	0.0	0.0	46.1	45.1
3	80.6	80.6	80.6	0.0	0.0	0.0	0.0	50.7	49.6
Sep. 1	70.6	70.6	70.6	0.0	0.0	0.0	0.0	24.5	54.2
2	54.1	54.1	54.1	0.0	0.0	0.0	0.0	24.5	54.1
3	31.7	31.7	31.7	0.0	0.0	0.0	0.0	31.7	31.7
Oct. 1	26.4	26.4	26.4	2.2	0.0	0.0	0.0	26.4	26.4
2	14.7	14.7	14.7	4.7	0.0	0.0	0.0	14.7	14.7
3	12.6	12.6	12.6	9.0	0.0	0.0	0.0	12.6	12.6
Nov. 1	3.0	3.0	3.0	3.0	2.4	0.0	0.0	3.0	3.0
2	0.9	0.0	0.0	0.9	0.9	0.0	0.0	0.9	0.9
3	1.2	0.0	0.0	1.2	1.2	0.0	0.0	1.2	1.2
Dec. 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.5	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5
3	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Total	862.4	836.6	836.6	25.9	30.8	8.8	62.1	633.0	671.9

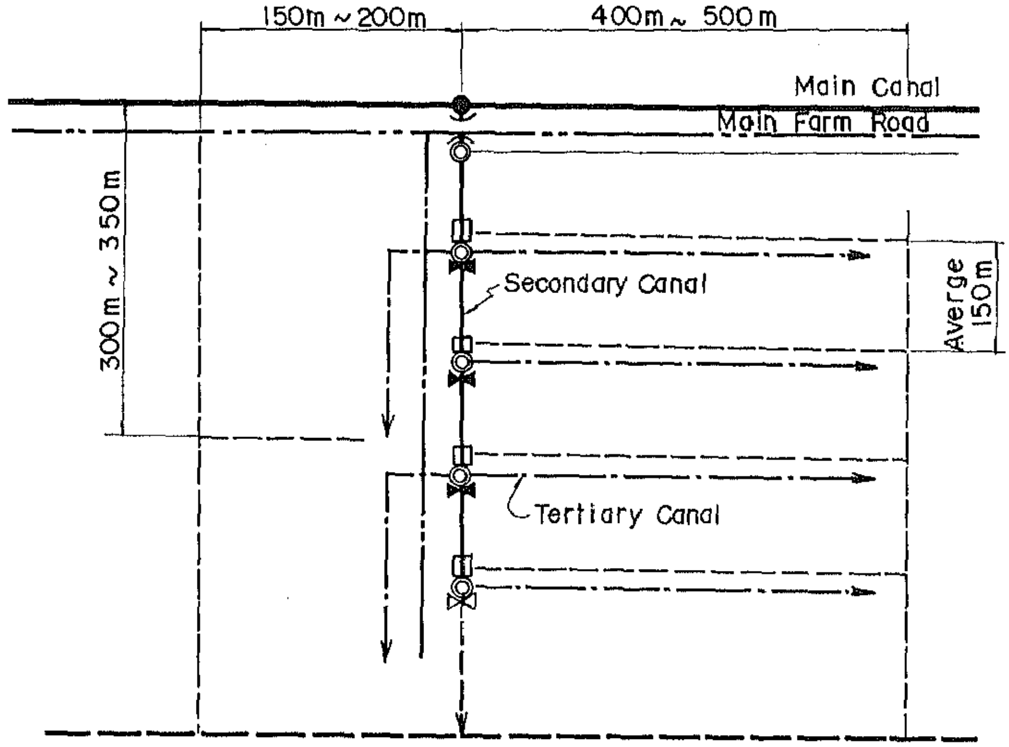
Table VI.6 DIVERSION WATER REQUIREMENT
(WITHOUT EFFECTIVE RAINFALL)

(Unit: mm)

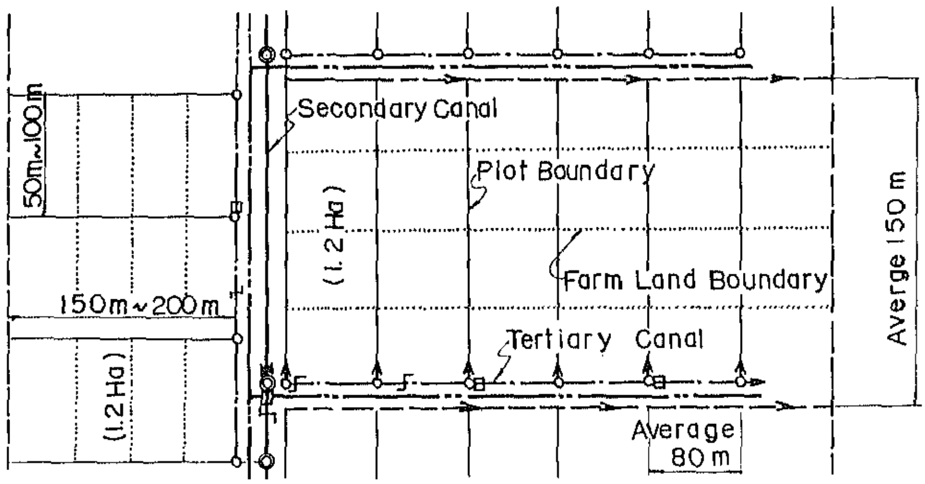
Month		Rice 1	Rice 2	French Beans	Tomato	Sorghum	Maize	Veget-able	Pasture	D.W.R. (m^3/sec)
Sep.	1	76.70	70.75	-	-	-	-	24.51	54.15	4.29
	2	69.90	64.01	-	-	-	-	24.51	54.15	4.14
	3	57.40	52.15	-	-	-	-	39.33	54.15	3.56
Oct.	1	46.50	42.41	2.22	-	-	-	42.09	57.95	3.06
	2	32.30	29.38	4.66	-	-	-	42.09	57.95	2.35
	3	20.47	18.54	8.97	-	-	-	46.30	63.75	1.66
Nov.	1	6.09	5.51	13.29	2.35	-	-	59.85	59.85	2.31
	2	-	-	18.73	4.98	-	-	59.85	59.85	1.76
	3	-	-	24.23	8.93	-	-	59.85	59.85	1.85
Dec.	1	-	-	27.39	13.98	24.80	2.42	58.90	58.90	2.31
	2	-	-	29.84	19.84	26.04	7.50	58.90	58.90	2.78
	3	-	-	32.83	28.40	34.10	14.39	64.79	64.79	3.32
Jan.	1	-	-	31.29	33.21	44.20	21.65	61.75	61.75	4.25
	2	-	-	31.29	39.12	55.25	32.05	61.75	61.75	5.18
	3	-	-	31.82	47.91	72.93	46.33	67.93	67.93	6.04
Feb.	1	-	-	30.38	47.69	81.00	58.95	71.25	71.25	7.71
	2	-	-	26.08	47.69	81.75	69.30	65.25	71.25	8.37
	3	-	-	16.23	35.92	66.60	62.04	52.20	57.00	8.90
Mar.	1	-	-	15.46	46.77	91.56	92.57	73.08	79.80	10.28
	2	-	-	8.13	41.50	87.36	95.09	73.08	79.80	10.31
	3	-	-	3.65	37.93	85.01	103.67	80.39	87.78	10.03
Apr.	1	-	-	-	27.48	31.76	92.92	28.71	82.65	9.25
	2	-	-	-	19.10	-	84.74	28.71	82.65	8.25
	3	-	-	-	10.88	-	64.90	28.71	82.65	6.71
May	1	19.72	19.55	-	2.63	-	40.19	49.28	65.45	6.90
	2	21.45	21.10	-	-	-	24.02	49.28	65.45	5.89
	3	36.03	35.53	-	-	-	11.69	54.21	72.00	3.05
Jun.	1	50.34	48.71	-	-	-	-	46.08	61.20	3.51
	2	66.02	63.22	-	-	-	-	46.08	61.20	4.31
	3	81.94	77.98	-	-	-	-	68.40	61.20	5.30
Jul.	1	62.92	57.96	-	-	-	-	53.20	47.60	4.04
	2	74.69	68.74	-	-	-	-	53.20	47.60	4.63
	3	83.07	76.53	-	-	-	-	58.52	52.36	4.68
Aug.	1	72.74	66.79	-	-	-	-	46.11	45.05	4.45
	2	73.27	67.32	-	-	-	-	46.11	45.05	4.48
	3	80.48	73.95	-	-	-	-	50.72	49.56	4.48

FIGURE VI.1 IRRIGATION UNIT

1. Secondary Unit



2. Tertiary Unit



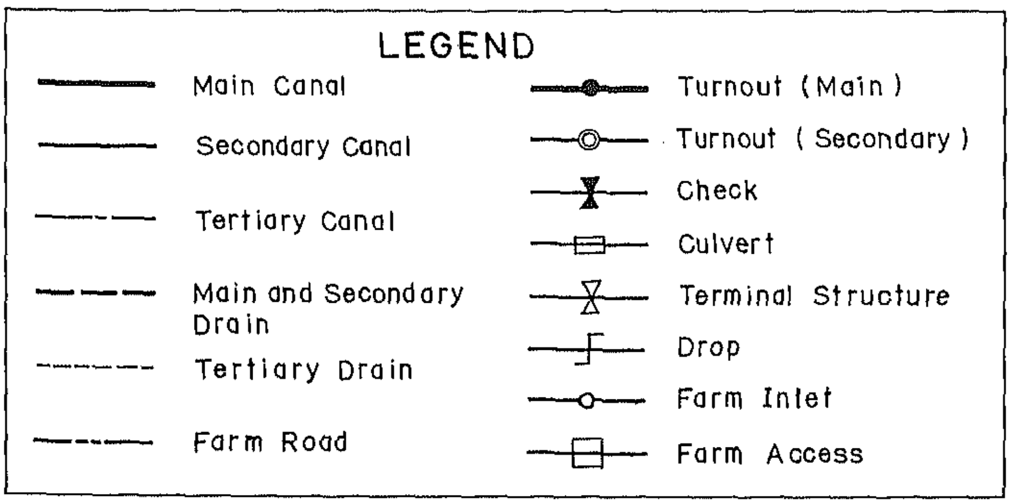


FIGURE VI - 2 POTENTIAL EVAPOTRANSPIRATION

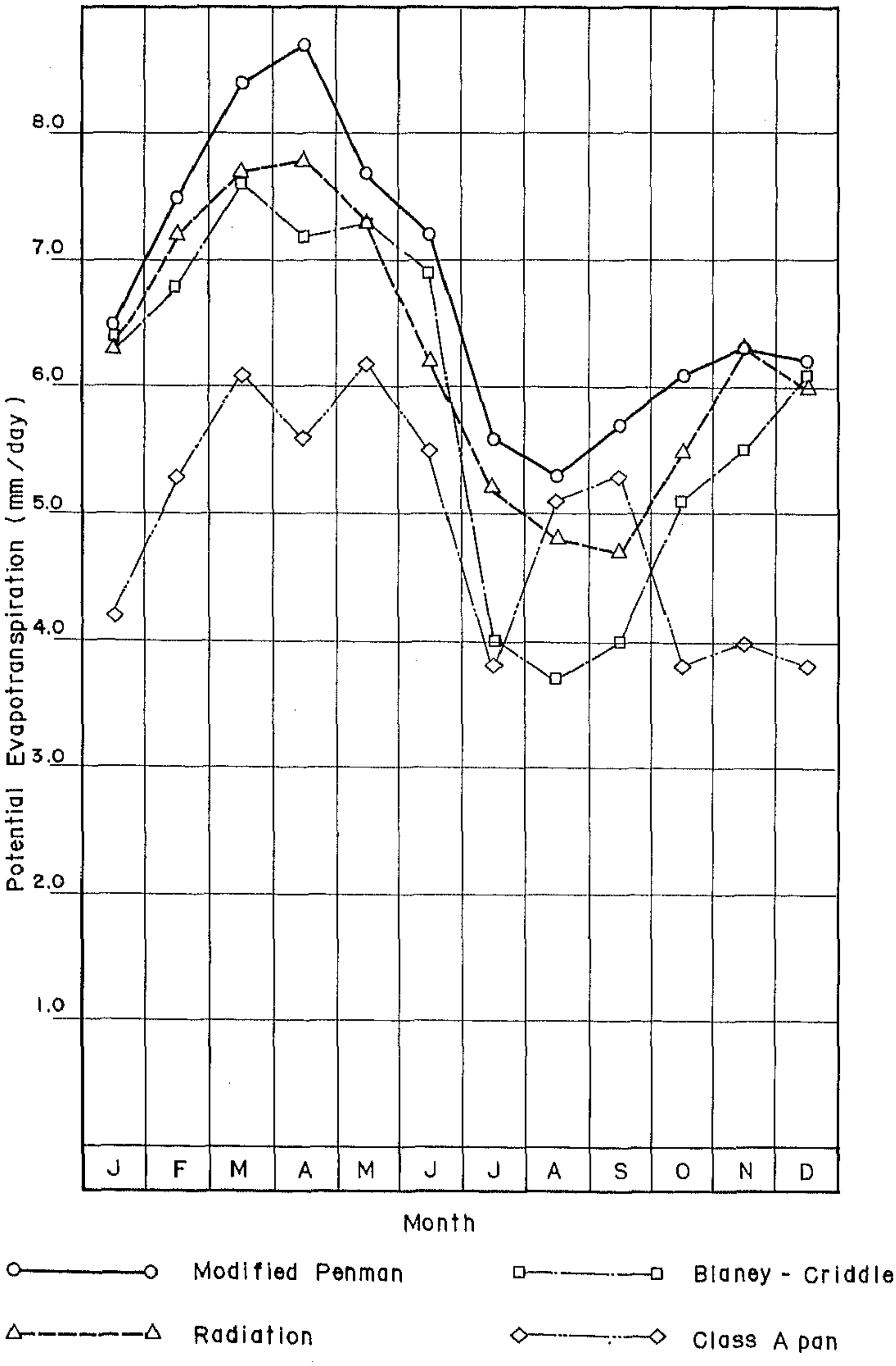
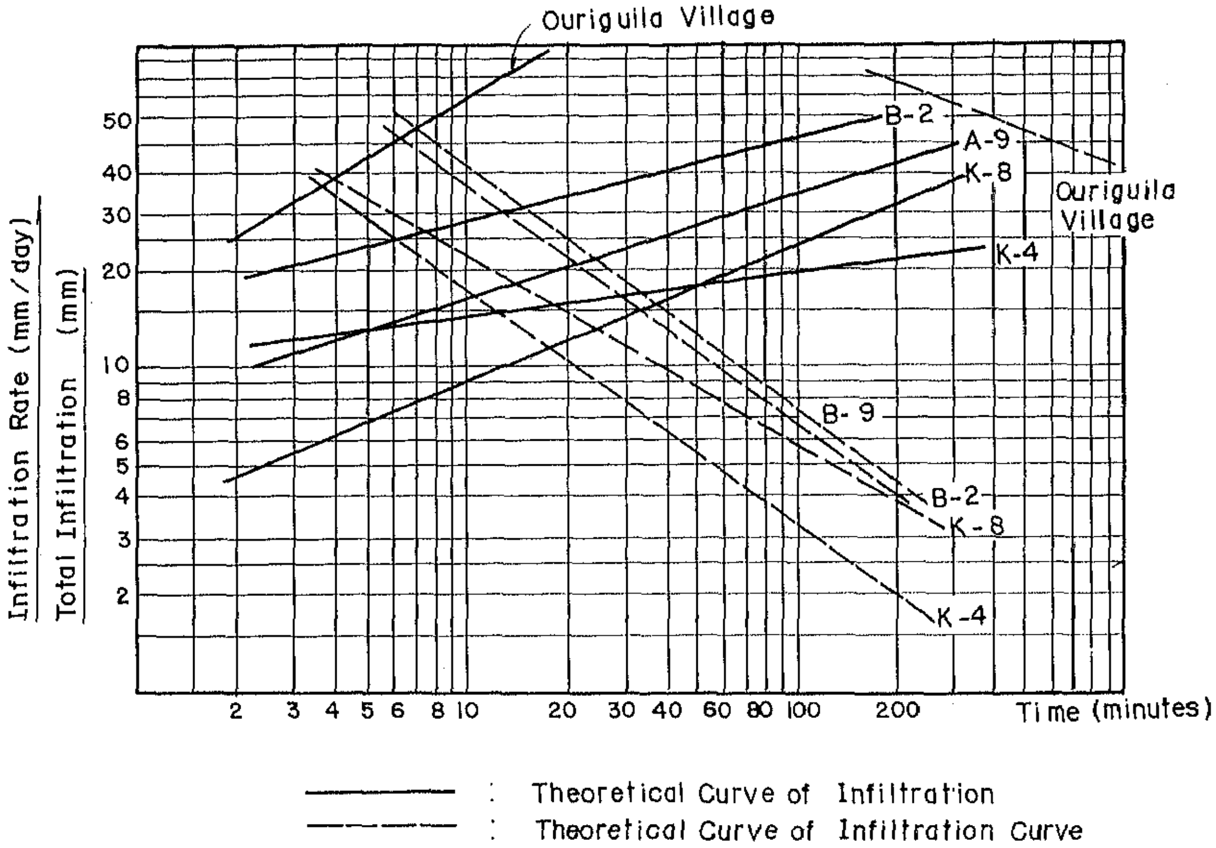


FIGURE VI-3 OBSERVED INFILTRATION AT SITE



Remarks : The above Curves have been obtained on the following formula

① $D = CT^n$
② $I = 60 . C.n.T^{(n-1)}$
D = Total ifiltration (mm)
I = Infiltration rate (mm/heure)
Cn = Coefficients depending on soil characteristics
T = Time (minutes)

Location	C	n	Ib (mm)	Remark
K - 8	3.38	0.42	2.86	Basic Intake Rate is defined as the rate at the time of 600 (1-n)
B - 2	16.01	0.25	2.46	
K - 4	5.47	0.28	1.16	
B - 9	7.51	0.33	2.68	
Ouriguila Village	16.87	0.61	73.55	

FIGURE VI-4 IRRIGATION DIAGRAM

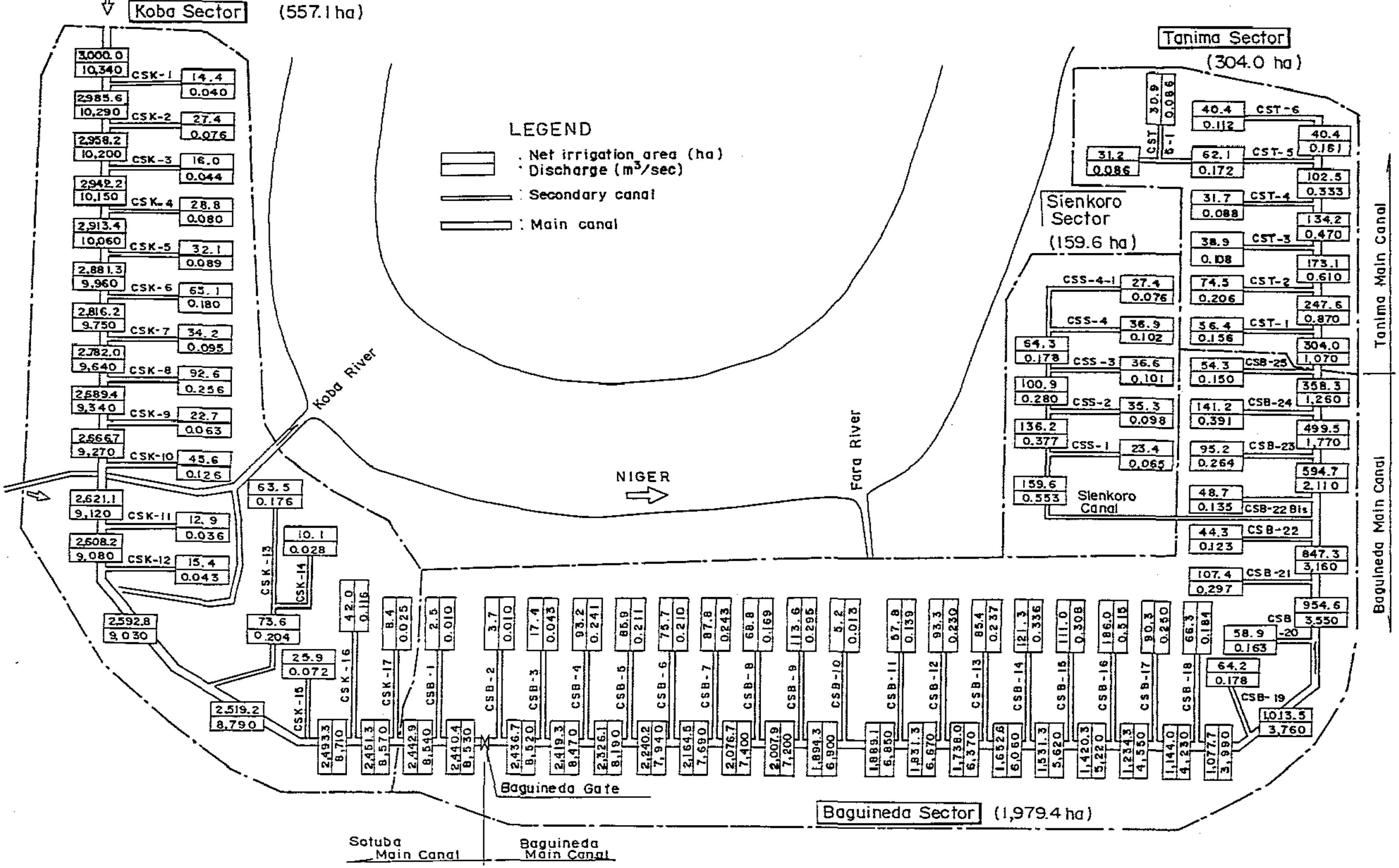


FIGURE VI-5 RELATION BETWEEN AREA AND DAILY RAINFALL ACCORDING TO "HORTON" FORMULA

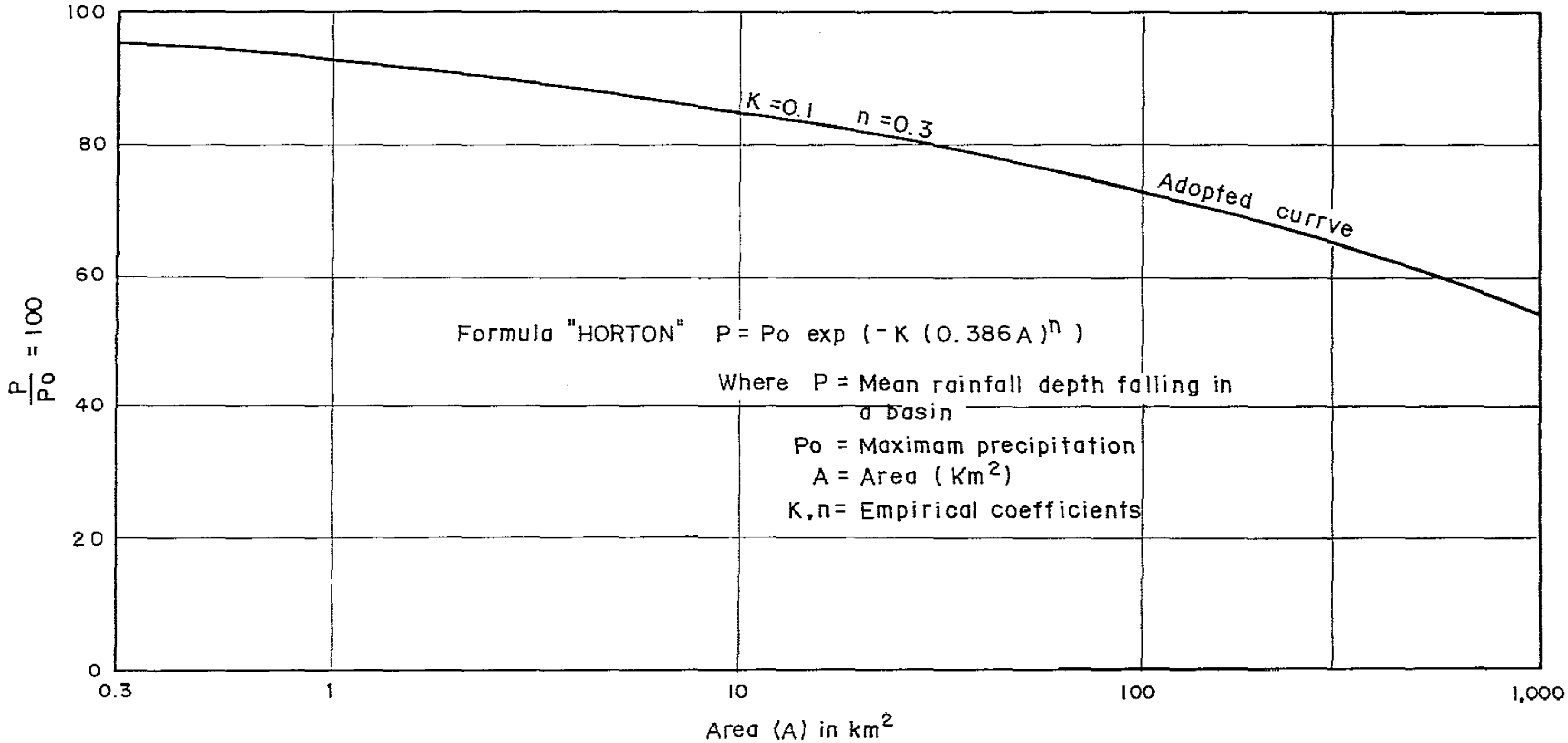
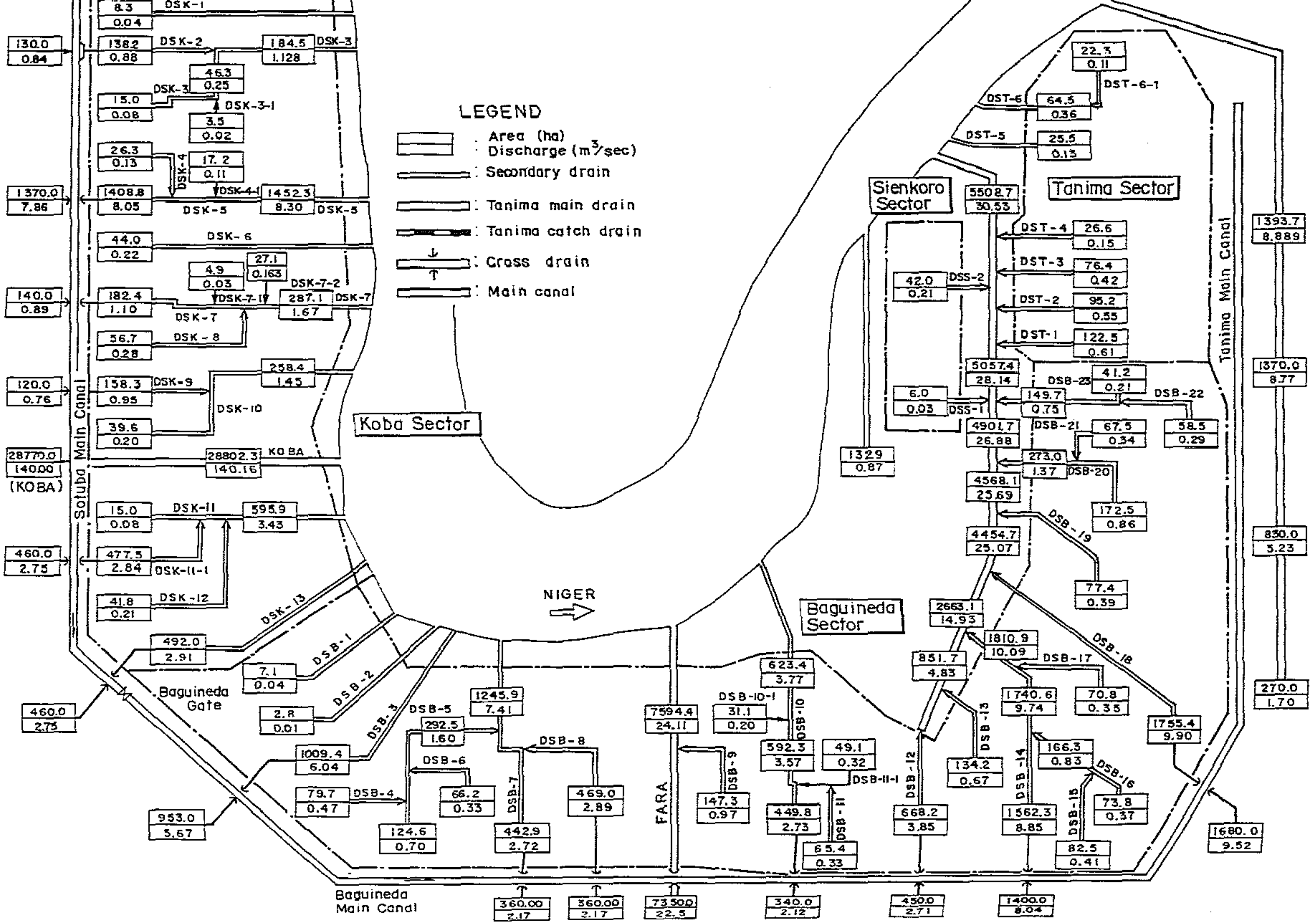


FIGURE VI-6 DRAINAGE DIAGRAMME



ANNEX VII

PRELIMINARY DESIGN

OF

CIVIL WORKS

ANNEX VII

PRELIMINARY DESIGN OF CIVIL WORKS

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PRELIMINARY DESIGN OF CIVIL WORKS

VII.1 Previous Design Principles

The design principles proposed in the previous feasibility study are summarized as follows:

Main irrigation canal

(1) For prevention of severe water leakage in the main canal, canal-lining by means of cast-in-place concrete is to be applied for about 10 km in total, comprising about 4 km in the most downstream part of the Sotuba canal and about 6 km in the upstream part of the Baguineda canal, respectively.

(2) The upstream part of the Sotuba main canal (about 15 km) will not need any rehabilitation because of negligibly small amount of water leakage.

(3) The so-called "Koba river crossing part" of about 1.4 km long is to be provided with a masonry overflow type dike of about 2.2 m high along its right bank. The run-off of the Koba river will be evacuated in two routes i.e., the one is through the drain under the canal bottom, and the other, over the dike and then through the existing two spill-ways to be rehabilitated.

(4) The downstream part of the Baguineda canal (about 12 km) will need rehabilitation and improvement consisting mainly of enlargement of the sections and adjustment of the bottom elevations.

(5) Because of the present unstable supply of irrigation water, the existing Tanima main canal will be abolished and a new canal will be constructed for 4.4 km long following in succession to the Baguineda canal.

(6) The water source of the Sienkoro canal, which is taking water from the Tanima main drain at present, will be switched to the Baguineda canal. For this purpose, one of the secondary canals of the Baguineda canal, CSB-22, will be extended and connected to the Sienkoro canal.

(7) Existing main canal structures will be utilized so far as possible, applying rehabilitation and improvement works. Major works consist of: (i) rehabilitation and improvement of turnouts inclusive mainly of replacement of gates, (ii) rehabilitation of gated- and side-spillways comprising mainly replacement of gates and water-proof treatment of structures, (iii) rehabilitation of cross-drains consisting mainly of replacement of pipes, etc. In addition to these rehabilitation and improvement works, new construction will be required especially for turnouts as the result of re-alignment of the secondary canal system to be mentioned later.

(8) The left bank of the main canal will be used as the trunk road for the project area. It will have a total width of 5 m and net width of 4 m will be paved by laterite layer of 20 cm thickness.

Secondary irrigation canal

(1) Number of the existing secondary irrigation canals is insufficient in number to cover the whole area. It is to be increased from 28 nos. of 34.6 km in total to 56 nos. of 78 km. An average spacing of the secondary irrigation canal system will be approximately 500 m.

(2) Severe deterioration has taken place especially in the Baguineda and Tanima/Sienkoro areas. A considerable rehabilitation works will be required for the canals and their related structures.

(3) Each secondary canal will have the OM road of 3 m wide, which is to serve also for the farming purpose. Laterite pavement will be applied with a thickness of 20 cm.

Main and secondary drainage canals

(1) The present drainage system, consisting of the Koba, the Fara rivers and the Tanima drainage canal, will be used as the principal drainage routes. Rehabilitation will be needed especially for the Tanima canal.

(2) Similar to the secondary irrigation canals, number of the secondary drainage canals is in short to cover the whole area. In conformity to the increase of the secondary irrigation canals, the number of the secondary drainage canals will have to be increased from the present condition of 30 nos., 48.5 km in total to 53 nos. of 79 km in total.

Tertiary irrigation and drainage canals

(1) The present density of the tertiary irrigation canals is about 50 m/ha which is insufficient to ensure stable and effective supply of irrigation water. It will have to be increased to about 85 m/ha. On an average, one tertiary irrigation canal will command about 6 ha of farm land, and it will be branched off from the secondary canal at an approximate interval of 120 m.

(2) The tertiary drainage canals are poorly developed at present. They will have to be provided alternately with the tertiary irrigation canals with the same density of about 85 m/ha.

Farm plot layout and land reclamation

(1) Size of the terminal irrigation unit, which is commanded by one tertiary canal, varies at present from area to area i.e., 1 - 25 ha in the Koba area, 10 - 20 ha in the Baguineda and Tanima areas. As stated above, it will be standardized to about 6 ha conforming to the re-establishment of the tertiary canal systems.

(2) On an average, one tertiary unit will encompass six plots of farmland, each of which covers the land of 120 m x 100 m. Farm road, which scarcely exists at present, will be provided to each plot with a width of 2 m. It will be used also as the OM road of the tertiary canal.

In the present study, thorough review is made on these previous design principles and the following results are obtained. (Ref. Table VII.1)

VII.2 Rehabilitation of Main Irrigation Canal

VII.2.1 Lining method of main canal

The previous study compared five alternatives i.e., (i) concrete-lining, (ii) rubber sheet, (iii) compacted earthfill, (iv) stone-masonry and (iv) corrugated steel pipes, and it proposed the concrete-lining method as the most suited to the project from viewpoints of water tightness, procurement of materials and durability. In the present study, the comparative study is made again to confirm the feasibility of the previous proposal.

(1) Selection of alternatives

In the present study, a comprehensive study is made on the following four alternatives.

Type	Lining Method
Hard surface lining	(1) Concrete lining
	(2) Soil cement lining
Buried membrane lining	(3) Synthetic rubber membrane lining with concrete block (Rubber sheet with concrete block)
Earth lining	(4) Thick compacted earth lining (Earth lining)

The two lining methods proposed in the previous study i.e., the stone-masonry method and the corrugated steel pipes, are excluded in the present study for reasons: (i) both initial cost and maintenance costs are very high, (ii) water-tightness cannot be guaranteed in case of the masonry works and (iii) much more manpower is required for the masonry works which may hinder timely execution of the works within the limited time available. Addition of the soil cement lining owes to that the cost is rather low and that materials are available at the site. The characteristics of the proposed alternatives are summarized in Table VII.2-1.

(2) Comparison of alternatives

A comparison of the alternatives is made by examination of the following technical and economic factors:

i) Durability
ii) Stability to physical damage
iii) Water tightness
iv) Availability of lining materials and practicability in construction
v) Construction cost
vi) Operation and maintenance
vii) Total lining cost

- Durability

The durability of linings depends on the type of lining, the quality of the construction materials used, the quality and accuracy of installation, climate conditions and operation and maintenance.

Concrete lining has best durability for more than 50 years among alternatives. The durability of soil cement and earth linings is only a half of concrete lining. The durability of synthetic rubber has been confirmed to be over 30 years in the field under the proper operation and maintenance.

- Stability to physical damage

Synthetic rubber sheet is very weak material against the physical damages caused by cattles' hoofs and sharpen debris, etc. The concrete lining has best stability to physical damages, seconded by soil cement and earth linings.

- Water tightness

Although the earth lining is less water tight than other alternatives, it is sufficient enough practically. Water losses of synthetic rubber is negligibly small and hence, synthetic rubber comes first in view of the water tightness.

- Availability of lining materials and practicability in construction

Synthetic rubber sheets are not available in the country and hence, they are obliged to be imported from abroad. Besides, there is no skilled worker for construction of rubber sheets. Even though some foreign workers will construct it, the problems and difficulties of maintenance and repair will be remained.

However, the rubber sheet lining has the merit that construction period can be shortened and is hardly affected by weather conditions.

Suitable soils for the earth lining are well-graded sand and gravel soil with a clay hinder, and clayey gravel, poorly graded gravel-sand-clay mixture soil, etc. According to the soil survey made so far, sufficient amount of suitable soils for earth lining was not found in and around the project area. Construction of the earth lining will be affected by climate condition because the control of soil moisture contents is very important for ensuring the quality of earthfilling.

The soil cement is advantageous where suitable sandy soils are available from canal excavation or nearby. Huge amount of sandy soils are available nearby the canals so that the procurement of materials for this lining material has no problem. Special construction procedures and methods are not required and construction is not so affected by climate conditions.

Aggregate and sand for the concrete lining are available in the project area. Because the concrete lining requires firm foundation, the foundation treatment will be required at some weak foundation sections. It takes longer construction period compared with the rubber sheet lining.

- Construction cost

The construction cost of each lining method is estimated based on the work quantities and unit costs of work items. The typical canal section for cost estimate, and work quantities per meter and unit cost are shown in Fig. VII.1 and Table VII.2-2, respectively. Summary of estimated construction cost is shown below:

Lining Method	Initial Cost (m2/$)	Remarks (Durability)
1. Concrete lining	27.9	50 years
2. Soil cement lining	21.9	25
3. Rubber sheet with concrete block	27.1	30
4. Earth lining	14.0	20

The earth lining cost is only a half of the costs for the concrete lining and the rubber sheet methods. However, the durable year is far shorter than those of the concrete lining and the rubber sheet lining methods.

- Operation and maintenance (O & M)

When the operation of a canal system requires frequent filling and emptying of water or causes frequent water level changes, a hard surface lining (concrete and soil cement linings) will be the most suitable, while the earth linings, under earth covered condition, would speed up the deterioration process and would require increased maintenance efforts. With regard to weed control, small repairs and silt removal, such lining offer little advantage over unlined earth canals.

Lining Method	Annual O & M Cost ($/m2)
1. Concrete lining	0.28
2. Soil cement lining	0.66
3. Rubber sheet with concrete block	0.54
4. Earth lining	0.98

- Total lining cost

Based on the estimated initial construction cost, period of depreciation and O & M and replacement costs of linings, total lining cost for 50 years are converted to net present value (NPV). The discount rate for calculating the NPV is assumed at 10% and the calculated NPV is shown below:

(Unit: $\$/m^2$)

Lining Method	Depreciation Period	Initial Cost	Annual O & M Cost	NPV
1. Concrete lining	50 yrs.	27.9	0.28	27.9
2. Soil cement lining	25	21.9	0.66	27.7
3. Rubber sheet with concrete block	30	27.1	0.54	30.9
4. Earth lining	20	14.0	0.98	23.7

Total cost of the earth lining is still lower than other linings but is only 85% of concrete lining. Although the initial cost of the earth lining is a half of the concrete lining, the annual O & M cost increases the total lining cost. There is no considerable difference among other three linings. With regard to the earth lining, replacement will be needed twice during the period of 50 years. As a matter of course, in case of the earth lining, there is no need of replacement.

(3) Selection of lining method

The foregoing study results are summarized as shown in Table VII.2-3. From technical viewpoints such as durability, stability, water tightness, availability of materials, construction and operation and maintenance, it can be judged that the concrete lining is the most suitable lining method for the project.

With regard to the economic aspects, the earth-lining method is the most cost-saving in terms of NPV. However, since its O & M cost is the highest among the alternatives, it is less suited to the present financial situation of the Mali Government. Consequently, it seems that the second lowest cost methods of the concrete and the soil cement-lining are preferable from the economic viewpoint.

From the above, it is concluded that the concrete-lining method will be suited to the project from both technical and economic viewpoints.

VII.2.2 Koba river crossing structure

(1) Present condition

The Sotuba canal crosses the Koba river by means of the so-called "Level-crossing" method. The canal section of 1,369 m from No. 150+65 to No. 164+34 has no right bank forming a retarding basin for the floods from the Koba river. The floods are retarded in the basin and evacuated gradually through the two existing spillways on the canal and one cross drain laid under the canal bed. Because of lack of the right bank embankment, a big amount of canal water is released to the basin to be wasted as evaporation and infiltration. Apart from that, the sediment loads contained in the river water are brought into the canal by the floods and caused reduction of the flow capacity of the canal.

(2) Alternatives for crossing-structure

The previous feasibility report proposed to construct a masonry dike on the right bank of the canal and to separate the flow of the Koba river from the irrigation water of the canal. The flood water of the river, which is estimated at 135 m^3/sec with a probability of 1/10, is partly drained through the cross drain existing at the site and partly flows over the dike, and then, drained through the two spillways existing on the left bank of the canal. For prevention of the flood water from flowing downstream to the Baguineda canal, a check structure will be constructed across the main canal just downstream of the crossing point. A schematic layout of the previous plan is shown in Fig. VII.2.

Against the above-mentioned previous plan, a siphon plan is proposed at the present study to pass the irrigation water of the canal under the river-bed. The plan consists of (i) 3-barrels of corrugated steel pipes 91 m long and 2,000 mm dia., (ii) a submergible bridge of 65 m long and 5 m wide along the left side of the siphon to pass the OM road along the main canal, (iii) embankment of the right bank of the canal for 1,278 m long, and (iv) some river improvement works at the crossing point. (See Fig. VII.2)

(3) Comparative study

Comparative study between the previous over-flow dike plan and the present siphon plan is carried out from both engineering and economic view-points. (Ref. Table VII.2-4) Comparison is made with regard to (i) drainability of the Koba river floods, (ii) sedimentation, (iii) enlargement of flow capacity of irrigation canal, (iv) hydraulic head loss, (v) inundation area by floods, (vi) utilization of existing spillways, (vii) construction and maintenance and (viii) construction cost. The result of the comparative study is summarized as below:

Drainability of the Koba river floods

The siphon plan is provided with far better drainability than the previous plan. The previous overflow dike plan has a demerit that the flow capacity is restricted by the capacity of the existing spillways and cross drain, which are hardly sufficient to release the design flood of 135 m^3/sec.

Sedimentation

The overflow dike plan cannot be free from bringing of river sediments into the canal, whereas the siphon plan is entirely free from such sediment inflow from the river. A sediment problem in the canal water would be insignificant since the flow velocity in the upstream canal is very slow (0.3 - 0.5 m/sec). Even though sedimentation takes place in the siphon, they can be removed easily by closing the barrels each by each.

Enlargement of canal capacity

In case of the siphon plan, increase of the flow capacity would virtually be difficult unless new conduit barrel is provided additionally, whereas in case of the dike plan, increase of the flow capacity would be easily attained by enheightment of the crest of the dike. From this, it follows that, in case of the siphon plan, selection of the conduit and determination of the size should be made in due consideration of future increase of irrigation water.

Hydraulic head loss

With regard to the overflow dike method, no hydraulic head loss occurs except friction loss of the canal. Although some head losses are caused in the siphon, lowering of water level by such losses will be recovered by check structures to be located in the downstream of the canal.

Inundation area by floods

Construction of flood dike creates the retardation area of about 250 ha at the peak flood time, while the inundation area of the siphon is negligibly small, and such land can be converted to farmland.

Utilization of existing spillways

Existing two spillways are fully utilized for the dike method, but as mentioned before, their spilling capacities are hardly sufficient to cope with the design flood of 135 m^3/sec. In the siphon plan, one spillway at upstream side is to be utilized as a safety device.

Construction and OM

With regard to easiness of construction, there will be no virtual difference between these two plans. As to OM, each of the plans has a merit and a demerit: Operation of the siphon will be easier than the overflow dike plan because the latter requires timely and rather frequent gate operation of the check structure especially in the rainy season; while maintenance of the siphon will be more costly because of desilting works.

Construction cost

Construction cost of the siphon plan is US$663 thousand, whereas that of the dike plan is US$1,123 thousand. The siphon plan is far less costly than the dike plan.

(4) Conclusion

From the above-mentioned comparative study, it is recommended that the siphon plan is more suited to the Project than the previous dike plan. To cope with increase of irrigation water requirement in future, it is proposed that the number and size of the conduit-barrels be designed to have the allowance of about 50%.

VII.2.3 Related structures

(1) Turnout

The present type of the existing turnouts is of the conventional sluice gate type and lacks accurate discharge measurement devices. The previous feasibility study proposes only rehabilitation of these existing turnouts, however, at the present study, entire replacement is proposed for reasons: (i) existing turnouts have already been deteriorated considerably, and (ii) installation of accurate measurement devices is indispensable to introduction of rational water management. For selection of the most optimum type, comparative study is made on the following three alternatives.

Type A : Check Cum Duckbill Weir, plus Distributer

Type B : Aviogate plus Distributor

Type C : Conventional type
(sluice gate plus discharge measurement weir)

The schematic layout of these alternatives is shown in Fig. VII.3. Type A will consist of several check cum duckbill weirs across the main canal and a distributor at each of the turnouts. It is intended that the water surface level of the main canal be kept constant by the check cum duckbill weirs even under various discharge conditions, and that diversion of water to secondary canals be made easily by the distributor in strict accordance with the requirement. Type B will consist of Aviogate plus distributor at each turnout. The aviogate is the structure to keep the water level constant regardless of fluctuation of the water level in the main canal. Type C is of the conventional type which is to be provided with a discharge measurement weir after diversion. From the standpoint of operation and maintenance, merits and demerits of each alternative is discussed as follows:

Type A:

Merits of this type are (i) easy operation and (ii) strict control of diversion water. Gate operation is needed only for the check gate and the diversion water is controled eadily by pulling-up or -down of the control panel(s) of the distributor. However, this type has a demerit that, for control of the water level in the main canal, more check gates are needed compared with Type B and Type C.

Type B:

Merits of this type are almost the same as Type A. Operation is very easy and strict discharge control is possible. However, this type has demerits: (i) additional installation of sluice gate is required for each of the turnouts since complete water proof can not be expected for the Aviogate and (ii) because of the rather sophisticated mechanism of the Aviogate, repairing may cause much troubles especially in acquisition of parts and availability of technicians.

Type C:

Merits of this type lie in the point that it has been used conventionally and very familiar to both officials concerned and farmers. However, it has a demerit that strict control of water diversion is very difficult requiring sensitive gate-opening adjustment reading the water level gauge at the measuring weir. In addition, on the contrary to the distributor, the sluice gate is apt to be kept fully opened due to arbitrary operation by farmers, causing diversion of water exceeding the requirement.

Cost comparison of these alternatives is summarized in Table VII.2-5, which shows the initial investment and annual O & M cost. The table tells that, in terms of the annual equivalent cost, Type A is the most cost-saving seconded by Type C, whereas Type B is the least cost-saving needing about 1.8 times higher cost than the others.

Based on the above discussions, it is concluded that Type A or "Check Cum Duckbill Weir, plus Distributor" be used as the turnouts for water diversion from main canal to secondary canals.

(2) Check

In the previous F/S study, installation of 4 check structures is proposed, however, due to adoption of the above-mentioned Type A turnout, number of necessary check structures will be increased to 16 comprising 2 in Sotuba, 5 in Baguineda, 5 in Tanima and 4 in Sienkoro, respectively. To facilitate easy adjustment of water level in the main canal, the Duckbill type weir will be applied to 7 checks in Sotuba and Baguineda canals, while the checks for Tanima and Sienkoro will be of the conventional sluice gate type.

(3) Cross drain

Cross drains are designed so as to drain the drainage modulus of 4.9 lit./sec/ha, estimated on the condition that the overland runoff caused by probable rainfall of 1/10 be drained within a period of 48 hours or 2 days. The previous feasibility study proposes rehabilitation of 21 cross drains. As the result of the present study, construction of 12 cross drains are needed in addition to these existing ones, due especially to the provision of new embankment on the right bank of the canal.

(4) Spillway

The previous feasibility study proposed construction of 5 new spillways in addition to the existing 9 spillways with the aim to supplement the discharge capacity of the cross drains. However, in the present study, the new construction is discarded for reason that, as a rule, inflow of the drainage water into the main canal will be prevented by thorough provision of the right bank embankment and the drainage water be evacuated by provision of an adequate number of cross drains. As such, necessary works for spillways will be limited to repairing and rehabilitation comprising mainly recovery of water-tightness at gate grooves.

(5) Bridge

The previous feasibility study proposed to use the existing 14 bridges with repairing and rehabilitation. However, because of heavy deterioration, the present study proposes entire replacement of the existing bridges with new ones. The new bridges will be provided with precast concrete beams supported by concrete gravity abutments and piers.

(6) Culvert

Culvert structures are proposed to be provided to the O & M road where the road crosses tributaries or waterways from spillways. Nine culverts are needed in total comprising 7 in Sotuba, and 2 in Tanima, respectively. Structurally, the culvert consists of several spans of semi-circular corrugated steel pipes to be protected by wet stone masonry.

(7) Underdrain

Underdrain is needed in the lining portion of the canal to cope with the up-lift pressure due to high groundwater table. It is provided to the main canal at places where the groundwater table in the adjoining area is expected to rise to about 50 cm higher than the canal bottom. The total length of the underdrain is estimated to reach to about 9.2 km.

VII.2.4 Treatment of upstream 15 km of Sotuba canal

The previous feasibility study does not propose any rehabilitation works for the upstream 15 km portion of the Sotuba canal, saying that water leakage in this portion is not so much as the downstream portion of about 4 km. However, as a result of the present field reconnaissance, the upstream portion seems also to have been suffered from considerable leakage because of lack of the right bank embankment at several places and deterioration of the existing bank.

Rehabilitation works, consisting mainly of provision of the right banks and restoration of the deteriorated bank, will need be executed also for this upstream portion. Bank construction will be executed for a length of 3.6 km in total and rehabilitation of the structures will mainly be carried out for turnouts, spillways, cross drains, etc.

Features of main canals and structures are summarized in Tables VII.2-6 to VII.2-8, and the typical profile of the main canal and design drawings of the related structures are shown in Plate-4 and Plate-5 to Plate-9, respectively.

VII.3 Rehabilitation of Secondary Irrigation Canals

Neigher modification nor revision is needed for the secondary canals except change of the number and length of the canals to 54 and 62.6 km long in total, respectively. As regards the related structures, modifications are proposed for turnouts and crossing structure of the canal. The previous plan proposes a masonry type turnout. However, for the convinience in construction, the present study proposes to change it to a pre-cast concrete type and, besides, to equip it with a discharge measuring device. In addition, to facilitate crossing of the canal, it is proposed to install a culvert type structure across the canal at appropriate internal of about 600 m. The O & M road will be provided to all the secondary irrigation canals with a width of 4 m and laterite pavement of 20 cm thick.

Principal features of secondary irrigation canals are shown in Table 3.1, and the typical canal profile and design drawings of the related structures are shown in Plate-4 and Plate-10 to Plate-11, respectively.

VII.4 Rehabilitation of Main and Secondary Drains

Neither modification nor revision is necessary for main and secondary drains except change of the number and length of the secondary drains from 53 nos., 79 km to 53 nos., 73 km. Tables VII.4-1 and VII.4-2 show principal features of main drain facilities and principal features of secondary canals. Plate-12 illustrates typical facility on drainage canals.

VII.5 Tertiary Canals and Farm Plate Layout

Following the layout shown in Fig. VI.1, all the irrigation and drainage canals will be constructed newly together with the farm plot layout works.

Related to the farm plot layout works, reclamation works inclusive of land clearing and rough levelling will have to be executed for the area of 1,784 ha which is now remained as grass land or upland field. Clearing works consist of removal of grass and shrubs, while the rough levelling works are to make the land surface almost level with accuracy of +10 cm. Minute levelling will be entrusted to farmers together with provision of plot borders and ridges.

Plate-2 shows a layout of the tertiary block for the Koba area and Plate-13 shows typical on-farm facility.

Table VII.1 SUMMARY OF REVISED AND MODIFICATIONS (1/3)

Item	Previous Study	Present Study
I. Main Canal		
(1) Canal Lining		
a) Canal length L	L = 10.0 km	L = 11.0 km
b) Canal section	Enlargement, embankment, re-shaping, etc.	Enlargement, embankment, re-shapint, etc.
c) Underdrain	None	L = 9.1 km
(2) Crossing Koba River (1.4km)		
a) Crossing scheme	Wet masonry over-flow dike 1.4 km	Siphon L = 91 m, Dia. = 2.00m x 3 nos.
b) Embanking of right bank	Above dike	New earth embankment of 1.3 km
c) O&M road of left bank	Bank shaping only	Rank shaping and construction of O&M and main road of 1.4 km
(3) Extension of Baguineda Canal	Enlargement and extension (3.5 km) by excavation	Enlargement and extension (3.5 km) by excavation
(4) Tanima Canal	Direct connection to Baguineda canal	Direct connection to Baguineda canal
(5) Sienkoro Area	Direct connection to Baguineda canal	Direct connection to Baguineda canal
(6) Rehabilitation of Structure		
a) Turnout	Rehabilitation of 38 existing ones and construction of 11 new ones.	All turnouts are replaced with distributor type

Table VII.1 SUMMARY OF REVISED AND MODIFICATIONS (2/3)

Item	Previous Study	Present Study
b) Check gate	Rehabilitation of 2 existing ones and construction of 4 new ones	Construction of 7 new checks of Duckbill type, construction of new checks of sluice gate type and rehabilitation of Baguineda check
c) Cross drain	Rehabilitation of existing ones and construction of 2 new ones	Rehabilitation of existing ones and construction of 5 new ones
d) Water through	Construction of 4 new ones (inlet and outlet hole on irrigation canal)	Cancelled. In stead of that, cross drains are provided adequately.
e) Culvert for road	Construction of 3 new ones for main road	Construction of 8 new ones for O&M and main road
f) Bridge	Rehabilitation of 8 existing ones	Replacement of 8 existing ones and construction of 3 new ones
g) Washing step	Construction of 10 new ones	Construction of 10 new ones
(7) Main Road	Laterite pavement on main canal (41.2 km)	Laterite pavement on main canal (41.2 km)
(8) Embanking of Left Bank (upstream of Sotuba)	Not proposed	New embankment of 3.6 km in the upstream reach of Sotuba main canal
II. Secondary Canal		
(1) Nos. and Length of Canal	Total length = 78 km, Nos. = 56	Total length = 59.8 km, Nos. = 54
(2) O&M Cum Farm Road	Total length = 78 km, Nos. = 56, Width = 3 m	Total length = 51 km, Nos. = 56, Width = 4 m
(3) Structure	Most of structures are made of concrete	Most of structures are made of concrete

Table VII.1 SUMMARY OF REVISED AND MODIFICATIONS (3/3)

Item	Previous Study	Present Study
III. Main and Secondary Drainage Canal		
(1) Tanima Main Drain	Enlargement and shaping for L = 7.2 km	Enlargement and shaping for L = 7.2 km
(2) Tanima Catch Drain	Construction of L = 6.6 km	Construction of L = 6.6 km
(3) Secondary Canal		
a) Nos. and length of canal	Total length = 79 km, Nos. = 56, Canal density per ha = 26 m/ha	Total length = 73 km, Nos. = 53, Canal density per ha = 24 m/ha
IV. Tertiary Irrigation and Drainage Canals		
(1) Tertiary irrigation canal and farm road	Total length = 258 km, Nos. = 514, Canal density per ha = 86 m/ha, Road width = 2 m	Total length = 150 km, Nos. = 459, Canal density per ha = 50 m/ha, Road width = 3 m
(2) Tertiary Drainage Canal	Total length = 258 km, Nos. = 514, Canal density per ha = 86 m/ha	Total length = 115 km, Nos. = 306, Canal density per ha = 38 m/ha
(3) Structure	Not mentioned in particular	Construction of farm inlet, access culvert, drop, etc. by using precast concrete
V. Land Reclamation		
(1) Tertiary Unit	6 ha (+ 500 m x 120 m)	7.2 ha (= 600 m x 120 m)

Table VIII.2-1 ALTERNATIVES FOR CANAL LINING

Type of Lining and Thickness	Cost ($/m2)	Durability*	Water Losses* ($m^3/m^2/24$ hrs)	Other Important Features
(Hard surface lining)				
1. Portland cement concrete, 10 cm	27.9	50 yrs	Below 0.03	Suitable for all size of canals, all topographical, climatical and operational conditions; firm subsoil required; availability of aggregates near the job site is essential.
2. Soil cement, dry mixed, 15 cm	21.9	25 yrs	0.03 - 0.06	Although less durable than portland cement concrete, low first cost makes this an economic lining, where suitable sandy soils are available from canal excavation or nearby.
(Buried membrane lining)				
3. Sublining of synthetic rubber sheeting under present concrete, 5 cm	27.1	30 - 50 yrs is expected. 30 years recorded in the field.	Negligible if property jointed and maintained.	Offers permanent seepage control if protected from physical damage; precast concrete is set to relieve any hydrostatic pressures, concrete joints and cracks need not be sealed but eventually filled with material to protect the underlying membrane.
(Earth lining)				
4. Thick compacted earth lining, 90 cm	14.0	20 yrs	Below 0.08	Suitable soils (well-graded sand and gravel with a clay binder and clayey gravels, poor graded gravel-sand-clay mixture) from canal excavation or nearby borrow area is essential for economy.

Source: * Irrigation canal lining, FAO, 1971

Table VII.2-2 COST ESTIMATE

(Unit: $)

Item	Q'ty	Unit Cost	Amount
1. Concrete lining (t = 10 cm)			
Concrete (t = 10 cm)	1.45 m^3	205.0	297.0
Strip/Exca. (t = 50 cm)	7.78 m^3	5.0	38.0
Backfill	6.22 m^3	9.5	59.1
Under drain	2.0 m	4.5	9.0
Total			404.0 (27.9 m/m^2)
2. Soil cement lining (t = 15 cm)			
Soil cement	2.18 m^3	100.0	218.0
Strip/Exca.	7.78 m^3	5.0	38.9
Backfill	5.44 m^3	9.5	51.7
Under drain	2.0 m	4.5	9.0
Total			317.6 (21.9 $/m^2$)
3. Rubber sheet with concrete block (t = 5 cm)			
Concrete	0.73 m^3	205.0	149.7
Strip/Exca.	3.11 m^3	5.0	15.6
Backfill	3.11 m^3	9.5	29.5
Under drain	2.0 m	4.5	9.0
Synthetic rubber	14.5 m^2	13.0	188.5
Total			392.3 (27.1 $/m^2$)
4. Thick earth lining (t = 90 cm)			
Stripping	14.0 m^3	5.0	70.0
Backfill	14.0 m^3	9.5	133.0
Total			203.0 (14.0 $/m^2$)

Table VII.2-3 COMPARISON OF ALTERNATIVES

Lining Name	Technical Aspects				Economic Aspects		
	Durability	Stability	Water Tightness	Materials and Construction	Construction Cost	O & M Cost	Total Lining Cost
1. Concrete lining	A	A	B	B	C	A	B
2. Soil cement lining	C	B	B	A	B	B	B
3. Rubber sheet with concrete block	B	B	A	C	C	B	C
4. Earth lining	C	B	C	D	A	C	B

Remarks: A: Excellent, C: Good
B: Moderate, D: Inferior

Table VII.2-4 COMPARISON BETWEEN OVERFLOW DIKE AND SIPHON METHODS (1/2)

Comparison Factor	Overflow Dike Method	Siphon Method
1. Drainability of excess discharge over the design flood	Inflow of excess discharge over the design flood is hardly spilled out by existing two spillways. Even in the design condition, the spillout capacity of two spillways is estimated at 94 m^3/sec and remaining 41 m^3/sec is storaged in the canal by the check gates.	Excess discharge over the design flood will be well discharged by freeboard of improved river section. No flood water will inflow to the canal. The siphon method is softer than the overflow dike method.
2. Sedimentation problem in the canal	Sedimentation loads will flow into the canal with flood. The clearing work of the sedimentation loads will be required more frequently than the siphon method. Unless the clearing work is made, the canal flow section is decreased. It causes the water shortage problem in the downstream area.	No sedimentation problem is occurred because no sedimentation loads of the Koba river is inflowed.
3. Extension of canal flow capacity	Extension work is easily expected by enheighting of crest elevation of the dike, but inundation area at the floods will be expanded.	The canal flow capacity is hardly extended. New conduit(s) is to be added when the canal is required more flow capacity. The design discharge of the siphon takes at 1.5 times of design discharge of canal taking into consideration the extension of commanding area.
4. Hydraulic head losses of the canal	No hydraulic head loss is occurred except friction loss of masonry canal.	Some head losses (about 30 cm) due to inlet, outlet, friction of conduits, screen, transition, etc. are occurred. But these head losses will be maintained by the check in the downstream.
5. Inundation area by flood	The area of about 250 ha is inundated at the peak of flood, and about 100 ha is extended below crest elevation of El. 315.7 m of dike. The storage volume below El. 315.7 m is estimated at one million m^3, and it takes over 10 days for drain by small scale drain.	Inundation area is negligible comparing with the dike method. Present inundation area will have some potential to develop the farm land.

Table VII.2-4 COMPARISON BETWEEN OVERFLOW DIKE AND SIPHON METHODS (2/2)

Comparison Factor	Overflow Dike Method	Siphon Method
6. Utilization of existing spillways	Existing two spillways are fully utilized but these capacity is estimated at only 94 m^3/sec while the design flood discharge is 135 m^3/sec.	Upstream side spillway at No. 148 is utilized as the safety device of the siphon. Because of no flood inflow, spillout capacity is sufficient.
7. Construction, operation and maintenance	Construction and repair work is simple and easy by available skilled masons and materials. Some foundation treatment of dike may be required because the foundation consists of piled silt and gravel by floods. Visual inspection of dike condition is made easily and small scale repair can be carried out by O & M staff and farmers. Proper and timely operation of check gates is required at flood time to prevent the flow down of flood discharge in the canal.	The construction work is more complex and hard than the masonry work. Because the repair work of the conduits is very difficult and take much costs, careful construction and operation is required. No operation is required at flood time except inspection of water level of improved river section.
8. Construction cost of 1,369 m (from No. 150+65 to No. 164+34) * Details are shown in Table 2	Item / Amount ($): 1. Masonry dike 1,023,830 2. Check 94,030 3. Cross drain 5,000 Total 1,122,860	Item / Amount ($): Siphon* 504,715 Canal 158,240 Total 662,955 * Including river improvement and submergible bridge

Table VII.2-5 COST COMPARISON OF MAIN CANAL TURNOUT

(Unit: US$)

Type	Initial Cost			Annual O & M Cost					Annual Cost
				Depreciation		Maintenance		Operation	
	Total	Civil	Gate	Civil Work	Gate	Painting	Greasing		
A	663,200	476,900	186,300	24,322	13,786	292	168	2,313	40,881
B	1,108,800	528,800	580,000	26,969	42,920	1,159	364	2,508	73,920
C	638,400	398,800	284,600	20,339	21,060	337	100	3,938	45,774

Table VII.2-6 PROPOSED IRRIGATION FACILITIES (1/2)

1. Main Canal

A. Principal Feature

Name	Length (km)	Discharge (m^3/sec)	Longitudinal Gradient	Earthwork Length (km)	Concrete Lining Length (km)	Right Bank Embankment Length (km)	Remarks
Sotuba Main Canal	19.0	10.3 - 8.5	1/5,000 - 1/1,600	*14.7	4.3	4.8	Existing Tanima main canal is abandoned.
Baguineda Main Canal	17.9	8.5 - 0.9	1/11,000 - 1/6,400	11.9	6.0	0.7	
Tanima Main Canal	4.4	0.9 - 0.2	1/1,000	4.4	-	3.7 (Both Bank)	*Including rock portion of 200 m.
Total	41.3			31.0	10.3	9.2	

B. Structure

Name	Number of Structure						
	Turnout	Cross Drain	Culvert	Spillway	Check Gate	Bridge	Washing Stop
Sotuba Main Canal	17	13	7	6	2	6	3
Baguineda Main Canal	27	8	0	1	5	10	6
Tanima Main Canal	5	0	1	0	0	0	1
Total	49	21	8	7	7	16	10

2. Secondary Canal

Sector	Nos. of Canal	Total Length (km)	Discharge (lit./sec)	Longitudinal Gradient	Structure (nos.)					
					Turnout	Check	Drop	CV	Terminal Structure	Aqueduct
Upper Koba Sector	10	8.9	40 - 256	1/1,500 - 1/500	57	48	11	22	9	0
Lower Koba Sector	6	3.3	25 - 204	1/1,500 - 1/500	27	24	6	4	3	0
Upper Baguineda Sector (DFB)	10	11.9	13 - 295	1/1,000 - 1/300	81	73	12	24	8	0
Lower Baguineda Sector	16	27.3	123 - 515	1/1,500 - 1/400	182	166	18	55	16	0
Tanima Sector	7	7.1	85 - 206	1/1,000 - 1/300	47	40	20	14	7	0
Sienkoro Sector	5	7.7	16 - 102	1/1,500 - 1/400	30	25	13	11	5	1
Total	54	66.2			421	373	80	127	48	1

Table VII.2-6 PROPOSED IRRIGATION FACILITIES (2/2)

3. Tertiary Canal

Sector	Nos. of Canal	Total Length (km)	Range of Discharge (lit./sec)	Structures		
				Farm Inlet	Farm Access	Drop
Upper Koba Sector	57	19.1	10 - 30	319	87	6
Lower Koba Sector	27	8.8	10 - 30	146	49	4
Upper Baguineda Sector	85	27.6	20 - 40	461	142	5
Lower Baguineda Sector	218	71.2	20 - 40	1,188	356	0
Tanima Sector	47	15.2	10 - 40	253	76	5
Sienkoro Sector	25	8.0	10 - 30	133	40	2
Total	459	149.9		2,500	750	22

4. Tertiary Drain

Sector	Nos. of Canal	Total Length (km)	Range of Discharge (lit./sec)
Upper Koba Sector	45	19.1	12 - 48
Lower Koba Sector	20	6.5	12 - 48
Upper Baguineda Sector	54	20.4	24 - 96
Lower Baguineda Sector	141	52.7	24 - 96
Tanima Sector	30	11.2	12 - 96
Sienkoro Sector	16	5.9	12 - 48
Total	306	115.8	

5. Tanima Main Drain, River as Drainage Canal and Catch Drain

Sector	Length (km)	Discharge (m^3/sec)	Longitudinal Incline	Number of Structures				River Improvement (m)
				Bridge	Aqueduct	Junction	Drop	
Tanima Main Drain	7.2	30	1/2,000 - 1/700	0	0	13	4	-
Koba	-	140	-	1	0	0	0	-
Fara	-	24	-	0	0	0	0	320
Tanima Catch Drain	6.6	8.9	1/1,500	0	2	0	0	-
Total				1	2	13	4	320

6. Secondary Drain

Sector	Nos. of Canal	Total Length (km)	Discharge (m3/sec)	Longitudinal Incline	Structures			
					Junction	Drop	Culvert	Aqueduct
Upper Koba Sector	14	14.0	0.02 - 8.13	1/2,000 - 1/300	8	19	28	0
Lower Koba Sector	5	4.8	0.3 - 3.43	1/1,000 - 1/150	3	12	9	0
Upper Baguineda Sector	8	12.2	0.01 - 9.67	1/1,500 - 1/300	4	18	35	1
Lower Baguineda Sector	17	34.6	-	1/2,000 - 1/400	8	17	71	0
Tanima Sector	7	5.8	0.11 - 0.60	1/1,500 - 1/150	1	5	11	0
Sienkoro Sector	3	4.2	0.03 - 0.87	1/2,000 - 1/200	0	5	3	2
Total	54	75.6			24	76	147	3

Table VII.2-7 PRINCIPAL FEATURE OF MAIN CANAL (1/3)

Name of Canal	Station	Existing Condition: Canal Condition	Existing Condition: Bank	Existing Condition: Longitudinal Gradient	Existing Condition: Leakage Portion	1/1 2/2 3/3	Proposed Condition: Normal Discharge	Proposed Condition: Work Condition	Proposed Condition: Canal Base Width (m)	Proposed Condition: Side Slope	Proposed Condition: Bank	Proposed Condition: Longitudinal Gradient
Sotuba (L = 18,966 m)	-No.1~24	Rock		1/5,000			10.34	Rock	8.0	1:2.0		1/5,000
	No.2											
	No.1+98	Common Soil	A					Common Soil			A	
	No.27		B								C	
	No.40		A								A	
	No.76											
	No.92+90		B				10.29				C	
	No.101											
	No.102						10.20					
	No.107+28						10.15					
	No.111+94		A				10.06					
	No.117+52						9.96				A	
	No.123+42						9.75					
	No.129+72						9.64					
	No.135+89						9.34					
	No.141+35						9.27					
	No.147+30			1/5,750	(from No.147+30)		9.12	D		1:1.5		1/5,750
	No.150+65						9.08					
	No.157+90		B				9.03				C	
	No.164+34						8.79					
	No.170+46		A			Rehabilitation (No.147+30 – No.189+96)	8.71				A	1/5,000
	No.172		B								C	
	No.175											
	No.176+8						8.57					
	No.181+50		A				8.54				A	
	No.182										C	
	No.187+6	D	B		(to No.187+6)							
	No.188											
	No.189+25		A				8.53					
	No.189+96											

Table VII.2-7 PRINCIPAL FEATURE OF MAIN CANAL (2/3)

Name of Canal	Station	Existing Condition: Canal Condition	Existing Condition: Bank	Existing Condition: Longitudinal Gradient	Existing Condition: Leakage Portion	1/1 2/2 3/3	Proposed Condition: Normal Discharge	Proposed Condition: Work Condition	Proposed Condition: Canal Base Width (m)	Proposed Condition: Side Slope	Proposed Condition: Bank	Proposed Condition: Longitudinal Gradient
Baguineda (L = 17,866 m)	No.0	D	A	1/6,400			8.53	D	6.0	1:1.5	A	1/7,500
	No.5+42	Common Soil										
	No.5+60		B	1/27,300			8.52				C	1/11,230
	No.12											
	No.13+15						8.47					
	No.22+55						8.19					
	No.29+81						7.94					
	No.36						7.69					
	No.43+45						7.40					
	No.51+45						7.20					
	No.59+72						6.85	Common Soil	8.0	1:2.0		
	No.70+4						6.67					
	No.73+45					Rehabili-tation	6.37					
	No.78+90		A				6.06				A	
	No.83+18						5.62		6.0			
	No.93+80						5.22					
	No.102+90						4.55					
	No.111+85						4.23		4.0			
	No.123+53						3.99					
	No.130+64						3.76					
	No.134+55						3.53		3.0			
	No.138+90						3.14					
	No.146+60						2.09		2.0			
	No.156+95						1.75					
	No.163+25						1.24					
	No.169+30						1.05					
	No.175+45						0.85					
	No.178+66											

Table VII.2-7 PRINCIPAL FEATURE OF MAIN CANAL (3/3)

Name of Canal	Station	Existing Condition: Canal Condition	Existing Condition: Bank	Existing Condition: Longitudinal Gradient	Existing Condition: Leakage Portion	1/1 2/2 3/3	Proposed Condition: Normal Discharge	Proposed Condition: Work Condition	Proposed Condition: Canal Base Width (m)	Proposed Condition: Side Slope	Proposed Condition: Bank	Proposed Condition: Longitudinal Gradient
Tanima (L = 4,380 m)	No.0					↑	0.87	Common Soil	2.0	1:20	↑ A	1/11,230
	No.6+80						↓				↓	
	No.7+75						0.61					↓
	No.11											1/720 ↓
	No.18						↓					1/1,230
	No.20						0.47 ↓				C	
	No.28+50						0.33 ↓				(Both Bank)	
	No.31+70						0.16					↓
	No.34											1/726
End Point of Tanima Main Canal	No.43+80					↓	↓	↓	↓	↓	↓	↓

Remarks:
- /1: New Construction
- /2: To be used as it is
- /3: To be rehabilitated
- A: Both Bank are existing
- B: Right Bank is not existing
- C: Bank Embankment
- D: Concrete lining

Table VII.2-8 PRINCIPAL FEATURES OF MAIN CANAL FACILITY (1/5)

Sector	Station	*	Existing Facility	1/2	2/3	*	Proposed Facility	Remarks
Sotuba	(No.-1 - 24)		Beginning point of Sotuba headrace *channel*	(o)			Beginning point of Sotuba headrace channel	
	No.0		Sotuba intake gate	o			Sotuba intake gate	
	No.1+98		Sotuba bridge		o		Sotuba bridge	
	No.6+21		S_1		o		S_1	
	No.14+90		S_2		o		S_2	
	No.25+88		S_3		o		S_3	
	No.28						Sabalibougou No.1 bridge	
	No.29+51 - No.30+39		Spillway A		o		Spillway A with culvert No.1	
	No.35+54 - No.36+76		Spillway B		o		Spillway B with culvert No.2	
	No.41+38		S_4		o		S_4	
	No.43+40						Sabalibougou No.2 bridge	
	No.58+20		S_5		o		S_5	
	No.66+10						Sabalibougou No.3 bridge	
	No.67+88		S_6		o		S_6	
	No.75+48		S_7		o		S_7	
	No.85+81		Spillway No.1		o		Spillway No.1 with culvert No.3	
	No.92+90						CSK-1	
	No.97+42		Spillway No.2		o		Spillway No.2 with culvert No.4	
	No.102						CSK-2	
	No.107+28		K1		o		CSK-3	
	No.107+78						Washing step No.1	
	No.108+92		Dougourakoro bridge		o		Dougourakoro bridge	
	No.111+94		K2		o		CSK-4	
	No.116+15		S_8		o		S_8	
	No.117+52		K3				CSK-5	
	No.123+42		K4		o		CSK-6	
	No.126+77		S_9		o		S_9	
	No.129+72		K5		o		CSK-7	
	No.133+20						Washing step No.2	
	No.133+50		Konini bridge		o		Konini bridge	

Table VII.2-8 PRINCIPAL FEATURES OF MAIN CANAL FACILITY (2/5)

Sector	Station	*	Existing Facility	1/1	2/2	3/3	*	Proposed Facility	Remarks
Sotuba	No.135+89	●	K6			o	○	CSK-8	
	No.139+15		K6BIS	o					
	No.142+33		S_{10}			o		S_{10}	
	No.142+60						○	CSK-9	
	No.144+29	●	K7	o					
	No.147+30	●	K7BIS			o	○	CSK-10	
	No.147+89 - No.148+40		Koba spillway No.1			o		Koba spillway No.1 with culvert No.5	
	No.150+65						○	CSK-11	
	No.150+80						⋈	Check gate No.1	
	No.153+67							Koba siphon with culvert No.6	
	No.157+90						○	CSK-12	
	No.161+41 - No.161+92		Koba spillway No.2			o		Koba spillway No.2 with culvert No.7	
	No.163+80							Washing step No.3	
	No.164+27		Kobala bridge			o		Kobala bridge	
	No.164+34	●	K8			o	○	CSK-13	
	No.168+26		S_{11}			o		S_{11}	
	No.170+46	●	K9			o	○	CSK-15	
	No.176+8	●	K10			o	○	CSK-16	
	No.178+24		S_{12}			o		S_{12}	
	No.181+50						○	CSK-17	
	No.181+70						⋈	Check gate No.2	
	No.184+11							S_{12}-1	
	No.188+23 - No.188+63		Spillway No.3		o			Spillway No.3	
	No.189+25						○	CSB-1	
	No.189+96	⋈	Baguineda check gate		o		⋈	Baguineda check gate	

Table VII.2-8 PRINCIPAL FEATURES OF MAIN CANAL FACILITY (3/5)

Sector	Station	*	Existing Facility	1/	2/	3/	*	Proposed Facility	Remarks
Baguineda	No.0	⋈	Baguineda check gate		o		⋈	Baguineda Check gate	Sotuba Main Canal (No.189+96)
	No.5+60						○	CSB-2	
	No.11						D	Washing step No.4	
	No.12+52	)(	Baguineda bridge			o	)(	Baguineda bridge	
	No.13+15						○	CSB-3	
	No.16+14	●	B1	o					
	No.17+44	}◀	S13			o	}◀	S13	
	No.22+55						○	CSB-4	
	No.24+61	●	B2	o					
	No.25+91	)(	Baguineda camp bridge		o		)(	Baguineda camp bridge	
	No.29+81	●	B2BIS			o	○	CSB-5	
	No.34+81	)(	Kogneba bridge			o	)(	Kogneba bridge	
	No.35+30						D	Washing step No.5	
	No.36						○	CSB-6	
	No.36+20						⋈	Check gate No.3	
	No.40+75	●	B3	o					
	No.43+45						○	CSB-7	
	No.48+48	}◀	S14			o	}◀	S14	
	No.51+45	●	B4			o	○	CSB-8	
	No.53+46	}◀	S15			o	}◀	S15	
	No.59+72	●	B5			o	○	CSB-9	
	No.59+77						D	Washing step No.6	
	No.60+61	)(	Soundougouba bridge			o	)(	Soundougouba bridge	
	No.63+70						○	CSB-10	
	No.67+4	▭▶	Fara spillway		o		▭▶	Fara spillway	
	No.68+73	}◀	Fara cross drain (S16)			o	}◀	Fara cross drain (S16)	
	No.69+50						D	Washing step No.7	
	No.69+95	)(	Gnognan bridge		o		)(	Gnognan bridge	
	No.70+4	●	B6			o	○	CSB-11	

Table VII.2-8 PRINCIPAL FEATURES OF MAIN CANAL FACILITY (4/5)

Sector	Station	*	Existing Facility	1/1	2/2	3/3	*	Proposed Facility	Remarks
Baguineda	No.73+45						○	CSB-12	
	No.75+27	)(	Ouriguila bridge			○	)(	Ouriguila bridge	
	No.75+44	}▶	S17			○	}▶	S17	
	No.78+90						○	CSB-13	
	No.83+18	●	B7			○	○	CSB-14	
	No.83+38						⋈	Check gate No.4	
	No.89+75	)(	Sebela bridge			○	)(	Sebela bridge	
	No.89+84	}▶	S18			○	}▶	S18	
	No.93+80						○	CSB-15	
	No.97+93	●	B8	○					
	No.102+90						○	CSB-16	
	No.107+46	)(	Masakoni bridge			○	)(	Masakoni bridge	
	No.107+65	}▶	S19			○	}▶	S19	
	No.111+85						○	CSB-17	
	No.116+77	●	B9	○					
	No.123+53	⋈ ⌐	Farakan check gate with drop	○			○	CSB-18	
	No.123+70						⋈	Check gate No.5	
	No.130+64						○	CSB-19	
	No.132+14	●	B10	○					
	No.134+55	)(			○		)(○	Farakan bridge and CSB-20	
	No.135						D	Washing step No.8	
	No.135+80	}▶	S20			○	}▶	S20	
	No.138+90						○	CSB-21	
	No.143+34	●	B11	○					
	No.146+60						○	CSB-22, CSB-22BIS, Sienkoro canal	
	No.156+95						○	CSB-23	
	No.157+10						⋈	Check gate No.6	
	No.158						D	Washing step No.9	
	No.158+26	)(	Mofa bridge			○	)(	Mofa bridge	
	No.163+25	●	B12				○	CSB-24	

Table VII.2-8 PRINCIPAL FEATURES OF MAIN CANAL FACILITY (5/5)

Sector	Station	*	Existing Facility	/1	/2	/3	*	Proposed Facility	Remarks
Baguineda	No.169+30						○	CSB-25	
	No.175+45						○	CST-1	
	No.175+50						⋈	Check gate No.7	
Tanima/4	No.7+75						⊙ ⊣⊢▶	CST-2 and culvert No.8	
	No.8+50						D	Washing step No.10	
	No.20						⊙	CST-3	
	No.28+50						⊙	CST-4	
	No.31+70						⊙	CST-5	
	No.43+80						⊙	CST-6	

Remarks: /1: *To be abandoned.*

/2: To be used as it is.

/3: To be rehabilitated or replaced.

/4: Existing Tanima main canal is abandoned and new Tanima main canal is constructed.

Legend :

- ● : *Rehabilitation of turnout*
- ○ : New construction of turnout
- }{▶ : Cross drain
- ⊣⊢▶ : Culvert
- □▶ : Spillway
- ⋈ : Check gate
- }{ : Bridge
- D : Washing step
- ⊣▶ : Flood spillway
- ⌐ : Drop

Table VII.3 PRINCIPAL FEATURE OF SECONDARY CANAL (1/3)

Sector	Old Name	1/1	2/2	3/3	New Name	Turnout Station	Length (km)	Principal Features: Longi-tudinal Gradient	Principal Features: Command-ing Area (ha)	Principal Features: Diverting Discharge (lit./sec)	Number of Structure (nos.): Turn-out	Number of Structure (nos.): Check	Number of Structure (nos.): Terminal Structure	Number of Structure (nos.): Drop	Number of Structure (nos.): Culvert	Remarks
Upper Koba					CSK-1	No.90+90	0	-	14.4	40	2	2	0	0	0	
					CSK-2	No.102	0.47	1/750	27.4	76	4	3	1	0	0	
	K-1			o	CSK-3	No.28	0.59	1/500	16.0	44	3	2	1	1	1	
	K-2			o	CSK-4	No.111+94	0.42	1/750	28.8	80	5	4	1	2	1	
	K-3			o	CSK-5	No.117+52	0.72	1/500	32.1	89	5	4	1	2	2	
	K-4			o	CSK-6	No.123+42	2.22	1/750	65.1	180	10	9	1	1	4	
	K-5			o	CSK-7	No.129+72	0.54	1/500	34.2	95	5	4	1	2	3	
	K-6			o	CSK-8	No.135+98	1.41	1/750	92.6	256	13	12	1	1	4	
					CSK-9	No.141+35	0.28	1/750	22.7	63	3	2	1	1	1	
	K-7	o														(No.144+29)
	K-7-BIS			o	CSK-10	No.147+30	2.25	1/1,500	45.6	126	7	6	1	1	6	
Sub-total							8.9		378.9		57	48	9	11	22	
Lower Koba					CSK-11	No.150+65	0	-	12.9	36	1	1	0	0	0	
					CSK-12	No.157+90	0	-	15.4	43	2	9	0	0	0	
	K-8			o	CSK-13	No.164+34	2.10	1/500	63.5	176	10	9	1	0	0	
	K-9			o	CSK-15	No.170+46	0.38	1/500	25.9	73	4	3	1	3	2	
	K-10			o	CSK-16	No.176+8	0.85	1/500	42.0	116	8	7	1	3	2	
					CSK-17	No.181+50	0	-	8.4	25	2	2	0	-	0	
Sub-total							3.3		178.2		27	24	3	6	4	
Upper Baguineda					CSB-1	No.189+25	0	-	2.5	10	1	1	0	1	0	
					CSB-2	No.5+60	0.30	1/300	3.7	10	2	1	1	1	0	
					CSB-3	No.13+15	0.64	1/300	17.4	43	4	3	1	5	1	
	B-1	o														(No.16+14)
					CSB-4	No.22+55	2.50	1/750	93.2	241	17	16	1	2	5	
	B-2	o														(No.24+61
	B-2-BIS			o	CSB-5	No.29+81	1.45	1/500	85.9	211	10	9	1	2	3	
					CSB-6	No.36	1.75	1/400	75.7	210	12	11	1	3	4	
	B-3	o														(No.40+75)
					CSB-7	No.43+45	1.67	1/300	87.8	243	11	10	1	0	4	
	B-4			o	CSB-8	No.51+45	1.25	1/300	68.8	169	8	7	1	0	2	
	B-5			o	CSB-9	No.59+72	2.32	1/1,000	113.6	295	16	15	1	0	5	
					CSB-10	No.63+70	0	-	6.4	13	2	2	0	0	0	
Sub-total							11.9		555.0		83	75	8	13	24	

Table VII.3 PRINCIPAL FEATURE OF SECONDARY CANAL (2/3)

Sector	Old Name	1/1	2/2	3/3	New Name	Turnout Station	Length (km)	Principal Features: Longitudinal Grarient	Principal Features: Commanding Area (ha)	Principal Features: Diverting Discharge (lit./sec)	Number of Structure (nos.): Turnout	Number of Structure (nos.): Check	Number of Structure (nos.): Terminal Structure	Number of Structure (nos.): Drop	Number of Structure (nos.): Culvert	Remarks
Lower Baguineda	B-6			o	CSB-11	No.70+4	1.90	1/500	56.6	139	13	12	0	0	4	
					CSB-12	No.73+45	1.60	1/400	93.3	230	10	9	1	1	3	
					CSB-13	No.78+90	1.30	1/600	85.4	237	9	8	1	1	3	
	B-7			o	CSB-14	No.83+18	2.90	1/1,500	121.3	336	19	18	1	0	6	
					CSB-15	No.93+80	2.05	1/1,500	111.0	308	14	13	1	0	4	
	B-8		o													DSB-13 (No.97+93)
					CSB-16	No.102+90	2.54	1/750	186.0	515	17	16	1	0	5	
					CSB-17	No.111+85	1.65	1/750	90.3	250	11	10	1	0	4	
	B-9		o													DSB-15 (No.116+77)
					CSB-18	No.123+53	0.72	1/500	66.3	184	4	3	1	1	1	
					CSB-19	No.130+64	1.46	1/500	64.2	178	10	9	1	2	3	
	B-10	o														(No.132+14)
	B-10-BIS	o														
					CSB-20	No.134+55	1.79	1/500	58.9	163	12	11	1	1	4	
					CSB-21	No.138+90	1.63	1/500	107.3	297	11	10	1	3	2	
	B-11		o													DSB-19 (No.143+34)
					CSB-22	No.146+60	1.54	1/500	44.3	123	10	9	1	2	3	
					CSB-22-BIS	No.146+60	1.53	1/500	48.7	135	10	9	1	1	3	
					CSB-23	No.156+95	1.46	1/500	95.2	264	10	9	1	1	3	
	B-12			o	CSB-24	No.163+25	2.21	1/500	141.2	391	15	14	1	3	4	
					CSB-25	No.169+30	1.03	1/400	54.3	150	7	6	1	1	2	
	T-1	o														
Sub-total							27.3		1,424.0		182	166	16	18	55	
Tanima					CST-1		1.72	1/500	56.4	156	11	10	1	2	3	
	T-2			o	CST-2	No.7+75	1.36	1/500	74.5	206	9	8	1	1	3	
					CST-3	No.20	0.85	1/300	38.9	108	6	5	1	11	2	
					CST-4	No.28+50	0.68	1/300	31.7	88	4	3	1	2	1	
	T-3			o	CST-5	No.31+70	1.17	1/600	62.1	172	8	7	1	4	2	
					CST-5-1	-	0.82	1/1,000		86	5	4	1	0	2	
					CST-6	No.43+80	0.53	1/1,500	40.4	112	4	3	1	0	1	
Sub-total							7.1		304.0		47	40	7	20	14	

Table VII.3 PRINCIPAL FEATURE OF SECONDARY CANAL (3/3)

Sector	Old Name	1/1	2/2	3/3	New Name	Turnout Station	Length (km)	Principal Features: Longi-tudinal Gradient	Principal Features: Command-ing Area (ha)	Principal Features: Diverting Discharge (lit./sec)	Number of Structure (nos.): Turn-out	Number of Structure (nos.): Check	Number of Structure (nos.): Terminal Structure	Number of Structure (nos.): Drop	Number of Structure (nos.): Culvert	Remarks
Sienkoro						No.146+60	3.64	1/2,000 - 1/500	159.6	553	3	3	0	1	3	Aqueduct: 1
					CSS-1	No.23+50	0.58	1/1,500	23.4	65	4	3	1	0	1	
					CSS-2	No.30+80	0.70	1/1,000	35.3	98	5	4	1	0	1	
					CSS-3	No.36+50	0.84	1/400	36.6	101	5	4	1	5	2	
					CSS-4	No.36+50	1.52	1/400	36.9	102	10	9	1	4	3	
					CSS-4-1	-	0.43	1/600	27.4	76	3	2	1	3	1	
Sub-total							7.7		159.6		30	25	5	13	11	
Total							66.2		3,000.0		423	378	48	80	126	Aqueduct: 1

Remarks: /1: This canal is to be abandon.

/2: This canal is to let us ever and to have to be used as it is.

/3: This canal is used after rehabilitation.

Table VII.4-1 PRINCIPAL FEATURE OF MAIN DRAIN FACILITY

Sector	Station		Proposed Facility	Remarks
Tanima	No. 0		Flow in point to Niger river	
	No. 5 + 60		Junction No.1 (DST-4)	
	No. 10 + 21		Junction No.2 (DST-3)	
	No. 14 + 40		Junction No.3 (DSS-2)	
	No. 17 + 60		Junction No.4 (DST-2)	
	No. 23 + 25		Junction No.5 (DST-1)	
	No. 23 + 75		Drop No.1 (1.5 m)	
	No. 26 + 25		Junction No.6 (DSS-1)	
			Junction No.7 (DSB-23)	
	No. 39 + 36		Junction No.8 (DSB-20)	
	No. 44 + 8		Drop No.2 (0.5 m)	
	No. 44 + 75		Junction No.9 (DSB-19)	
	No. 49 + 96		Junction No.10 (DSB-18)	
			Drop No.3 (1.0 m)	
	No. 54 + 85		Junction No.11 (DSB-14)	
	No. 65 + 35		Junction No.12 (DSB-13)	
			Drop No.4 (0.5 m)	
	No. 71 + 85		Junction No.13 (DSB-12)	
			End point of Tanima Main Drain	

Remarks: Existing Tanima main canal is abondoned.

Legend: : Junction
: Drop

Table VII.4-2 PRINCIPAL FEATURE OF SECONDARY DRAIN (1/3)

Sector	Old Name	1/1	2/2	3/3	New Name	Length (km)	Principal Features: Longi-tudinal Gradient	Principal Features: Command-ing Area (ha)	Discharge (m^3/sec)	Number of Structure (nos.): Drainage Junction	Number of Structure (nos.): Drainage Culvert	Number of Structure (nos.): Drainage Drop	Remarks
Upper Koba					DSK-1	0.43	1/2,000	8.3	0.04	0	1	0	
					DSK-2	0.70	1/500	138.2	0.88	0	1	4	
	DK-1		o		DSK-3	1.13	1/500 - 1/750	184.5	1.13	2	2	3	
					DSK-3-1	0.63	1/2,000	3.5	0.02	0	1	0	
	DK-2				DSK-4	1.02	1/500	26.3	0.13	0	2	2	
					DSK-4-1	0.75	1/500	17.2	0.11	0	2	1	
	DK-3			o	DSK-5	1.36	1/1,500	1,452.3	8.30	2	3	5	
	DK-4		o		DSK-6	1.21	1/400	44.0	0.22	0	2	1	
	DK-5				DSK-7	1.63	1/500 - 1/1,000	287.0	1.67	3	3	1	
					DSK-7-1	0.39	1/500	5.9	0.03	0	1	0	
					DSK-7-2	0.59	1/1,000	27.1	0.16	0	1	0	
	DK-6		o		DSK-8	1.06	1/300	56.7	0.28	0	2	0	
	DK-7			o	DSK-9	0.71	1/500	158.3	0.95	0	2	0	
	DK-8		o		DSK-10	2.35	1/200 - 1/750	258.4	1.45	1	5	1	
Sub-total						14.0				8	28	19	
Lower Koba	DK-9			o	DSK-11	2.06	1/750 - 1/1,000	595.0	3.43	2	4	2	
					DSK-11-1	0.63	1/750	477.5	2.84	0	1	0	
	DK-10		o		DSK-12	0.90	1/250	41.8	0.21	0	2	0	
	DK-11			o	DSK-13	1.09	1/750	492.0	2.91	1	2	10	
					DSK-13-1	0.23	1/150	46.0	0.30	0	9	12	
Sub-total						4.8				3	9	12	

Table VII.4-2 PRINCIPAL FEATURE OF SECONDARY DRAIN (2/3)

Sector	Old Name	1/1	2/2	3/3	New Name	Length (km)	Principal Features: Longi-tudinal Gradient	Principal Features: Command-ing Area (ha)	Discharge (m^3/sec)	Number of Structure (nos.): Drainage Junction	Number of Structure (nos.): Drainage Culvert	Number of Structure (nos.): Drainage Drop	Remarks
Upper Baguineda					DSB-1	0.28	1/300	7.1	0.04	0	0	1	
	DB-1		o		DSB-2	0.59	1/300	2.8	0.01	0	1	0	
	DB-2			o	DSB-3	0.73	1/1,500	1,009.4	6.04	0	1	4	
					DSB-4	1.92	1/400	79.7	0.47	0	4	0	
	DB-3		o		DSB-5	2.20	1/500	292.5	1.60	2	4	1	
					DSB-6	1.80	1/300	66.2	0.33	0	4	0	
	DB-4			o	DSB-7	2.90	1/600	1,245.9	7.41	2	6	9	
	DB-5			o	DSB-8	1.75	1/600	419.0	2.89	0	5	3	
Sub-total						12.2				4	25	18	
Lower Baguineda	DT-1		o		DSB-9	2.60	1/600	147.3	0.97	0	5	0	
				o	DSB-10	2.80	1/700	623.4	3.77	2	6	8	
					DSB-10-1	0.70	1/600	31.1	0.20	0	1	1	
					DSB-11	1.90	1/1,000	65.4	0.33	0	4	0	
					DSB-11-1	2.41	1/2,000	49.1	0.32	1	5	0	
	DT-2		o		DSB-12	2.25	1/2,000	668.2	3.85	0	4	0	
	DT-2'	o											
					DSB-13	2.26	1/750	134.2	0.67	0	5	0	
	DT-3		o		DSB-14	2.83	1/1,500	411.4	10.09	2	6	3	
					DSB-15	1.53	1/600	82.5	0.41	0	3	0	
	DT-4		o		DSB-16	1.72	1/600	166.3	0.83	1	4	0	
					DSB-17	1.74	1/600	70.8	0.35	0	4	1	
	DT-5			o	DSB-18	2.35	1/1,500	1,775.4	9.90	0	5	3	
					DSB-19	1.89	1/400	77.4	0.39	0	4	0	
	DT-6 & DT-6'		o		DSB-20	2.23	1/400	273.0	1.37	1	4	0	
					DSB-21	1.85	1/500	67.5	0.34	0	4	0	
					DSB-22	1.57	1/900	58.3	0.29	0	3	0	
	DT-7 & DT-7'		o		DSB-23	2.00	1/400	149.7	0.75	1	4	1	
Sub-total						34.6				8	71	17	

Table VII.4-2 PRINCIPAL FEATURE OF SECONDARY DRAIN (3/3)

Sector	Old Name	1 /1	2 /2	3 /3	New Name	Length (km)	Principal Features: Longi-tudinal Gradient	Principal Features: Command-ing Area (ha)	Discharge (m^3/sec)	Number of Structure (nos.): Drainage Junction	Number of Structure (nos.): Drainage Culvert	Number of Structure (nos.): Drainage Drop	Remarks
Tanima					DST-1	1.58	1/300	122.5	0.61	0	3	0	
					DST-2	0.85	1/300	95.2	0.55	0	2	1	
	DT-8	o											
					DST-3	0.68	1/200	76.4	0.42	0	2	0	
					DST-4	1.00	1/400	26.6	0.15	0	2	4	
					DST-5	0.37	1/500	25.5	0.13	0	0	0	
	DT-12			o	DST-6	0.97	1/1,500	64.5	0.36	1	2	0	
	DT-11			o	DST-6-1	0.31	1/150	22.3	0.11	0	0	0	
Sub-total						5.8				1	11	5	
Sienkoro						2.40	1/2,000	132.9	0.87	0	0	0	
	DT-10			o	DSS-1	0.72	1/1,500	6.0	0.03	0	1	0	
					DSS-2	1.04	1/200	42.0	0.31	0	2	5	
Sub-total						4.2				0	3	5	
Total						75.6				24	147	76	

Remarks: /1: This canal is to be abandon.

/2: This canal is to let us ever and to have to be used as it is.

/3: This canal is used after rehabilitation.

FIGURE VII - 1 TYPICAL CANAL SECTIONS

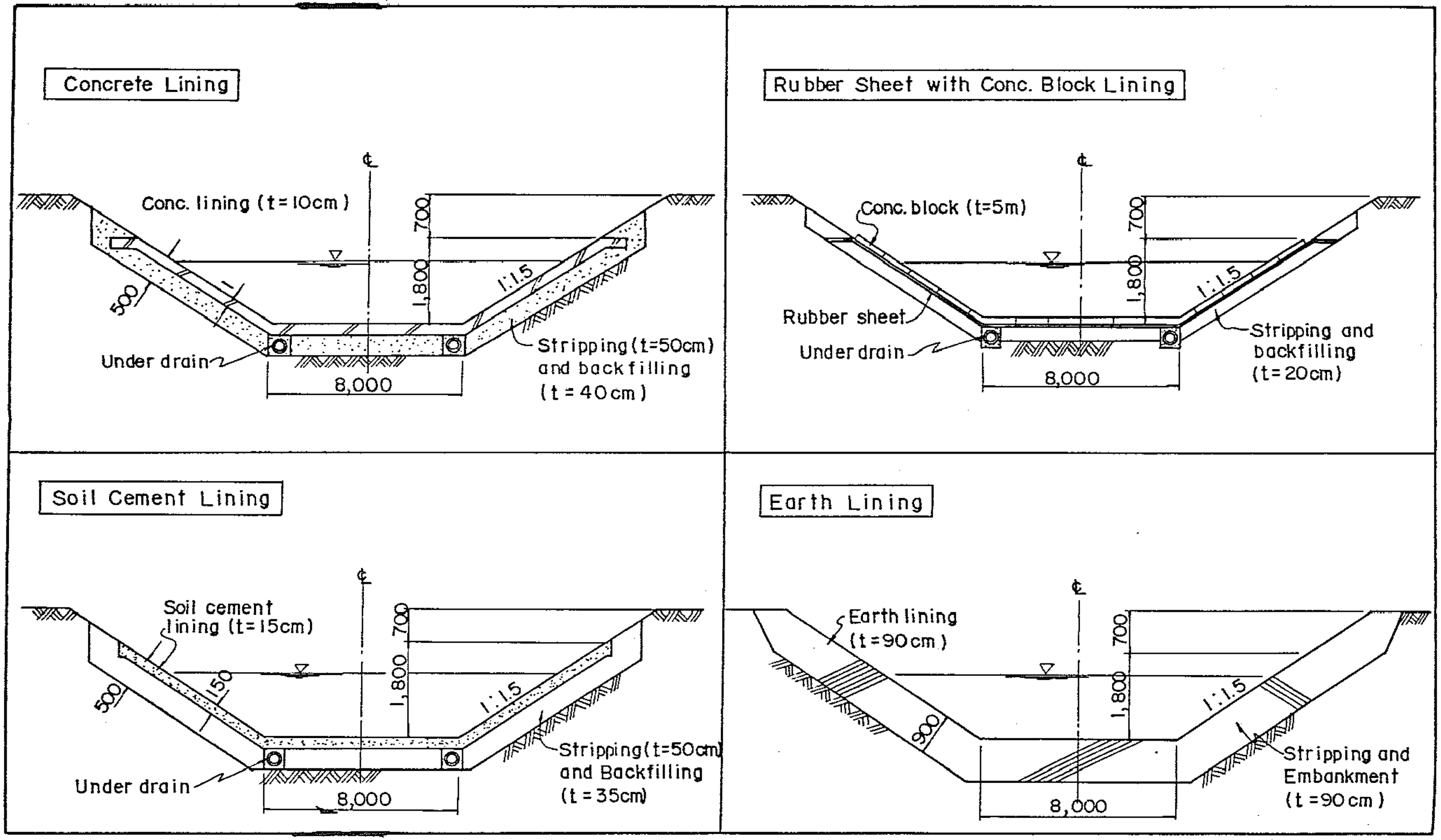
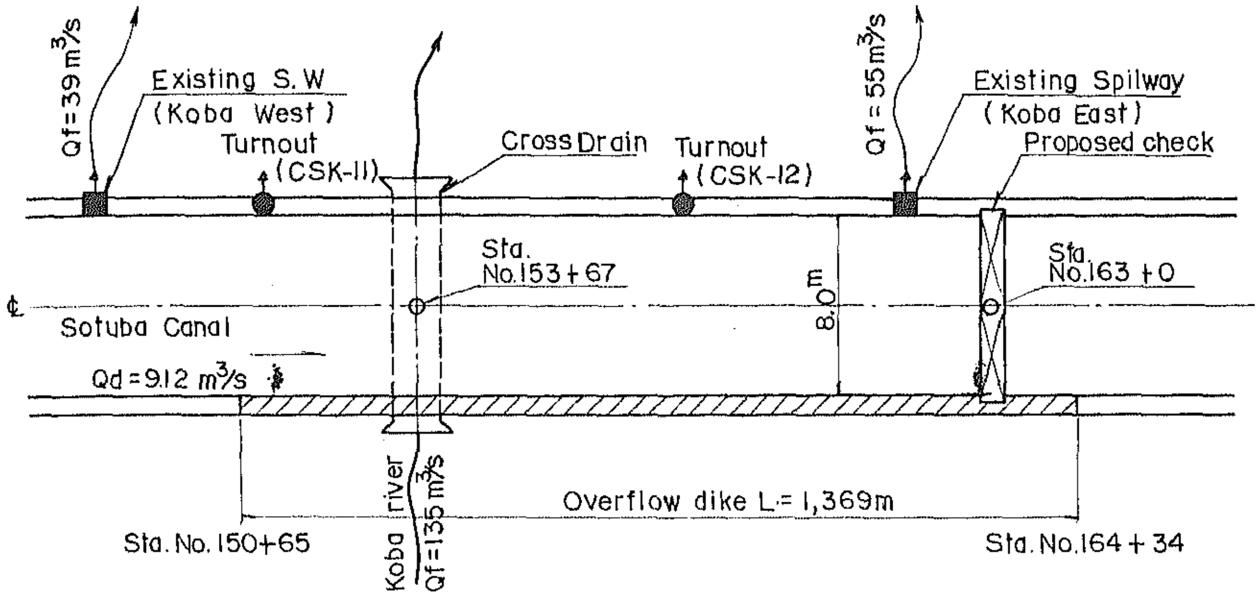
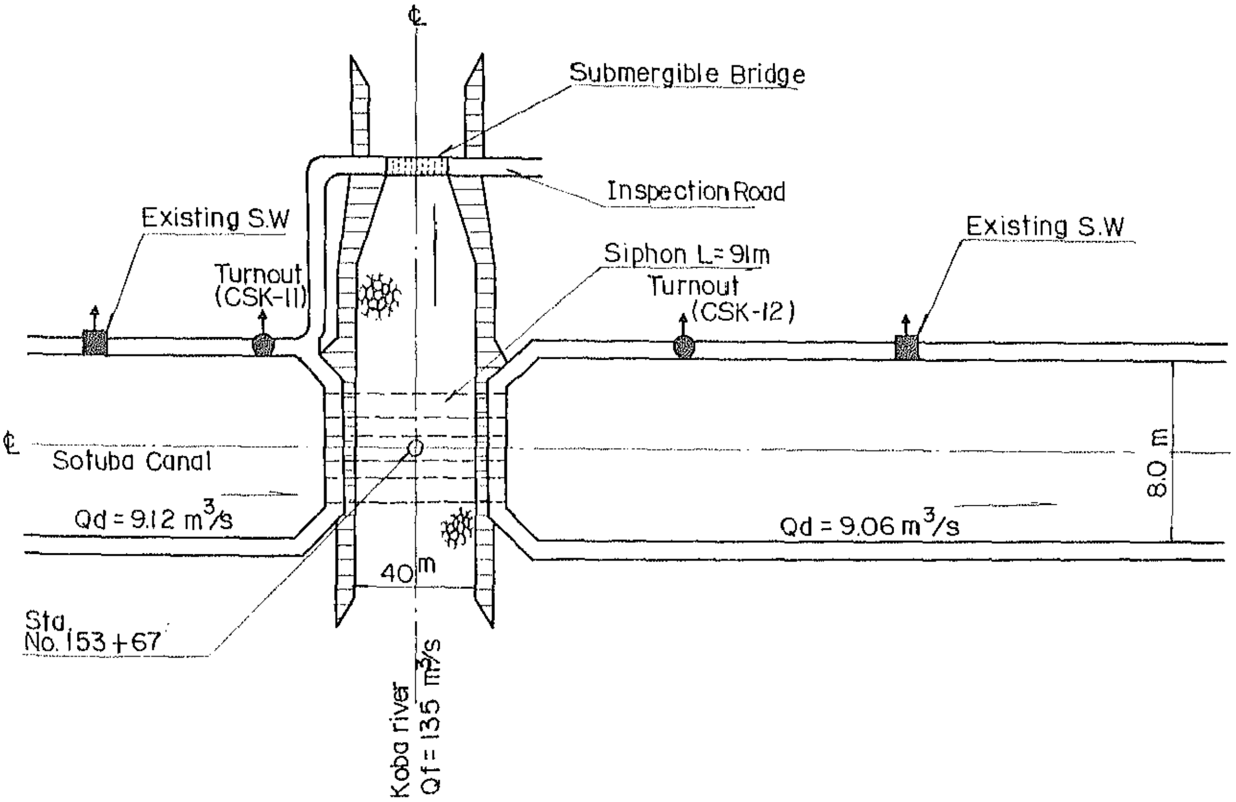


FIGURE VII - 2 CROSSING METHODS OVER THE KOBA RIVER



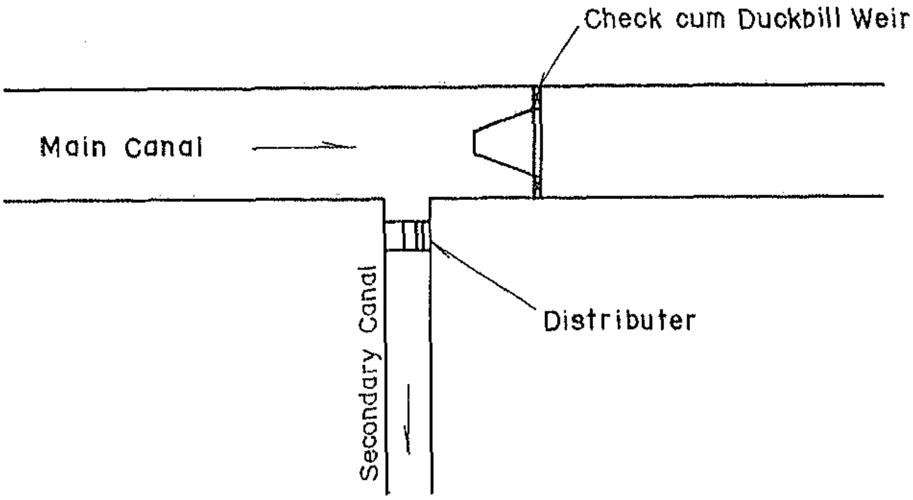
OVERFLOW DIKE METHOD



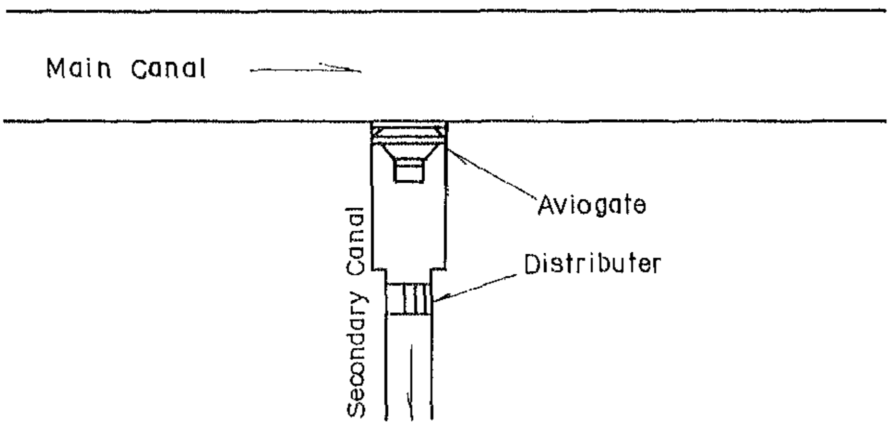
SIPHON METHOD

FIGURE VII-3 COMPARATIVE STUDY OF TURNOUT

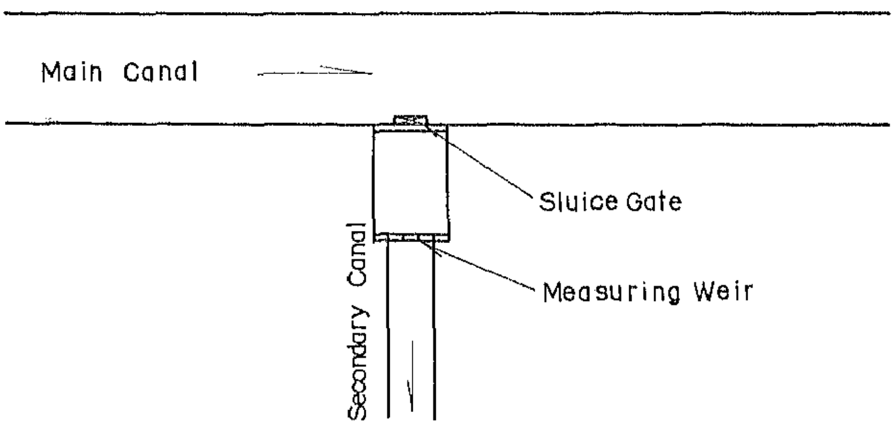
TYPE-A : Check cum Duckbill Weir + Distributer



TYPE-B : Aviogate + Distributer



TYPE-C : Sluice Gate + Measuring Weir



ANNEX VIII

ORGANIZATION AND MANAGEMENT

ANNEX VIII

ORGANIZATION AND MANAGEMENT

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ANNEX VIII

LIST OF FIGURES

ANNEX VIII

ORGANIZATION AND MANAGEMENT

VIII.1 Organization of the Project Construction Stage

As the Baguineda Operation will be responsible for the project implementation and management under control of Ministry of Agriculture, it would be necessary to expand and reinforce the present organizational structure of the Operation. Such a structure shall enable the Operation to effectively control the work execution during the construction stage and to undertake the operation and management of the project upon its completion.

At the project implementation stage, the main duty of the organization would be to control the execution of the construction works. The organization chart is presented in Fig. VIII.1. In view of its present activities in the project area and its future functions during the project execution, the Baguineda Operation should need administrative cooperation from Directorate of Rural Engineering, Directorate of Agriculture and Rural Economy Institute. It is proposed to create a Project Coordination Committee consisting of experts from these directorates and institute.

The actual project construction works would be controlled by the construction and Inspection Division which would be established by extending the existing Rural Engineering Division of the Baguineda Operation. For smooth carrying out the farmers resettlement plan, it would be necessary to add Resettlement Section in the Administration Division. In view of the importance of accounting operations during the construction stage, the present Accounting Section in the Administration and Finance Division would be transformed into Finance Division. Other existing Divisions of the Baguineda Operation would also have to be strengthened progressively to enable to undertake efficiently the future operation of the Project.

VIII.2 Organization after Completion of the Construction Works

Upon completion of the project construction works, the Project Coordination Committee would be dissolved. The project operation and management would then be controlled by Directorate of Agriculture. The organization chart is presented in Fig. VIII.2. The organization of the Baguineda Operation after completion of construction works should be a reinforced organization based on the present structure.

The Construction and Inspection Division would be transformed into Operation and Maintenance Division which will undertake all maintenance and repair works for irrigation system, structures, infrastructure, farm machinery, operational equipment, etc.

For smooth operation and commercialization of milk, Livestock Section under Production Division would be extended to the Division. In addition, the procurement of farm inputs and commercialization of agricultural products would be undertaken by Procurement and Commercialization Division.

The Administration Division and Finance Division would be combined again into one Administration and Finance Division as before. This Division, however, would comprise two Sections, i.e. Resettlement and Cooperative Section and Accounting and Loan Collection Section.

VIII.3 Agricultural Support Institute

VIII.3.1 General

In order to attain the anticipated agricultural production in the project area, it is important to establish a system of technical and financial assistance to farmers. Therefore it would be essential in the initial stage of the Project to use rationally the existing agricultural support institutes, such as extension organizations, agricultural credits, cooperatives, research institutes, etc. In parallel with the increase in service requirements, their respective structures would have to be strengthened.

On the other hand, it would be recommended to establish the farmers' associations in respective areas on their own initiative, so that they will undertake the development of the said areas by themselves under the control of the Baguineda Operation.

VIII.3.2 Extension services

There are the activities of extension services in the project area. The Extension Services Section in the Production Division consists of two sectors which are further divided into four sub-sectors as mentioned in the preceding section III.5. Their function is just to give technical guidance to farmers engaged under contract with the Baguineda Operation.

It is proposed that Baguineda Operation will distribute to each farm household a plot of 1.2 ha out of the total cultivate area of 2,600 ha. The number of households to be resettled in the project area would be 2,170. These households would be divided into eleven (11) development units for training purpose. Twenty (20) representative households would be selectd in each development unit and they would transfer the techniques learned from the extension workers to another 8 or 9 households. For successful introduction of intensive farming practice, one (1) extension worker would be assigned for every 200 households. In total thirteen (13) extension workers would be required. Total personnel required for extension services would amount to 26 persons: 13 chiefs of development units and 13 rural cadres.

In order to realize the main objectives of the project, it would be indispensable to strengthen the Operation and Maintenance Division and the Rural Engineering Division so that these divisions could perform the repairs and maintenance of farm machinery and equipment and phyto-sanitary operations in due time.

As to dairy farming, the ranch with 400 ha of pasture land would be operated under the control of the Livestock Division. Therefore, the present staff of this Division also should be increased (See Tables VIII.1 and VIII.2).

VIII.3.3 Cooperatives and agricultural credits

In Bamako and its surrounding areas within a radius of 30 km, there exists the Cooperative of Market-Gardeners and Planters of Bamako with a membership of about 1,200. However, for lack of organization and operational budget, this Cooperative is not so active.

There is more cooperative among the farmers organized by the Baguineda Operation, because the Operation undertakes itself all activities of a cooperative.

With regard to agricultural credits, BNDA extends financial means for production to farmers against the guarantee by the Baguineda Operation or the Cooperative. With the progressive increase in development requirements, it would be necessary to strengthen the personnel, extend the facilities, etc. not only of BNDA but also of the manufacturers of farm machinery (SMECMA) chemical fertilizers, phyto-sanitary products, etc. The structure of OPAM and FRUITEMA should also be reinforced for meeting the needs of transportation and storage of farm products.

VIII.3.4 Farmers' associations

According to the new strategy of the Government of Mali focusting on the "self-centred" base development the village level, the role of the Baguineda Operation will be lessened in the long run progressively with the realization of such strategy.

In the future, therefore, all transactions between the farmers' associations and the agricultural support institutions such as BNDA, ECIBEV, OPAM, etc. will be effectuated without intermediary of the Baguineda Operation. However, it should be understood that this stage cannot be attained before long. Anyhow, the farmers' associations would be established only when the organization of the Baguineda Operation will have been strengthened.

VIII.3.5 Researches and experimental farm

As mentioned in Section III.5.3, the existing agricultural and geo-technical research institutions are the SRCVO under the Rural Economy Institute of Ministry of Agriculture, the CNRZ and the LCV under the Directorate General of Stock Farming of Ministry of Livestock, Water and Forestry.

The crops proposed to be introduced in the project area are varied. In order to attain their anticipated yields, it would be necessary to conduct as soon as possible researches and trials to select the varieties of crops, methods of plant protection species of milk cows, sanitary measures, etc. the most suitable to the project area.

Before proceeding with the development of the total project area, it would be recommended to start at the first stage with the trial cultivation of the proposed crop varieties in an experimental farm. These experimental cultivations would be mainly aimed at on-farm training and transfer of the following farming techniques to the farmers and rural cadres:

(1) Method of preparation of lands (levelling by man power) extending from tertiary and quaternary canals
(2) Irrigation method
(3) Farming practices
(4) Seed and plant multiplication, etc.

With regard to item (4) above, CEAO has planted to establish a seed multiplication center in the project area. If this plan would be realized, the Baguineda Operation may participate in the seed production program. The location and area of the experimental farm would be defined at the stage of detailed design of the Project.

As to dairy farming, it is proposed to introduce highly productive Jersey breed and to produce milk cows from this species by means artificial insemination. Therefore, researches would have to be conducted on sanitary measures, nursing, growth, etc. of the milk herd, in collaboration with CNRZ and LVC. At the same time, it would be necessary to strengthen the structure of the institutions concerned by increasing their staff and equipment.

FIGURE VIII.1 ORGANIZATION CHART AT THE PROJECT IMPLEMENTATION STAGE

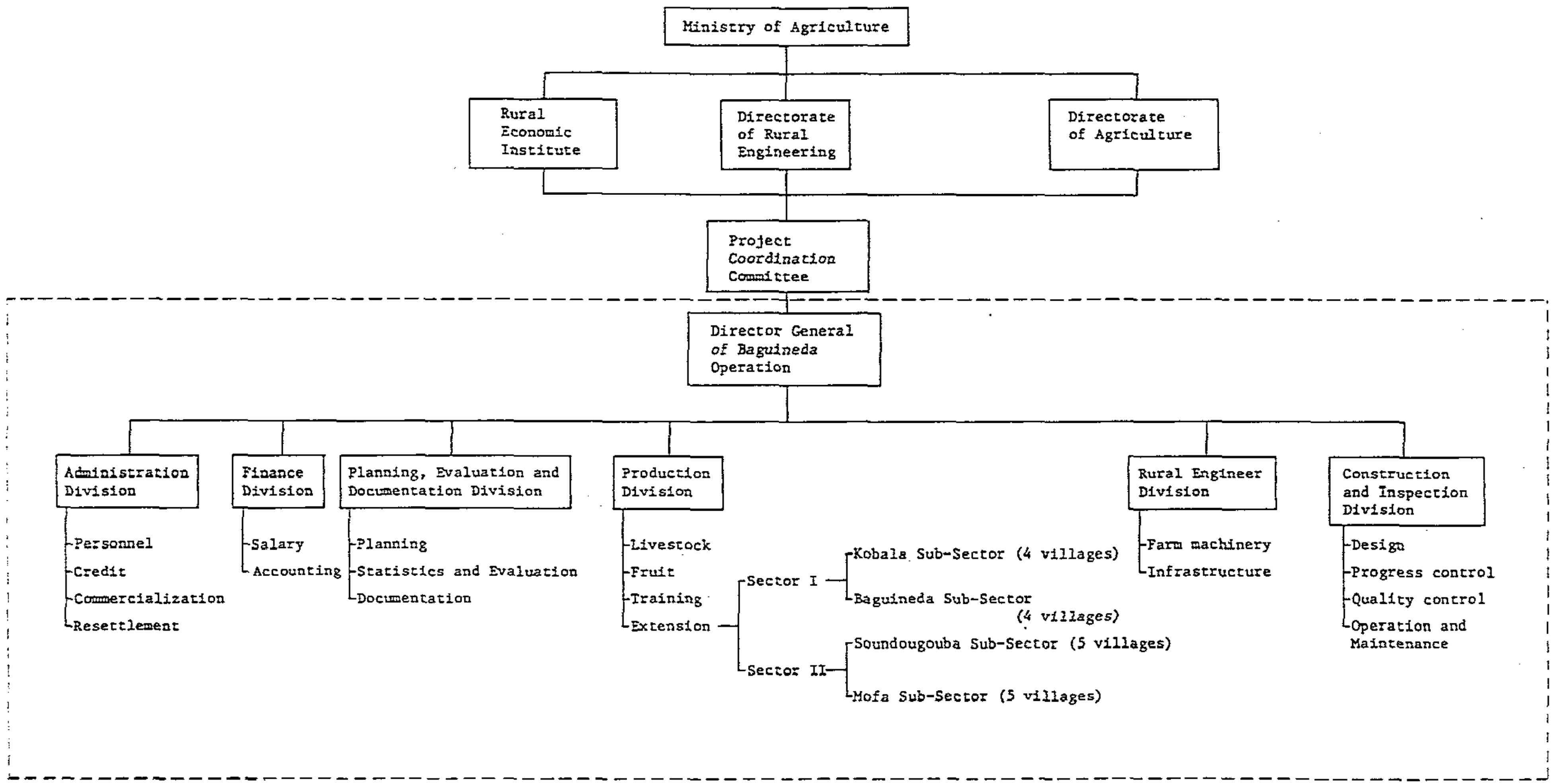
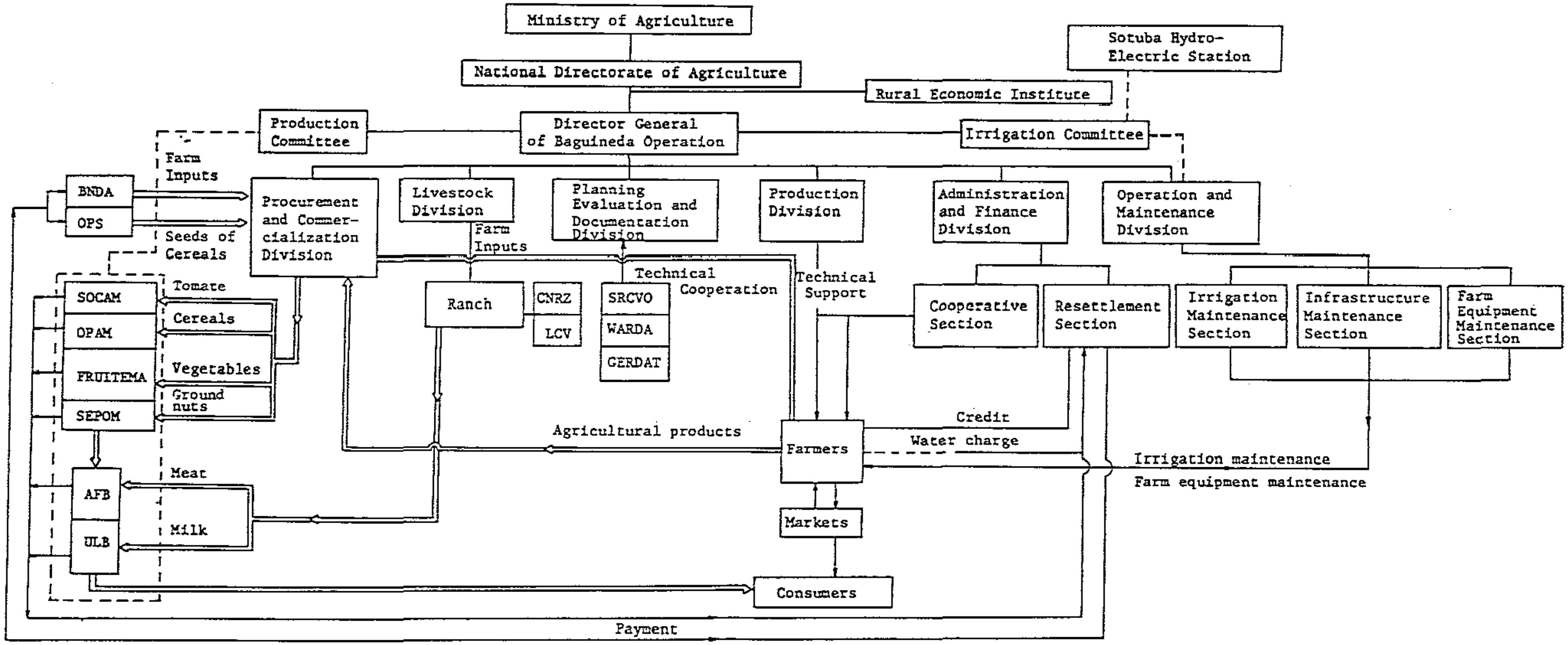


FIGURE VIII.2 ORGANIZATION CHART AFTER COMPLETION OF THE CONSTRUCTION WORKS



ANNEX IX

PROJECT IMPLEMENTATION SCHEDULE

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IX.1 Basic Consideration

The previous feasibility study proposes to implement the whole construction works in three years dividing the works into three stages i.e. the first stage for main canals, the second stage for secondary canals and development of Koba and Upper Baguineda areas of 1,112 ha and the third stage for the same kind of works for Lower Baguineda, Tanima and Sienkoro areas of 1,888 ha. The plan aims at the realization of all the major project works at first and then, proceeding to the minor works from the upstream to the downstream areas. It took a rather orthodox way of approach and assumes that all the fund requirement will be available from one foreign lending agency, supplemented by local finance from the Government, and that all the works are executed in one stroke under one package of contract.

The above-mentioned previous plan is rather difficult to follow at present in view of the current financial situation of the Malian Government and availability of financial assistance sources from abroad. The fund requirement is too big to be appropriated from a sole financial agency and, besides, it is concentrated overwhelmingly in the first stage. The plan needs modification with a view to decrease the fund requirement in the first stage, limiting the initial works to those of utmost importance and of urgent need. In addition, the following basic concepts should be applied:

(1) A top priority should be accorded to rehabilitation of the main irrigation canal especially to prevention works of the severe leakage portion of about 10 km.

(2) Among the five sub-areas i.e. Koba 557 ha, Upper Baguineda 555 ha, Lower Baguineda 1,424 ha, Tanima 304 ha and Sienkoro 160 ha, priority in development should be given at first to Koba and Upper Baguineda of 1,112 ha. Development of other areas are put in second or third priorities because of their locations, less socio-economic and agricultural activities and much higher per ha construction cost. (See Table IX.1)

IX.2 Implementation Schedule

Based on the above consideration, the implementation schedule of the Project is prepared as shown in Fig. IX.1. It aims basically at earliest solution of the most serious problem of the water shortage and proposes to execute the leakage prevention works for main canal in the first stage. The second stage works will involve rehabilitation of the remaining portion of the main canal for Koba and Upper Baguineda, together with development of these areas. The works necessary for Lower Baguineda, Tanima and Sienkoro will be carried over to the final and third stage. Since the leakage in the main canal is a problem of utmost importance and needing urgent treatment, the above development plan is expected to bring about the highest direct return to the project area.

More specifically, each of the stages will comprise the following works, for which it is to be noted that development of a small part of the Upper Baguineda area, CSK-5 of 86 ha located nearest to the Baguineda Camp, is included in the first stage works for the purpose to demonstrate the construction and rehabilitation of secondary and tertiary facilities as well as practices of water management from the main to the terminal facilities.

<u>Stage-I</u>

(i) Construction of a siphon across the Koba river (L = 91 m)

(ii) Canal lining works (L = 7.5 km)

(iii) Right bank embankment at the Koba river crossing portion (L = 1.7 km)

(iv) Consolidation of farmland of 86 ha

(v) Rehabilitation of major structures along the heavy leakate portion and the upstream reach of the Sotuba canal

(vi) Rehabilitation of a connection road from the highway RN-6 to Baguineda Camp (L = 4.3 km)

Stage-II

(i) Rehabilitation of main canal from the head of the Sotuba to the end of the Lower Baguineda, excluding the heavy leakage portion constructed in the first stage (L = 29.3 km)

(ii) Construction and rehabilitation of secondary irrigation canals for Koba and Upper Baguineda (L = 22.7 km)

(iii) Construction and rehabilitation of secondary drainage canals for the above areas (L = 31.9 km)

(iv) On-farm development including tertiary canals for the above areas, excluding the partially developed area in the first stage (1,026 ha)

Stage-III

(i) Construction of the new Tanima main canal (L = 4.4 km)

(ii) Construction and rehabilitation of secondary irrigation canals for Lower Baguineda, Tanima and Sienkoro (L = 42.2 km)

(iii) Construction and rehabilitation of main and catch drains (L = 14 km)

(iv) Construction and rehabilitation of secondary drainage canals for the above areas (L = 44.6 km)

(v) On-farm development including tertiary canals for the above areas (1,888 ha)

The whole works will be executed in 55 months or about four and a half years including 6 months for the detail design and tender and awarding period.

The first stage works will be executed in 20 months in succession to the design and contract period utilizing two dry seasons each spanning over a period of about 6 months. The major works such as the Koba river crossing siphon and the related canal lining and right bank embankment will be executed in the first dry season, whereas the partial land consolidation works and the remaining canal lining works will be carried out in the next dry season. Rehabilitation of the structures will be continued even in the rainy seasons. It is expected that the effect of the first stage works is realized immediately after its completion.

The second stage works will be carried out in 21 months including 2 dry seasons. The works consist mainly earthworks for canals and will be executed concentratedly in these dry seasons. On-farm works are proposed to be executed mainly by manpower and will be continued in both dry and rainy seasons, together with the structural works related to main and secondary canals.

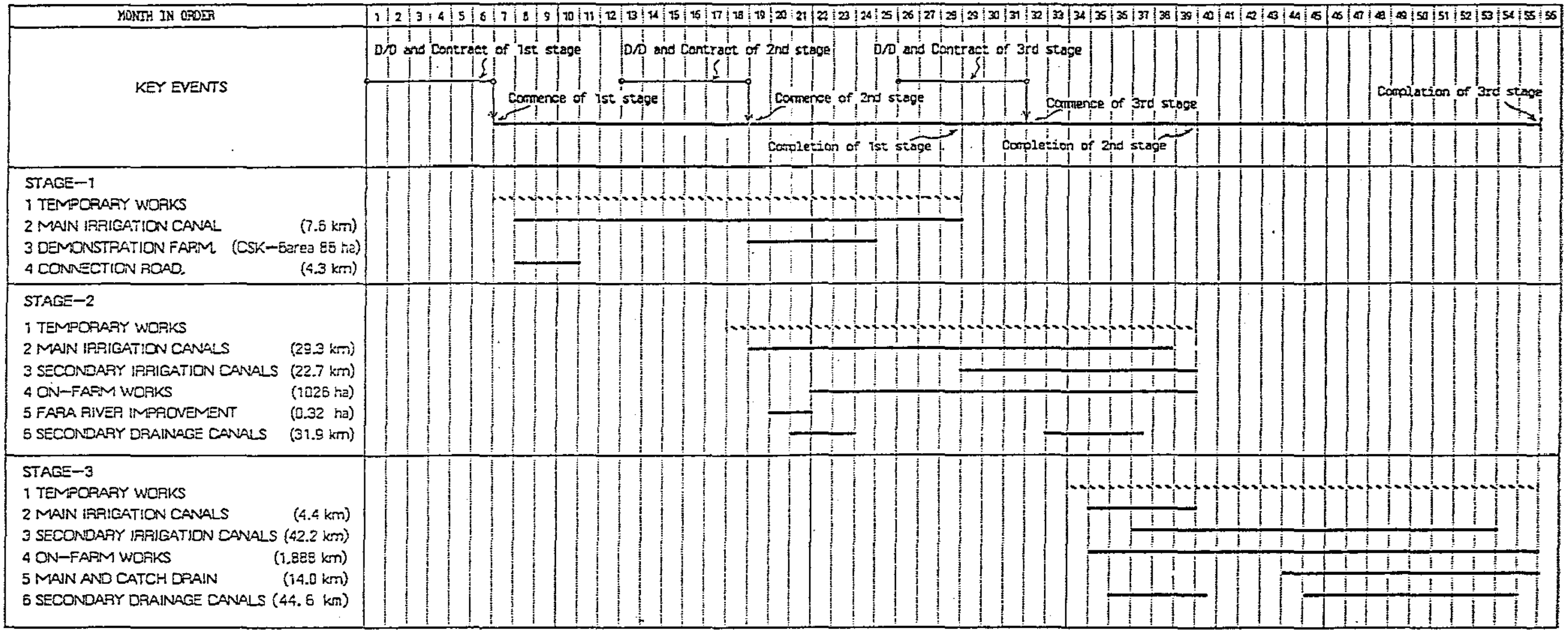
The third stage works will be executed in 24 months intervened also by two dry seasons. Construction of the new Tanima canal will be mainly executed in the first dry season, while secondary canal construction and rehabilitation will be executed in two dry seasons.

Table IX.1 COMPARISON OF SUB-AREAS

Item	Unit	Koba	Upper Baguineda	Lower Baguineda	Tanima/ Sienkoro	Total
(1) Irrigation Area	ha	557	555	1,424	464	3,000
(2) Population	peerson	1,436	3,266	1,583	779	7,064
(3) Population Density	person/ha	2.6	5.9	1.1	1.7	2.4
(4) Nos. of household	nos.	172	523	112	70	877
(5) Planted Area	km	440	1,165	726	243	2,574
- In Operation	ha	90	370	222	65	747
- Outside	ha	350	795	504	178	1,827
(6) Required Cost/1	$US\$10^3$	4,707	4,528	12,522	4,338	26,145
(7) Per ha Cost	US$	8,450.6	8,158.6	8,793.5	9,349.1	8,715

Remarks: Cost of each area is obtained by allocating the main canal cost to each area in accordance with the acreage.

FIGURE IX.1 IMPLEMENTATION SCHEDULE



ANNEX X

COST ESTIMATE

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COST ESTIMATE

X.1 General

The project cost consists broadly of (i) civil works cost for the rehabilitation works and (ii) initial farm investment. These costs are estimated based on the preliminary design of the facilities, construction work method, construction materials, construction equipments and man-power, and job-site conditions.

Following assumptions are adopted in cost estimation.

1) Civil works and construction of agro-pastoral facilities will be carried out under contract basis with international bidding. Equipment required for civil works will be procured by the contractor.

2) Heavy equipments and plants such as bulldozer, backhoe, compaction roller, trucks, motor grader and concrete plant and required construction materials such as reinforcement bars, corrugated metal pipes, gates, other steel materials and cement if required, will be imported by the contractor themselves. Those imported equipments and materials will be exempted from import duties and taxes.

3) Required local construction materials such as cement, sand, gravel, masonry stone, plywood, timber, fuel and lubricants will be purchased at the site or in local market.

4) Utilization of lands necessary for work execution such as borrow area for earth material, quarry site for aggrigates, masonry stone and the contractor's camp, will be free of charge.

5) Earth materials and aggregates will be utilized as below:

a. Earthfill materials for main irrigation canals; Hauling distance of within 1,000 m on the hill area along the right bank of main canals.

b. Earthfill material for secondary and tertiary irrigation canals; Hauling distance of within 500 m on the high land or farm land along the canals.

c. Soil material for laterite pavement; Hauling distance of within 1,500 m on the hill area along the right bank of main canals.

d. Aggregate for concrete and masonry stone

- Sand; Bad sand of Niger river along the project area.
- Crushed stone; The quarry site would be utilized in the project area or along the main canal.
- Masonry stone; The quarry site would be utilized in the project area or along the main canal.

6) Calculation formula of depreciation cost for the equipments are adopted the Japanese Industrial Standards Committee in Japan, and the hourly equipment costs are including the transportation costs from Japan to Bamako through Abidjan.

7) Yearly workable days are adopted 213 days for earthworks and 267 days for concrete works. These workable days exclude Sundays, National holidays and days that have more than 5 mm of rainfall days.

8) Daily working hours are adopted from 7:00 a.m. to 4:00 p.m. including one hour of lunch time. Therefore, the actual moving time of equipments are as follows:

For earth works;	8 hr x 0.75 = 6.0 hr/day
For concrete works;	8 hr x 0.65 = 5.2 hr/day

Then yearly working hour of equipment:

For earth works;	213 days x 6.0 hr ≒ 1,270 hr
For concrete works;	267 days x 5.2 hr ≒ 1,380 hr

9) 10% of direct costs for civil works and facilities construction works are added as physical contingencies in cost estimate.

10) Escalate rates of 3% and 10% per annual are applied respectively for the costs in foreign currency and those in local currency.

11) Costs are estimated based on the price indexes and local market prices in Bamako in October 1985. The applied exchange rate is US$1 = F CFA 426.

X.2 Project Construction Cost

Following charges and expenditures are included in the project construction cost:

(1) Cost of civil construction works,
(2) Initial investment cost, and
(3) Remuneration for engineering services.

Estimated of respective costs are given below:

X.2.1 Cost of civil construction works

Construction cost consists of the costs for i) temporary works, ii) main irrigation canal, iii) secondary irrigation canals, iv) on-farm works, v) main drainage canals, vi) secondary drainage canals and vii) connection road.

These costs are summarized below:

Item	Foreign Currency (US$ 10^3)	Local Currency (F CFA 10^6)	Total (US$ 10^3)
1. Temporary Works	317	113	582
2. Main Irrigation Canal	3,819	2,012	8,542
3. Secondary Irrigation Canals	2,737	761	4,523
4. On-farm Works	2,926	1,015	5,308
5. Main Drainage Canals	506	187	946
6. Secondary Drainage Canals	583	291	1,266
7. Connection Road	28	11	54
Sub-total	10,915	4,390	21,221
8. Physical Contingency	1,092	439	2,122
Total Construction Cost	12,007	4,829	23,343
9. Engineering Services	1,441	580	2,801
Total	13,448	5,409	26,145

The summary of civil construction costs and those breakdown are shown in Tables X.1 and X.2 respectively. Investigated costs of basic construction material and man-power, operation cost of major equipment, estimated unit cost of civil construction works and summary of civil construction costs for each construction stage are also shown in Tables X.3, X.4, X.5 and X.6 respectively.

The disbursement schedule set up in accordance with the project implementation schedule is shown in Table X.7.