decomposed muck and mucky peat with loamy muck topsoils. The main crops are early maize, cassava, sweet potatoes and rice. These crops are mainly fed through rain water, groundwater, and through the Musiamo main lateral canal which runs along the entire plain edge.

This area commonly forms a pond during heavy rain showers and is locally flooded by the Zambezi towards the end of the wet season. The Namushakende verification farm is part of this area.

(2) Mataba Sitapa area

This area is mainly confined to the transitional zone between the Sishanjo area along the plain edge and the somewhat elevated Saana sand terraces further out into the flood plain. The topography is flat with an elevation comparable or slightly higher than the Sishanjo area. The soils of the Mataba Sitapa area are mucky loams and sandy loams overlying sand. This area is part of the Mataba seepage zone and is also flooded during the flood period. The fluctuations of the groundwater table are considerable when compared to that in the Sishanjo area.

The main crop is early maize which is planted in August-September using the soil moisture following the recession of the floods and harvested in December-February before the onset of the next floods. Other crops are rice, pumpkin, cucumber and finger millet. Maize yields are generally unstable due to an erratic flood regime and unreliable rainfalls.

As for rice, it is generally planted in November - December using the early rainfall and harvested in May - June. At given places in this area paddy rice is raised through irrigation utilizing the water of canals streamed from the tableland such as the Sefula river and the Namitome canal.

3.1.2 Natural Conditions of the Target Area

Two cultivated land areas were selected as model areas to be investigated for the land consolidation standards. These model areas lay in the Sishanjo and Mataba Sitapa soil type and were identified as:

- Sefula model area

This area is located at the western part of Sefula village in the plain edge which is at 15km south of Mongu and 10km north of Namushakende. Approximately 25 ha of the cultivated lands exist within this model area located at the right bank of the natural river, Sefula which has a catchment basin in the eastern upland.

- Limulunga model area

This area is located at the north-western part of Limulunga village in the plain edge which is at 15km north of Mongu. Approximately 30 ha of the cultivated lands exist within this model area located at the right bank of an artificial canal, Namitome.

The natural conditions relating to the target areas, are described below.

(1) Soil texture and nature

1) Soil texture and nature

The Sishanjo and Mataba Sitapa soils are distributed in the Sefula model area and their top-soils are mainly muck in the Sishanjo and sandy loam in the Mataba Sitapa, and sub-soils are loamy sand to sand. In the Limulunga model area, the Sishanjo, Mataba Sitapa and Saana soils are distributed. The top-soils are muck and muck peat in the Sishanjo, sandy loam in the Mataba Sitapa, and the sub-soils are muck peat and muck loamy sand in the Sishanjo, loamy sand and sand in the Mataba Sitapa. The Saana soil texture is sandy in all layers.

The values of soil pH(H_20) were 5.9 ~ 6.5 in Sefula and 5.6 ~ 6.3 in Limulunga, and these values were higher than the values recorded at the Namushakende verification fields.

These results are shown in the Appendix, Table III.1.1.

2) Soil permeability

A permeability test was carried out using the auger-hole method in order to determine the hydraulic conductivity of the soils. The permeability of these areas were relatively high and the values of hydraulic conductivity were between 2.6 x 10^{-3} cm/sec and 3.4 x 10^{-4} cm/sec.

These results are shown in the Appendix, Table III.1.2.

3) Ground bearing capacity

In order to verify the possibility of cultivation by oxen, the penetration resistance was measured using a cone-penetrometer mainly in the Sishanjo soil type which shows weak foundations in both model areas.

The average values of penetration resistance at the depths of 10 cm and 15 cm below the field surface were 1.8 kg/cm^2 and 3.4 kg/cm^2 in the Sefula area and 1.5 kg/cm^2, 2.5 kg/cm^2 in the Limulunga area, respectively.

According to an actual bearing capacity test by oxen in the Namushakende fields, 0.8 kg/cm^2 was verified as the minimum bearing capacity for cultivation by oxen. In consideration of these results, it might be acceptable to use oxen for the cultivation of paddy fields in this area.

Results on the values of penetration resistance are shown in the Appendix, Table III.1.3.

(2) Hydrology

1) Discharge of water resources

Water discharge of the Sefula river and the Namitome canal has been measured in order to estimate the irrigable area and to make sure of the possibility of water use from these streams during the dry season.

The water discharge fluctuations from Sep. 1991 to Apr. 1992 were 0.29 m^3/sec ~ 0.86 m^3/sec at the Sefula river and 0.22 m^3/sec ~ 0.79 m^3/sec at the Namitome canal. The minimum water discharge was observed in October and the maximum was in December due to heavy rains.

The monthly discharge fluctuations of the Sefula river and Namitome canal are shown in the Appendix, Table III.1.4 and the Appendix, Figure III.1.1.

2) Water level fluctuations in the model areas

Groundwater table and the surface water levels have been measured in both model areas since Oct. 1991 to study the possibility to use the groundwater in the dry season and ponding/flooding in the wet season. These water levels were measured using a plastic-pipe for the groundwater table and a staff gauge for the surface water. Measurements were made at two locations: one being the low portion; and the other the high portion of each model area.

In the Sefula model area, inundation of the fields began in the middle of December at both low and high portions due to the rainfall and the irrigation water from the canal. In the Limulunga model area, inundation began in the middle of November at the low portion by the irrigation water, and toward the end of December at the high portion by rainfall. The fluctuations of the groundwater table in the Mataba Sitapa which is located slightly away from the plain edge are bigger than in the Sishanjo. The maximum water depths in the fields were 0.25 m in the Sefula model area and 0.35 m in the Limulunga model area. These results are shown in the Appendix, Table III.1.5 and Figure III.1.3.

In this wet season, flooding from the Zambezi could not reach both model areas because the rise of the water level of the Zambezi was much smaller than usual. The peak water level of the little Zambezi at Matongo this season was 1.04 m lower than last season.

3) Water level fluctuations of the little Zambezi

The water level fluctuations of the little Zambezi at Matongo and Nawinda from Oct. 1991 to May 1992 are shown in the Appendix, Table III.4.1, Figure III.1.3 and Figure III.1.4.

At both sites the lowest water levels were recorded towards the end of October and the highest at the beginning of March. The maximum amplitudes of fluctuations were 3.1 m at Matongo and 2.5 m at Nawinda. Water levels at both sites fluctuated with a small amplitude, less than 0.2 m, from the peak at the beginning of March to the end of April. However, a sharp drop started early May, which reached approximately 1.0 m at the end of that month. Both the highest water level and the maximum amplitude of fluctuations at Matongo this year were 1.0 m smaller than last year.

The Matongo gauging station is located 6 km west of Mongu, and Nawinda 10 km west of Namushakende and 20 km down stream of Matongo.

(3) Meteorological conditions

1) Temperature and relative humidity

The data of the monthly average maximum and minimum temperature and relative humidity from July 1989 to April 1992 are shown in the Appendix, Table III.4.2 (relative humidity data from Jun. 1990 to February 1991 are missing)

The maximum temperature is highest between September and December; the absolute maximum temperature during the study term was 38°C on the 12th Nov. 1990.

The average maximum temperature was 29.8°C and the average minimum 15.8°C. The minimum temperature is lowest between Jan. and July, the absolute minimum temperature was 2°C on the 10th Jan. 1991.

The comparisons of the maximum and minimum temperatures at Mongu meteorological station and Namushakende AVS farm at the months of apparition of the absolute maximum and minimum are shown in the Appendix, Figure III.1.7 ~ Figure III.1.12.

The difference in the maximum temperatures between the Mongu meteorological station and the Namshakende AVS farm was more pronounced than the minimum temperature.

The minimum temperature at Namushakende in Jun. and July is usually 3°C ~ 4°C lower than at Mongu, because the main wind direction after sunset is East during that period. And this wind blows from the ridges down the plain edge slopes a cool air.

A frost was recorded on 20th July, 1989 at Namushakende AVS farm; however, no frost was recorded at Mongu meteorological station the same day, and the minimum temperature was 6.9°C.

The monthly average maximum relative humidity usually ranges between 75% and 90%, with values below this range only recorded at three occasions, namely September and October 1991 and April 1992, when the absolute monthly average maximum relative humidity was 80.3 %.

The monthly average minimum relative humidity was as high as 40 % from November to April but dropped to 30 % in the dry season. The monthly average relative humidity was 33 % for the period considered.

2) Rainfall

The comparisons of rainfall data at Namushakende AVS farm, Lealui AVS farm, Mweke dambo and Mongu meteorological station from Jun. 1990 to May 1992 are shown in the Appendix, Table III.1.6.

The ground total at the Namushakende AVS farm for the 2 years 1990 and 1991 was 1643.9 mm; and the percentage amounts recorded at the other sites are 82% (Lealui), 50% (Mweke) and 98% (Mongu)..

The monthly rainfall values are shown in the Appendix, Figures III.1.13 and III.1.14.

According to these figures, there are differences among sites which are located around the plain edge area.

The differences between Namushakende and Mongu can be deducted from the Appendix, Table III.1.6. The table shows that there is not much difference in annual rainfall while differences more than 80 mm were recorded in daily rainfall. It is also noted that one site may be rainy while the other is not on the same day.

The first rains at both sites in 1990 and 1991 started at the end of September and middle of October for respectively the two years. After the first rains, there were more than 10 days dry spell until November. The monthly totals from December to March were over 100 mm but the rainy season ended in April.

3.2 Guideline of Irrigation and Water Management

3.2.1 Scope of Application and Prerequisite for the Guideline

(1) Scope of application of the guideline

1) Target areas

The Sishanjo and Mataba Sitapa areas located in the Mataba seepage zone are the selected target areas .

2) Target agricultural requirements

The accepted cultivation systems in the guideline involve paddy rice single and double cropping systems in association with upland crops under irrigation. Farm works are carried out by manpower and animal draft.

Considering the now actually existing farm size (0.5 ~ 2 ha) and the targeted cropping systems, a farm block of 2 ~ 5 ha is recommended as a basic unit of farming scale. A typical farming system will group several farm blocks (10 ~ 50 ha).

(2) Premises for the preparation

1) An irrigation plan is prepared, that takes into consideration an adequate and stable supply of irrigation water for better crop production. In the Zambezi flood plain where there is no experience in irrigation, the irrigation plan also takes into consideration water losses due to poor management and failure of the irrigation facilities.

2) A drought year with three to five years return period is targeted as reference year for design. Probabilities of non-exceedance computed for 13 years of annual rainfall recorded at Mongu meteorological station led to the selection of 1983 as the reference year for design. (Daily rainfall and other meteorological data at Mongu meteorological station in 1983 are shown in the Appendix, Tables III.2.2 ~ III.2.6)

3) Required data to determine relevant irrigation factors are obtained from the findings of the AVS. In case of shortage of data, additional survey is carried out.

4) A water management plan is prepared to decide on the irrigation interval, irrigation method and farming plan. The operation and management of the irrigation facilities not including the water resources facilities is to be carried out by beneficiary farmers who should be supervised by the district agricultural office.

According to the prerequisite conditions, the relevant irrigation factors are determined and the computed decadal gross irrigation water requirements under the double cropping system (paddy rice + upland crops) are shown in Figure 3.2.5.

3.2.2 Paddy Rice Irrigation and Water Management

(1) Present condition of paddy rice irrigation and water management

Paddy rice in the Zambezi flood plain edge area is cultivated in traditional rice farms under natural water ponding depending on seasonal river water fluctuation and rain. These farm lands do not have levees and do not carry out land leveling. Therefore, Paddy fields are annually naturally flooded and dried out following the seasonal increase or decrease of the Zambezi river water levels. Annual recurrence of this seasonal fluctuation constitutes the balance commanding rice growing. Therefore, if this seasonal balance is upset by rainfall conditions in the upper river basin, rice production is subsequently affected. Today, because farmers of the flood plain are still using traditional low yielding varieties whose culm length is more adapted to the water rising rate, variety diversification to boost yield and fit market needs is not yet tempted.

(2) Purpose of paddy field irrigation and water management

To establish a paddy rice cultivation which can keep stable and high yields and not be affected by adverse fluctuations of rainfall and river water levels.

(3) Water management plan

A water management plan is prepared for the calculation of irrigation water requirement, which consider cultivation methods and farming plan as prerequisites.

1) Farming plan and cultivation methods

A consolidated field usage plan model which is based on the AVS findings is shown in Figure 2.2.1. The farming plan and cultivation methods are developed following this model.

2) On-farm Water management plan.

For the plain edge area direct dry seeding is recommended. The applying time of initial ponding should be determined in the planning stage because the water requirement at this period corresponds to the peak water requirement. Generally the initial ponding application time is recommended at the three or four leaves apparition stage which occurs approximately one month after seeding. From the AVS findings, intermittent irrigation and seven to ten days irrigation interval are selected as the irrigation method which constitutes an essential factor to the determination of the water requirement.

3) Water management organization and irrigation facility plan.

A water requirement plan is needed not only for the water requirement of paddy rice but also for water delivery loss and delivery water requirement. The delivery water requirement depends on management organization, scale of irrigation facility and management method. It is important that this situation be considered in the planning stage.

There are no established irrigation farms at this moment, except for few commercial or public organizations run experimental farms. Therefore, there is no clear example of management organization to base recommendations of water management system or rules on. This should be the object of future research activities, but at this stage it can be recommended that farmers carry out operations and management under the guideline of the public organization such as the district agricultural office.

(4) Paddy field water requirement plan

Gross irrigation water requirement in paddy field can be calculated by substracting effective rainfall from accumulated daily water requirement rate which is the sum of evapotranspiration and percolation loss, and consider irrigation efficiency. Water requirement plan should take into consideration agricultural modernization and suitable farm land consolidation, farming and cultivation plans. The decadal gross irrigation water requirement shown in Table 3.2.6, is calculated considering the relevant irrigation factors mentioned below.

1) Field daily water requirement

Daily water requirement which is a portion of irrigation water is expressed as a water discharge per unit area or daily water depth. In the plain edge area where there is no available data of actually measured water requirement rate, daily field water requirement will be calculated using the elements shown in Figure 3.2.1.

- Water requirement rate in the field
  - Evapotranspiration
    - Climatic conditions (Air temperature, Humidity, Solar radiation, Wind direction and velocity etc.)
    - Growing conditions of rice (Variety, Soil, Climate, Field management practices etc.)
  - Percolation
    - Hydraulic conditions (Topography, Water level of drainage canal, Ground water table, Evapotranspiration of rice plant)
    - Permeability of soil (Structure of soil layers, Cracks, Oxidation and reductions, Volatilization of gas, Cultivation operation, Water management, etc.)
  - Seepage from levee
    - Hydraulic conditions (Differences in elevation of neighbouring paddy fields and in their water level, Water management
    - Permeability of levee(Materials of soil, Moisture content, Management of border, Fauna in soil etc.)

Figure 3.2.1 Primary Elements involved in the Daily Field Water Requirement Rate.[1)]

a) Evapotranspiration

Evapotranspiration can be found by multiplying the reference crop evaporation by the crop coefficient "FAO Irrigation and drainage paper no.24, Guidelines for predicting crop water requirement" (herein termed FAO I.D.P No.24) such as shown by the following formula. The Penman method has been used to calculate the reference crop evapotranspiration and the results for the reference year are shown in the Appendix, Tables III.2.7.

ETcrop = ETo * Kc

where,

ETcrop : crop evapotranspiration

1) S. Nakagawa: Investigation and Planning Method of Paddy Rice Water Requirement, vol. 2 and vol. 5

ETo	:	reference crop evapotranspiration
Kc	:	crop coefficient

The crop coefficients used for rice in northern Australia, FAO IDP No. 24, which is almost located at the same latitude a Zambia, were applied as shown in Figure 3.2.2, because the coefficients for Zambia are not available. The crop coefficient at the final decade is zero which coincides with the period when ponding water is released from the field. In addition, irrigation is not needed until one month after seeding due to the option of direct seeding in dry field selected in the farming plan.

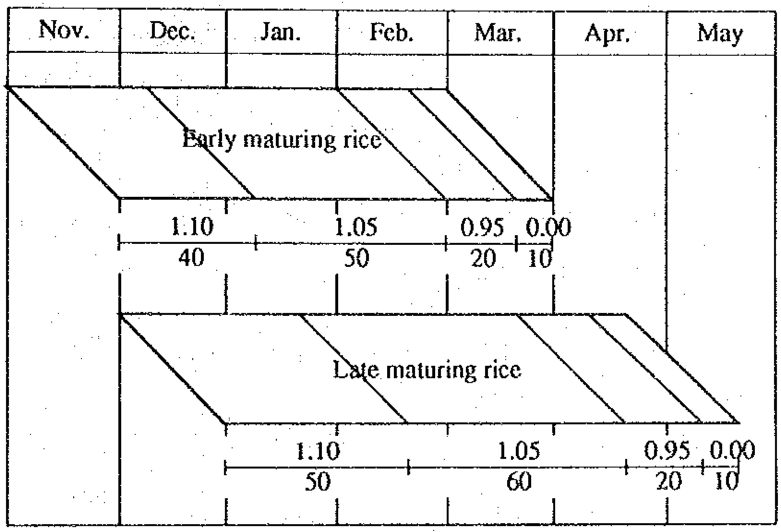

Figure 3.2.2 Crop Coefficients for Paddy Rice

b) Percolation and seepage losses

Percolation losses depend on groundwater, soil and puddling conditions. The losses from levees or seepage losses which have a horizontal direction will be influenced by the levee coating, the water level of the neighboring paddy fields, the drainage canal and levee material. Percolation and seepage losses are not annually constant but they are usually estimated to be 5 to 10 mm/day for planning purposes. In this plan, to compare the actually measured data of daily water requirement in the Namushakende AVS farm with the crop evapotranspiration mentioned in the preceeding paragraph, percolation was assumed to be 5 mm/day and seepage from levees 2 mm/day.

2) Periodical fluctuations of field water requirement

The water use of paddy field can be divided into the initial ponding water requirement which refers to the water use during the initial ponding period and the ordinary water requirement which corresponds to the water requirement after initial ponding and covers all the period leading to the release of the ponding water from the field. In the transplanting cultivation system, nursery water requirement, puddling water requirement and puddling period water requirement have to be considered. But, in this plan the direct seeding cultivation system being applied, the initial ponding water requirement has been considered instead. The ordinary water requirement can be found by adding the crop evapotranspiration, which has been defined in the previous sections, to the corresponding percolation and seepage losses.

a) Initial ponding water requirement for direct seeding in dry field

The initial ponding water requirement for direct seeding in dry field is defined as the water requirement covering the first ponding period to the stage of initiation of three or four leaves. The initial ponding water requirement is influenced by soil hydraulic conductivity and groundwater level as puddling is not carried out in the direct seeding method. Therefore, water requirement is high in a field with high hydraulic conductivity and low ground water level and low vice-versa.

In this plan, the initial ponding water requirement is considered to be 150 mm per month after November in early rice cultivation and from January in late rice cultivation.

b) Ordinary water requirement

The ordinary water requirement in the direct seeding cultivation system is higher than in the transplanting system. Because, the leaching losses increase due to the absence of puddling and levee coating. Percolation is not important when the hydraulic conductivity below the plow layer is below 10^{-5} or when the groundwater level is high. In general, the ordinary water requirement for direct seeding cultivation tends to be bigger than for transplanting cultivation depending on the above mentioned conditions. The water requirement becomes maximum just after the initial ponding period then it decreases and stabilizes around 10 to 20 days after ponding.

3) Effective rainfall

Effective rainfall is directly computed from rainfall in the field and is influenced by rainfall amount, intensity, period and water management conditions.

The computation of effective rainfall, Re, for paddy field assumes an allowable potential storage capacity, Ro, whose maximum limit is set at 60 mm above the regular ponding water surface considering the actual level of land consolidation, and a minimum limit set at 5 mm. Rainfall over the maximum limit or below the minimum limit is considered not valid. 80% of daily rainfall is considered effective rainfall with 20 % selected to allow for various water losses and errors. For a given day:

$Re = 0$ when $R < 5$ mm

When $R \geqq 5$ mm

$Re = 0.80R$ when $Ro > 0.80R$

$Re = Ro$ when $Ro < 0.80R$

with R: daily rainfall and Ro: [60mm - (Re + water requirement) day before]

4) Net irrigation requirement

Net irrigation requirement is calculated as follows:

Net irrigation requirement = (seasonal water requirement)-(effective rainfall)

5) Gross irrigation requirement

Gross irrigation requirement is given as follows:

Gross irrigation requirement = Net irrigation requirement / (1-conveyance loss percentage)

The planned irrigation system assumes farming lands of approximately 50 ha, a total length of main canal of about 2 km and an unlined canal surface. Following these considerations a 15 % conveyance loss was selected.

The annual gross irrigation requirement is 1190 mm as shown on the table 3.2.6. For a typical farming system involving 50 ha, the corresponding average inlet rate will be 33.4 l/s. A peak water requirement is recorded on the 3rd decade of February, which corresponds to 120.0 mm or a required peak inlet rate of 86.9 l/s.

3.2.3 Upland Crop Irrigation and Water Management

(1) At present, in the Zambezi flood plain, rainfed agriculture is practiced for upland crops. However, the lack of established irrigation system associated with erratic rainfall conditions, make yield unstable. The farmers in the area have to select drought resistant varieties and crops.

(2) The purpose of establishing plans for upland irrigation and water management is to secure stable, and high yields for the area.

(3) Upland crop water requirement plan

The amount of water necessary at each irrigation depends on the crop consumptive use, effective rainfall, and soil moisture characteristics in the target areas.

These processes are shown in Figure 3.2.3

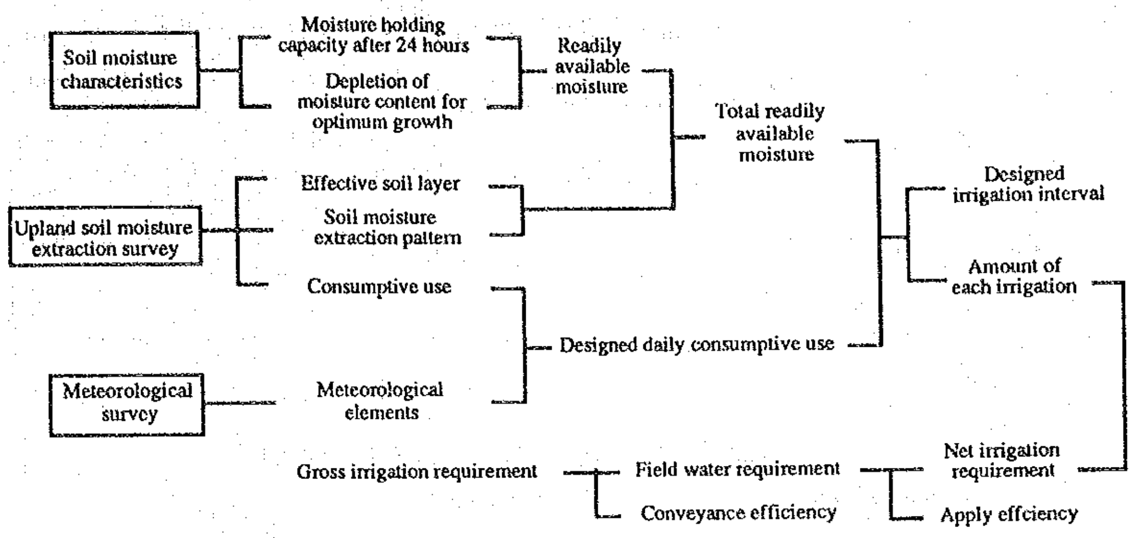

Figure 3.2.3 Calculation Process of Upland Water Requirement

1) Soil moisture characteristics

The moisture holding capacity after 24 hours and the depletion of moisture content for optimum growth are defined as soil moisture characteristics in the upland irrigation plan. The measured soil moisture characteristics for maize in the Namushakende AVS farm are shown in Tables 3.2.1 and 3.2.2.

Table 3.2.1 Soil Moisture Characteristics in the Effective Root Zone 40 cm

Layer	Depth (cm)	Moisture Holding Capacity after 24 hours (Volume %)	Depletion of Moisture Content for Optimum Growth (Volume %)
1st layer	0 ~ 10	51.0	28.9
2nd layer	10 ~ 20	58.0	40.7
3rd layer	20 ~ 30	40.2	29.4
4th layer	30 ~ 40	37.0	28.4

Table 3.2.2 Soil Moisture Characteristics in Case of Effective Root Zone 80 cm

Layer	Depth (cm)	Moisture Holding Capacity after 24 hours (Volume %)	Depletion of Moisture Content for Optimum Growth (Volume %)
1st layer	0 ~ 10	54.5	34.8
2nd layer	10 ~ 20	38.6	28.9
3rd layer	20 ~ 30	37.0	28.4
4th layer	30 ~ 40	37.0	28.4

a) Moisture holding capacity after 24 hours

Soil moisture 24 hours after a rainfall or an irrigation is defined as the moisture holding capacity after 24 hours. Its corresponds to the upper limit of the available moisture (equivalent PF1.5 to 2.0)

b) Depletion of moisture content for optimum growth.

To increase and improve crop yield and quality by irrigation, the moisture content corresponding to the depletion of moisture content for optimum growth is defined as the portion of the available moisture held between the upper limit (equivalent PF1.5 to 2.0) to that held at PF3.0.

It can be measured by the pressure membrane method.

c) Readily available moisture.

The available moisture in upland irrigation plan is distributed between the moisture holding capacity after 24 hours and the depletion of moisture content for optimum growth. The readily available moisture can be found following the formula.

$$RAM = (fc - Me) \times D \times 1/cp \quad \text{(mm)}$$

Where RAM : readily available moisture

fc : moisture holding capacity after 24 hours (volume %)

Me : depletion of moisture content for optimum growth (volume %)

D : Depth of soil layer (mm)
cp : value of soil moisture extraction pattern (%)

2) Upland moisture consumptive use

a) Effective soil layer and important soil layer for growth

The effective soil layer is the depth of the soil layer whose soil moisture is consumed by evapotranspiration and capillarity after the soil moisture reaches the moisture holding capacity after 24 hours. Associated with vegetables and maize cultivation, 2 depths of effective soil layer are considered in the plan. These are 40 cm and 80 cm.

The important soil layer for growth is defined as the layer in the effective soil layer where the consumptive use is the highest.

Moisture condition in the soil layer directly influences crop growth, yield and quality and can be given for each soil layer considering the soil moisture extraction pattern.

b) Soil moisture extraction pattern

In general, the rate of decrease of soil moisture in the effective soil layer is uniform and becomes gradually smaller from surface to deeper layers.

The soil moisture extraction pattern is shown as a ratio of moisture decrease for each soil layer . This plan considers four soil layers in the effective soil layer and values of the moisture extracting pattern as 40%, 30%, 20% and 10% from surface.

The readily available moisture values which are calculated for the Namushakende AVS farm are shown in Tables 3.2.3, 3.2.4.

Table 3.2.3 Available Moisture for the of Effective Root Zone 40 cm

Layer	Depth (cm)	Soil Moisture extraction Pattern	Available Moisture (Volume %)
1st layer	0 ~ 10	40	98.5
2nd layer	10 ~ 20	30	64.7
3rd layer	20 ~ 30	20	86.0
4th layer	30 ~ 40	10	172.0

Table 3.2.4 Available Moisture for the of Effective Root Zone 80 cm

Layer	Depth (cm)	Soil Moisture extraction Pattern	Available Moisture (Volume %)
1st layer	0 ~ 10	40	55.3
2nd layer	10 ~ 20	30	57.7
3rd layer	20 ~ 30	20	54.0
4th layer*	30 ~ 40	10	86.0

According to these findings, the third layer becomes the important soil layer for growth and the total readily available moisture is 54.0 mm for an effective soil layer depth of 40 cm. For an effective soil layer depth of 80 cm, the second layer become the important soil layer for growth and the total readily available moisture is 64.7 mm.

Therefore, 59.4 mm of averaged total readily available moisture for a soil layer depth of 40 cm and 80 cm is selected in this plan.

3) Consumptive use

The consumptive use is the consumed moisture amount in the effective soil layer under the conditions of good crop growth, high yield and high quality. The consumptive use can be found by actual measurement or by applying the computed Penman crop evapotranspiration. Penman is selected in this plan because actual data are not available in the plain edge area.

a) Calculation of evapotranspiration by the Penman method.

The reference crop evapotranspiration can be given by the following equation which considers such meteorological data as temperature, relative humidity, wind speed, duration of sunshine, etc.... recorded at Mongu meteorological station .

ETo = c {W x Rn + (1-w) x f(u) x (ea-ed)}

where : ETo = reference crop evapotranspiration in mm/day

W = temperature-related weighting factor

Rn = net radiation in equivalent evaporation in mm/day

f(u) = wind-related function air temperature and the mean actual vapor pressure of the air, both in mbar

c = adjustment factor to compensate for the effect of day and night weather conditions

The crop evapotranspiration can be found by multiplying ETo by the crop coefficient.

ET crop = ETo x Kc[1)]

where : ET crop : crop evapotranspiration

Kc : crop coefficient

The crop coefficients which are applied in this computation are shown in Figure 3.2.4.

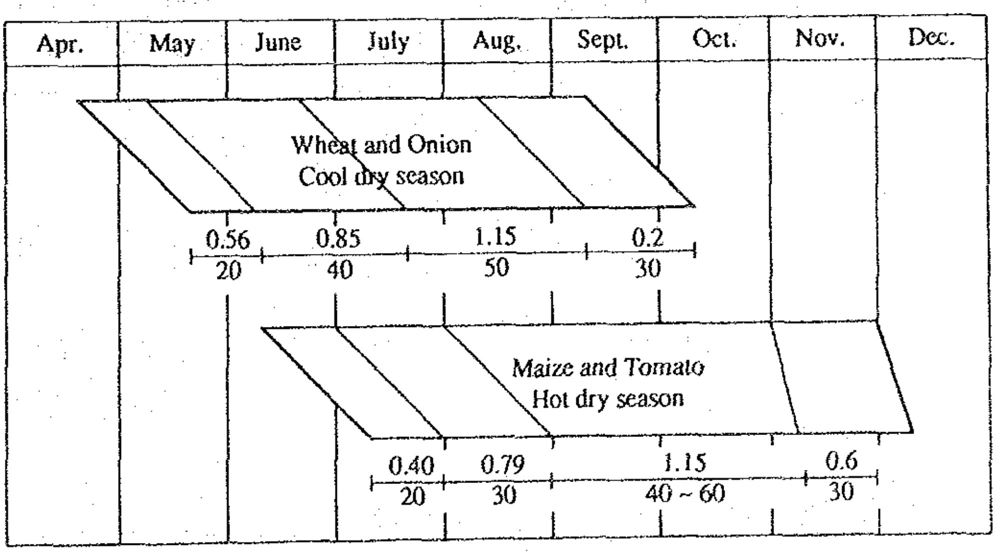

Figure 3.2.4 The Values of Crop Coefficient (Kc)

1) Refer to "FAO irrigation and Drainage Paper No. 24 Chapter 2"

4) Effective rainfall

The effective rainfall, Re for upland crops whose upper limit is defined as the total readily available moisture and lower limit as 5mm (equivalent to daily pan evaporation rate) can be given by multiplying 80% as a safety factor. However in case of continuous rainfall, the upper limit is applied such as the following equations.

When $R \geqq 5$ mm

① multiplying rainfall (R) and safety factor (80%) :
effective rainfall = 0.80 x R (when R < 5mm, Re=0)

② *the upper limit, Ro, of effective rainfall is given as such:*
Ro = [TRAM - (effective rainfall + daily consumptive use) the day before]

③ determination of effective rainfall

when	$Ro \geq 0.80 \times R$	effective rainfall = 0.80 x R
when	$Ro < 0.80 \times R$	effective rainfall = Ro

5) The irrigation interval and amount for design can be found dividing TRAM by the peak and omitting the figures after the first decimal place. When the consumptive use is not at a peak,the computed irrigation interval for design should not be changed but should be adjusted according to irrigation application time. The irrigation interval for design is as follows:

$$\text{Irrigation Interval for Design} = \text{TRAM} / (\text{ETo, max}) = 59.4 / (3.04/0.60) = 11.7 = 11 \text{ days.}$$

Where the value 3.04 mm/day represents the daily consumptive use (Table 3.2.7), and the value 0.60 the percent of the area devoted to upland crops.

The amount of each irrigation for design can be given multiplying the irrigation interval for design by the daily consumptive use for design in each period. The maximum irrigation water requirement can be found by multiplying the irrigation interval and maximum daily consumptive use.

The maximum amount of each irrigation for design = (ETo, max) x irrigation interval = (3.04 mm/day/0.60) x 11 days = 55.73 = 56 mm

6) Net and gross irrigation requirement

The net irrigation requirement per decade can be found by subtracting comsumptive use in each period to effective rainfall.

The gross irrigation requirement can be given by dividing net irrigation requirement to the irrigation efficiency. Application efficiency depends on irrigation method and conveyance efficiency on total canal length, canal lining materials and canal management condition. In the plain edge area, the conveyance efficiency is assumed to be 15%, and the application efficiency 70% according to the farm irrigation plan shown in Appendix III.

Then the irrigation efficiency can be found as follows :

irrigation efficiency = (1-0.15) x 0.70 ≒ 60%

The computed values of the gross irrigation requirement at each decade are shown in Table 3.2.7.

Table 3.2.5 Gross Irrigation Requirement (Rice + Upland Crops)

	Av.Kc	ETo day	Days	ETo Dec.	ET crop	Loss(p.+s.)	Init. pond	Sub Total	Rain	Eff. Rain	Net I.R.	Gross I.R.
Nov.1	0.35	4.7	10	47.0	16.5	5.8		22.3	26.0	6.6	15.7	21.4
Nov.2	0.47	4.6	10	46.0	21.6	17.5		39.1	11.0	4.1	35.0	48.0
Nov.3	0.66	3.9	10	39.0	25.7	29.2	12.5	67.4	40.0	19.4	48.0	65.8
Dec.1	0.73	3.5	10	35.0	25.6	40.8	25.0	91.4	31.0	18.5	72.9	99.8
Dec.2	0.82	3.5	10	35.0	28.7	52.5	25.0	106.2	44.0	23.7	82.5	97.1
Dec.3	1.00	3.1	11	34.1	34.1	64.2	12.5	110.8	67.1	44.9	65.9	77.5
Jan.1	1.08	2.8	10	28.0	30.2	70.0	12.5	112.7	25.0	16.0	96.7	113.8
Jan.2	1.08	3.0	10	30.0	32.4	70.0	25.0	127.4	47.0	37.6	89.8	105.6
Jan.3	10.70	2.6	11	28.6	30.6	70.0	25.0	125.6	165.0	129.6	0.0	0.0
Feb.1	10.60	3.2	10	32.0	33.9	70.0	12.5	116.4	86.0	65.7	50.7	59.7
Feb.2	1.03	4.1	10	41.0	42.2	70.0		112.2	35.0	26.2	86.0	101.2
Feb.3	0.93	5.1	8	40.8	37.9	64.2		102.1	4.0	0.0	102.1	120.2
Mar.1	0.77	3.7	10	37.0	28.5	52.5		81.0	78.0	57.5	23.5	27.6
Mar.2	0.61	4.4	10	44.0	26.8	40.8		67.7	18.0	8.6	59.0	69.5
Mar.3	0.52	4.7	11	51.7	26.9	35.0		61.9	6.6	0.0	61.9	72.8
Apr.1	0.50	4.3	10	43.0	21.5	35.0		56.5	16.0	3.2	53.3	62.7
Apr.2	0.41	4.7	10	47.0	19.3	29.2		48.4	11.0	3.9	44.6	52.4
Apr.3	0.27	4.8	10	48.0	13.0	17.5		30.5	0.0	0.0	30.5	41.7
May.1	0.16	5.8	10	58.0	9.3	5.8		15.1	15.5	5.0	10.1	13.8
May.2	0.16	6.3	10	63.0	10.1			10.1	0.0	0.0	10.1	16.5
May.3	0.21	5.3	11	58.3	12.2			12.2	0.0	0.0	12.2	20.1
Jun.1	0.24	5.3	10	53.0	12.7			12.7	0.0	0.0	12.7	20.9
Jun.2	0.26	5.1	10	51.0	13.3			13.3	0.0	0.0	13.3	21.7
Jun.3	0.27	5.6	10	56.0	15.1			15.1	0.0	0.0	15.1	24.8
Jul.1	0.30	5.9	10	59.0	17.7			17.7	0.0	0.0	17.7	29.0
Jul.2	0.33	6.3	10	63.0	20.8			20.8	0.0	0.0	20.8	34.1
Jul.3	0.37	7.2	11	79.2	29.3			29.3	0.0	0.0	29.3	48.0
Aug.1	0.41	6.9	10	69.0	28.3			28.3	0.0	0.0	28.3	46.4
Aug.2	0.42	6.6	10	66.0	27.7			27.7	0.0	0.0	27.7	45.4
Aug.3	0.38	7.1	11	78.1	29.7			29.7	0.0	0.0	29.7	48.7
Sep.1	0.33	9.2	10	92.0	30.4			30.4	0.0	0.0	30.4	49.8
Sep.2	0.31	7.8	10	78.0	24.2			24.2	0.0	0.0	24.2	39.6
Sep.3	0.32	8.3	10	83.0	26.6			26.6	0.0	0.0	26.6	43.5
Oct.1	0.34	7.5	10	75.0	25.5			25.5	0.0	0.0	25.5	41.8
Oct.2	0.35	6.4	10	64.0	22.4			22.4	6.0	1.4	21.0	34.4
Oct.3	0.35	4.6	11	53.9	18.9			18.9	26.4	4.7	14.2	23.2
Total			365		869.6	840.0	150.0	1859.6	758.6	476.6	1387.0	1838.5

Table 3.2.6 Gross Irrigation Requirement (Rice)

	Av.Kc	ETo day	Days	ETo Dec.	ET crop	Loss(p.+s.)	Init. pond	Sub Total	Rain	Eff. Rain	Net I.R.	Gross I.R.
Nov.1	0.09	4.7	10	47.0	4.2	5.8		10.1	26.0	1.4	8.7	10.2
Nov.2	0.28	4.6	10	46.0	12.9	17.5		30.4	11.0	1.9	28.5	33.5
Nov.3	0.46	3.9	10	39.0	17.9	29.2	12.5	59.6	40.0	11.3	48.3	56.8
Dec.1	0.64	3.5	10	35.0	22.4	40.8	25.0	88.2	31.0	14.7	73.5	86.5
Dec.2	0.82	3.5	10	35.0	28.7	52.5	25.0	106.2	44.0	23.7	82.5	97.1
Dec.3	1.00	3.1	11	34.1	34.1	64.2	12.5	110.8	67.1	44.9	65.9	77.5
Jan.1	1.08	2.8	10	28.0	30.2	70.0	12.5	112.7	25.0	16.0	96.7	113.8
Jan.2	1.08	3.0	10	30.0	32.4	70.0	25.0	127.4	47.0	37.6	89.8	105.6
Jan.3	1.07	2.6	11	28.6	30.6	70.0	25.0	125.6	165.0	129.6	0.0	0.0
Feb.1	1.06	3.2	10	32.0	33.9	70.0	12.5	116.4	86.0	65.7	50.7	59.7
Feb.2	1.03	4.1	10	41.0	42.2	70.0		112.2	35.0	26.2	86.0	101.2
Feb.3	0.93	5.1	8	40.8	37.9	64.2		102.1	4.0	0.0	102.1	120.1
Mar.1	0.77	3.7	10	37.0	28.5	52.5		81.0	78.0	57.5	23.5	27.6
Mar.2	0.61	4.4	10	44.0	26.8	40.8		67.7	18.0	8.6	59.1	69.5
Mar.3	0.52	4.7	11	51.7	26.9	35.0		61.9	6.6	0.0	61.9	72.8
Apr.1	0.50	4.3	10	43.0	21.5	35.0		56.5	16.0	3.2	53.3	62.7
Apr.2	0.41	4.7	10	47.0	19.3	29.2		48.4	11.0	3.9	44.5	52.4
Apr.3	0.24	4.8	10	48.0	11.5	17.5		29.0	0.0	0.0	29.0	34.1
May.1	0.08	5.8	10	58.0	4.6	5.8		10.5	15.5	3.1	7.4	8.7
Total			191		466.5	840.0	150.0	1456.7	726.2	449.3	1011.4	1189.8

Table 3.2.7 Gross Irrigation Requirement (Upland Crops)

	Av.Kc	ETo day	Days	ETo Dec.	ET crop	Rain	Eff. Rain	Net I.R.	Gross I.R.
Apr.3	0.03	4.8	10	48.0	1.4	0.0	0.0	1.4	2.4
May.1	0.08	5.8	10	58.0	4.6	15.5	1.9	2.7	4.5
May.2	0.16	6.3	10	63.0	10.1	0.0	0.0	10.1	16.5
May.3	0.21	5.3	11	58.3	12.2	0.0	0.0	12.2	20.1
Jun.1	0.24	5.3	10	53.0	12.7	0.0	0.0	12.7	20.9
Jun.2	0.26	5.1	10	51.0	13.3	0.0	0.0	13.3	21.7
Jun.3	0.27	5.6	10	56.0	15.1	0.0	0.0	15.1	24.8
Jul.1	0.30	5.9	10	59.0	17.7	0.0	0.0	17.7	29.0
Jul.2	0.33	6.3	10	63.0	20.8	0.0	0.0	20.8	34.1
Jul.3	0.37	7.2	11	79.2	29.3	0.0	0.0	29.3	48.0
Aug.1	0.41	6.9	10	69.0	28.3	0.0	0.0	28.3	46.4
Aug.2	0.42	6.6	10	66.0	27.7	0.0	0.0	27.7	45.4
Aug.3	0.38	7.1	11	78.1	29.7	0.0	0.0	29.7	48.7
Sep.1	0.33	9.2	10	92.0	30.4	0.0	0.0	30.4	49.8
Sep.2	0.31	7.8	10	78.0	24.2	0.0	0.0	24.2	39.6
Sep.3	0.32	8.3	10	83.0	26.6	0.0	0.0	26.6	43.5
Oct.1	0.34	7.5	10	75.0	25.5	0.0	0.0	25.5	41.8
Oct.2	0.35	6.4	10	64.0	22.4	6.0	1.4	21.0	34.4
Oct.3	0.26	4.9	11	53.9	18.9	26.4	4.7	14.2	23.2
Nov.1	0.26	4.7	10	47.0	12.2	26.0	5.1	7.1	11.7
Nov.2	0.20	4.6	10	46.0	9.2	11.0	2.2	7.0	11.5
Nov.3	0.20	3.9	10	39	7.8	40.0	8.1	0.0	0.0
Dec.1	0.09	3.5	10	35	3.2	31.0	3.8	0.0	0.0
Total			234		403.3	155.9	27.2	377.0	618.0

Note : The values of water requirements computed here are based on the area of the field solely devoted to upland crops or 60 % of the total field area.

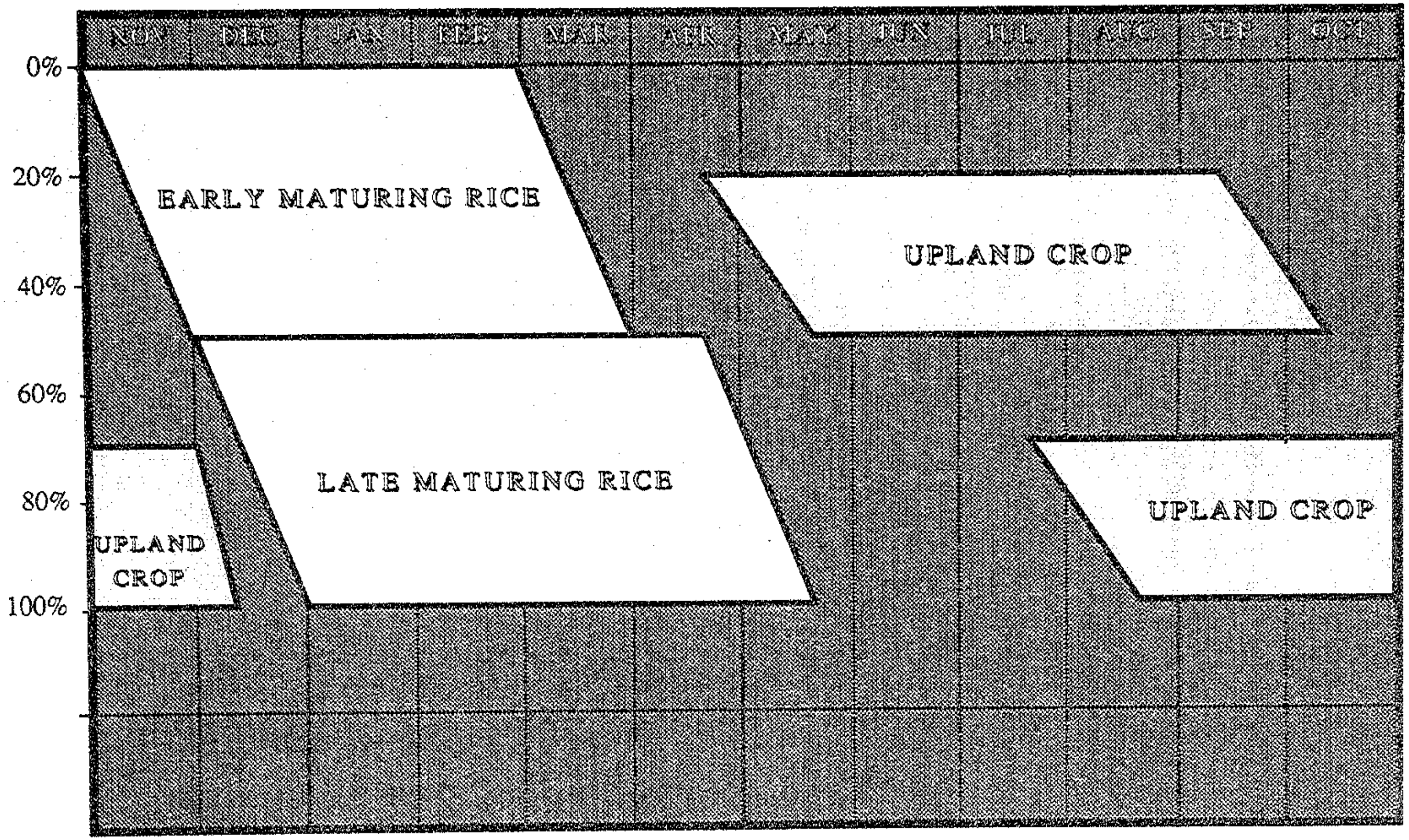

Figure 3.2.5 Cropping Calendar for Double Cropping System

3.3 Guideline of Farm Land Consolidation

3.3.1 *Aim and Scope of the Guideline*

(1) Aim of the guideline

This guideline specifies general and basic technical terms to be considered during the planning and design of farm land consolidation standards which can be applicable to the potential agricultural development areas of the Zambezi flood plain. This guideline is especially, aimed at areas where small scale farming systems are anticipated with paddy rice as a single or double crop system associated with upland crops under irrigation.

(2) Scope of the guideline

1) Applicable areas

This guideline mainly applies to the Sishanjo and the Mataba Sitapa soil type areas selected as potential development areas in the Zambezi flood plain considering topography, hydrology, soil conditions, and present agricultural practices.

2) Target agricultural requirements

The accepted cultivation systems in the guideline involve paddy rice single and double cropping systems in association with upland crops under irrigation. Farm labour is to be carried out with manpower and animal draft.

Considering the existing farm sizes (0.5 ~ 2 ha) and the targeted cropping systems, a farm block of 2 ~ 5 ha is recommended as a basic farming scale unit. A typical farming system will group several farm blocks. In one farm block, farm work management and water management are to be performed in the same condition.

3.3.2 Objectives and Standard of Farm Land Consolidation

(1) Objectives of farm land consolidation

The main objective of farm land consolidation is to increase agricultural productivity through the comprehensive consolidation of agricultural land which is the basis of agricultural production.

Farm land consolidation will result in the rearrangement or consolidation of farm lots, improvement or construction of irrigation/drainage facilities and farm roads with the aim of ensuring highly productive conditions for effective farming and rationalized water management to meet future agricultural requirements.

(2) Consolidation standard of farm land

It is difficult to introduce a high level of farm land consolidation in these areas considering natural conditions and present social, economic and agricultural standards. The basic concept for establishing the consolidation level should, therefore, be considered as follows:

1) Land consolidation here is aimed at a farm land which groups several farm blocks, and its scale should cover areas of 10 to 50 ha considering the village size in the targeted area.

2) A proposed farm land (herein referred to as "the farm land") is to be surrounded by a farm road which is useful for farming and water management and is also effective for flood protection, serving as an embankment.

3) Since direct seeding of paddy rice in dry conditions and irrigation are proposed for the farm land, minimum land grading and leveling are required. In order to minimize the earth work involved in the cutting and banking, field lots should be laid following the natural topographic slopes of the area as much as possible. And levees are to be provided at the borders of the field lots.

4) A gravity irrigation system is to be introduced from the economical viewpoint, and the most economical earth canal should be adopted. Natural small rivers/canals streamed from the tableland or the Musiamo canal which

runs along the plain edge are considered as water resources for the farm land.

5) A minimum number of irrigation canals should be planned to minimize costs depending on the present topography and the grouping conditions of farm blocks in the farm land, and plot-to-plot irrigation is basically applied in the farm block.

6) Drainage canals are to be provided at necessary portions in the farm land in order to eliminate the surplus irrigation water as well as rainwater. However, the canal section and density should be minimized to reduce the space used by the installations.

7) The number of ancillary structures in the farm land such as hydraulic facilities and other structures should be minimized. And these structures are to be structurally simple to allow easy operation and maintenance with low costs.

3.3.3 Guideline of Farm Land Consolidation

(1) Elements of farm land consolidation

This guideline covers the standard consolidating plans on the following elements:

1) Farm road,
2) Farm land readjustment,
3) Irrigation canal,
4) Drainage canal, and
5) Ancillary facility.

As previously mentioned, the scale of the proposed farm land specified in this guideline covers 10~50 ha.

(2) Farm road plan

1) *Arrangement of farm roads*

A farm road is provided around the farm land which is composed of several farm blocks with the purpose of protecting the farm land from the influence of floods. This road will also be used for farming work and the transportation of farming inputs and harvests.

In addition, field roads should be provided as farm roads inside the farm land, allowing for efficient farming operation. It is preferable to make these roads by widening the embankment of irrigation canals, the ditch border of drainage canals and levees instead of constructing them separately in order to maximize space in the farm area.

2) Width and surface elevation of farm roads

a) Peripheral road

Since the peripheral road which surrounds the farm land is required to be effective against the floods, its width and surface elevation should be decided accordingly.

i) Width of the peripheral road

The top width of the peripheral road can be determined according to the following formula which is used to determine the top width of the dike of an irrigation pond in Japan based on the safety against water wave and osmotic action.

$$B = 0.2H + 2.0 \geqq 3.0$$

where, B: Bank top width (m)
H: Embankment height (m)

Considering the embankment height (max. 2.0 m) in this area, 3.0 m for the bank top width should be enough.

On the other hand, the width of roads should be determined taking into consideration the kinds and types of expected traveling vehicles or agricultural machineries. Although there are no agricultural machinery or vehicles in the targeted area at present, small-sized trucks, tractors and trailers will have to be introduced in accordance with the farm land consolidation standards in the future.

In consideration with the above situation, the proposed width of the peripheral road should be determined in a range of 3.0 m to 3.5 m (see Figure 3.3.1).

In case two vehicles should pass each other on this road, one should yield at the crossing of the roads.

Table 3.3.1 shows the total width of vehicles expected to travel on the farm roads.

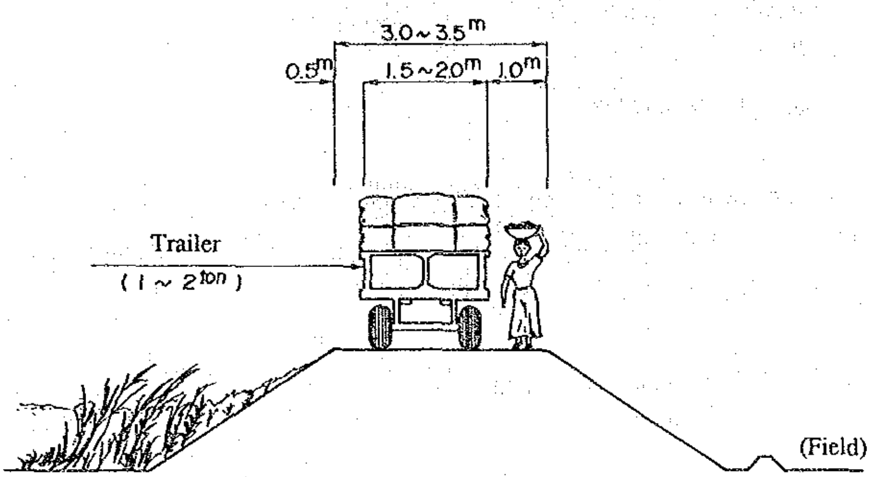

Figure 3.3.1 Top Width of Peripheral Road

Table 3.3.1 Width of Various Kinds of Vehicles for Reference

Kind	Whole-width (m)
Truck (5 ton)	2.4
" (2 ton)	1.7
Trailer (2 ton)	1.9
" (1 ton)	1.5
Tractor (Wheel type, 40 ps class)	2.0
" (Wheel type, 10 ps class)	1.3

ii) Elevation of road surface

The elevation of the peripheral road surface from the field surface is to be determined in accordance with the flooding depths. It is assumed that the flooding depths at the paddy fields in the targeted area during the flood seasons are 0.2 m ~ 0.6 m.

Furthermore, the recent big flood in 1989 recorded the maximum depths of 1.0 m ~ 1.2 m in this area.

The water level of the Little Zambezi in 1989 was the 5th highest in the last 20 years and was nearly equal to the 5-year return period. (See Appendix III.3.1)

The embankment height of the peripheral road should be determined from the 3~5-year return period flood depths. As a result, the maximum embankment heights of the peripheral road should be planned as follows:

H_{max} = FD + FB, where

H_{max} : Maximum embankment height (m),
FD : Flooding depth (m); and
FB : Height of the freeboard.

In our case, H_{max}; 1.8 m considering a flooding depth of 1.2 m and a freeboard height of 0.6 m.

b) Field road

A field road is the road used to enter the farm blocks from the peripheral road and to move from one farm block to another. It is desirable to use the embankment of irrigation canals for these purposes as much as possible. When moving inside a farm block, the ditch border of canals and levees can be used.

The top width of the main field road should be planned in a range of 2.5 ~ 3.0 m considering the travel of a single vehicle.

The height of the field road surface should be more than 30 cm above the field surface. Taking into account the passage of farming oxen to the field lots and the openness over the fields, 30 ~ 40 cm height is deemed appropriate.

3) Farm road structure

The peripheral road should include some impervious layers in its structure to protect against the flood.

Areas that are ordinarily flooded in the targeted area are composed of sandy or sandy loam soils with a permeability coefficient relatively high, in the order of 10^{-3} cm/sec. Therefore, carriage earth which shows a low permeability is required for the impervious materials of the embankment.

Clay or sandy clay soil, belonging to the Bulozi soil type and available at the lower parts of the Zambezi flood plain, is considered to be suitable as impervious material.

To prevent the piping phenomenon, which usually occurs on sandy foundations due to the difference of water head across the impervious wall of an embankment, a safe creep length must be ensured under the foundation of the embankment.

Creep length should be determined using the Bligh and Lane method. A necessary depth of 1.0 m for the cut-off wall is considered in this guideline (See III.3.2, Appendix). In this case, the maximum head difference between the outside and inside water levels is planned at 0.8 m based on the following conditions;

Outside water level:	a flooding depth of 1.2 m (5-year return period)
Inside water level:	an inundated depth of 0.4 m for the limit of maximum water depth allowing harvesting work in the paddy field.

Sodding on the side slopes of embankments is desirable to prevent slope erosion caused by waves and rainfall.

A typical cross section of the peripheral road is shown in Figure 3.3.2.

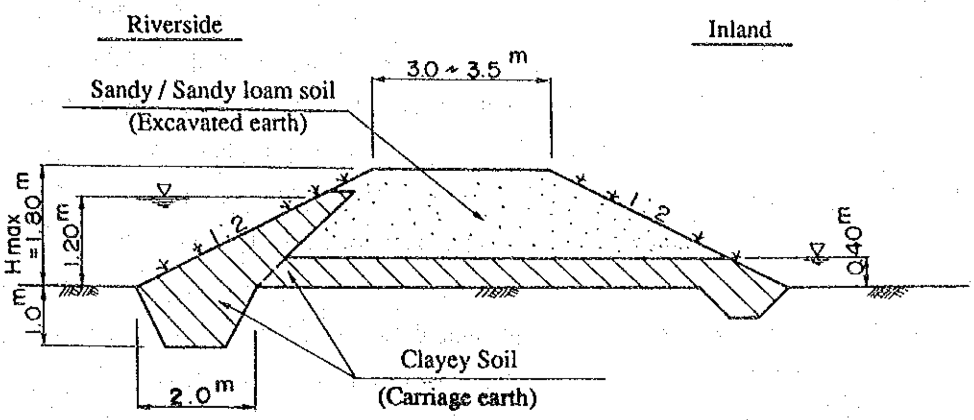

Figure 3.3.2 Typical Cross Section of Peripheral Road

As for the field road, which does not require an impervious function on its structure, excavated earth from the project area shall be used to construct the embankment of the road.

(3) Farmland readjustment plan

1) In consideration with the economy and problems related to land ownership, any parcel of land lot included in the farm land must become part of the status quo before use. In addition, necessary readjustments should be carried out in such cases as mentioned below:

a) Furrow ditches should be newly constructed when proper or adequate ditches do not exist for paddy cropping.

b) Under conditions where a land lot is extremely small, and is free of any limitations involving problems related to topography (elevation difference) or land ownership, it should be grouped together with other lots for easier cultivation and water control.

c) Any potentially cultivable land included in the Farm Land should be incorporated in a readjustment plan for the accomplishment of more efficient farming work and water allocation.

2) Sizes and shapes of field lots

The size of a field lot is generally decided by considering these main factors; introduced means of farming, water management conditions such as irrigation and drainage operations, and topographical conditions such as slope and undulations of the land.

In Japan, during the old days when plowing by oxen and horses was common practice, the typical size of a field lot was 20 m by 50 m or an area equal to 0.1 ha. With the introduction of the power tiller this size increased to 2.5 m by 80 m or an area of 0.2 ha. Nowadays, mechanized rice cropping using large-sized tractors and combines has brought the standard size between 0.3 ha to 0.5 ha.

Ordinarily, it is recommended for field lots to lay the long side in parallel with contour lines and the short side in right angle in order to minimize earth work from the viewpoint of land grading levelling costs.

Considering the present field sizes in the proposed area, and the farm labour means such as oxen and manpower, the standard size of a field lot should be 25 m by 50 with an area equal to 0.125 ha (half a lima).

3) *Levelling of paddy fields*

It is recommended in Japan that the allowable limit of land levelling of finishing works in paddy rice cropping be ±2.5 cm in the case of direct seeding in ponding conditions, ±5 cm in the case of transplanting, and ±7.5 cm in the case of direct seeding in dry conditions.

In the case of direct seeding in dry conditions, all surface water has to be drained rapidly and no residual water is permitted to remain on any part of the field during plowing as well as during the seeding and budding stage of rice.

In the proposed area the drainage conditions during the periods of plowing, seeding and budding is good due to a low groundwater table, except in a part of the Sishanjo soil type area. Therefore, the allowable limit of land levelling can be adjusted accordingly.

As a result, allowable limits of land levelling on the paddy fields in the proposed area can be recommended at ±10 cm.

4) Surface soil handling

The top soil of arable land has good characteristics for plant growth due to the accumulation over a long period of organic matters. Therefore, during the construction work of the reclamation and consolidation of paddy fields, the top soil should not be lost. To handle this properly one method is adopted, which is named as "surface soil handling". The procedure in this method is as follows: first the top soil is removed and put aside, then the subsoil is cut and banked to make a foundation, and then the top soil is refilled.

The biggest problem in cropping when surface soil handling is omitted is that subsoil will be bare and therefore productivity will extremely decrease at the cut places.

Considering the situation mentioned above, surface soil handling is desirable during the earth work of farm land consolidation in the proposed area as the thickness of the top soil layer of this area is generally thin at less than 15 cm.

5) Levee

Levees provided at the borders of all field lots play a major role in maintaining the ponding water at an even level in each field lot and also as passages for farming works.

Levees, installed as earth structures, can be embanked with borrowed earth material from near by, except where field soils are peat.

The dimensions of the levee will be planned at 0.3 m of top width, 0.3 m height with side slopes of 1:1.

(4) Irrigation canal plan

1) Canal classification

Canals described here are aimed at farmlands of approximately 10 - 50 ha in area and are functionally classified into the following branch canal and farm ditch.

Branch canal: Water is drawn off source rivers or canals into a targeted area and further into farm ditches covering each individual farming block (2 - 5 ha).

Farm ditch: A minimum unit of ditch which covers irrigation performed in each farm block of a targeted area. It is placed laterally on contour in a higher part of each farm block, to which plot-to-plot irrigation is perpendicularly applied.

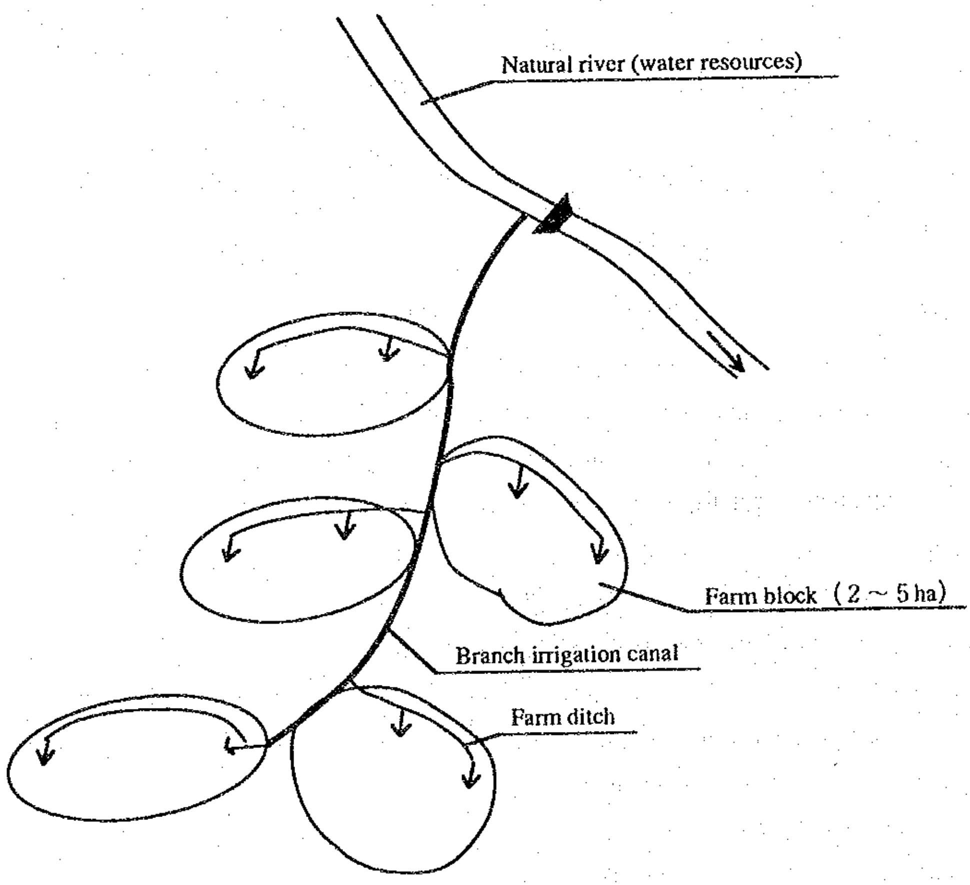

Figure 3.3.3 Typical Layout of Irrigation Canal System

2) Irrigation canal structure

Among irrigation canals, the most economical earth canal is commonly selected. However, lining or earth replacement method should be examined in such cases where ground permeability is high ($K = 10^{-4}$ cm/sec and higher) and leakage loss is significant (approx. 10% and higher), as well as where scouring and slides tend to occur and thus the maintenance of sectional shapes becomes difficult.

As the targeted area is presumably composed of sandy soil and the permeability coefficient is of the order of 10^{-3} cm/sec, the adoption of a lining method using cohesive soil is desirable.

Lining is carried out using clay or sandy clay from the flood plain, which is similarly used for the peripheral road construction material, on the base and side slopes of irrigation canals to allow a lining thickness of 10 cm and over.

3) Cross-section of irrigation canal

a) Sectional form of irrigation canal

Due to the fact that the canal has an earth canal structure and is small in scale, the section of an irrigation canal takes a trapezoidal single section form which is simple and economical.

b) Longitudinal canal gradient

The longitudinal canal gradient should be determined by the limited flow velocity in a canal which varies depending on the topographical conditions (topographical gradient) and the soil conditions of a canal included in a targeted area.

c) Allowable flow velocity in a canal

An allowable flow velocity in a canal should be, in principle, within the range of a minimum allowable flow velocity which does not cause sedimentation or the growth of aquatic plants, to the maximum allowable flow velocity in which materials inside the canal are free of erosion as well as a hydraulically unstable flow regime.

i) Maximum allowable flow velocity: V_{max}

Since the maximum allowable velocity varies remarkably with the materials used for the canals and is unclear, experience and other examples must be considered. A maximum allowable flow velocity depending on soil type recommended by Scobey is shown in Table 3.3.2 and is the one used for Japanese design standards in Table 3.3.3.

Table 3.3.2 Maximum Allowable Velocities (Scobey)

Nature of soil forming bed of the canal	Maximum allowable velocity (m/sec)		
	Clear water	Water charged with colloidal suspension material	Water charged with non-colloidal material (sand)
Fine sand (non-colloidal)	0.45	0.75	0.45
Sandy loam (non-colloidal)	0.50	0.75	0.60
Silt loam (non-colloidal)	0.60	0.90	0.60
Alluvial silt (non-colloidal)	0.60	1.00	0.60
Firm loam	0.75	1.00	0.70
Volcanic ash	0.75	1.00	0.60
Fine gravel	0.75	1.50	1.10
Stiff clay, very colloidal	1.10	1.50	0.90
Mixture of loam, sand and gravel (without colloidal elements)	1.10	1.50	1.50
Alluvial silt (colloidal)	1.10	1.50	0.90
Mixture of loam, sand and gravel (without colloidal elements)	1.20	1.70	1.50
Gravel	1.20	1.80	2.00
Cobbles and shingles	1.50	1.70	2.00
Shales and hard pans	1.80	1.80	1.50

Table 3.3.3 Maximum Allowable Velocity (Japanese design standard: canal works)

Soil type	Flow velocity (m/sec)
Sandy soil	0.45
Sandy loam	0.60
Loam	0.70
Clayey loam	0.90
Clay	1.00
Sandy clay	1.20
Soft rock	2.00
Semi-hard rock	2.50
Hard rock	3.00

As the canal in the targeted area is mainly composed of sandy loam, a maximum allowable velocity is set to V_{max} = 0.6 m/sec. (For a durable structure, e.g. perfect clay lining Vmax = 0.9 m/sec. can be satisfactory; otherwise, Vmax = 0.6 m/sec. as has been recommended in this plan is selected for safety.)

ii) Minimum allowable flow velocity: V_{min}

Kennedy's formula is widely used to determine the mean flow velocity which does not cause sedimentation or scouring inside a canal.

$$Vs = C \cdot D^{0.64}$$

where, *Vs*: Flow velocity which does not cause sedimentation and scouring (m/sec)
D: Water depth (m)
C: Coefficient of soil texture
light fine sandy soil: 0.46
heavy coarse sandy soil: 0.51
sandy loam: 0.56
coarse silt or hard soil: 0.60

Based on the above formula, Vs values depending on water depth in a canal are shown in Table 3.3.4. Value C there is 0.56 (sandy loam).

Table 3.3.4 Vs Values by Kennedy's Formula

D (m)	0.2	0.3	0.4	0.5
Vs (m/sec)	0.20	0.26	0.31	0.36

As the water depth of the canal in the targeted area is 0.4 m and under, a minimum allowable flow velocity is set to V_{min} = 0.3 m/s.

d) Rate of discharge in a canal and calculation of flow velocity

i) Discharge of canal

Discharge rate is calculated using the following expression.

$$Q = A \cdot V$$

where, Q: Discharge (m^3/sec)
A: Cross-section area (m^2)
V: Mean velocity (m/sec)

ii) Formula of mean flow velocity

Mean flow velocity (uniform flow) in an open channel is calculated following the Mannings' formula which is widely used because of its high accuracy and easiness.

$$V = \frac{1}{n} \cdot R^{2/3} \cdot I^{1/2}$$

where, V: Mean flow velocity (m/sec)
I: Hydraulic gradient (canal bed slope)
R: Hydraulic radius (m)
n: Coefficient of roughness

Roughness coefficient is determined as n = 0.030 based on values used in Japanese design standard and deducted from various canal construction examples as well as ones otherwise recommended in other literatures, taking the conditions of planned canal into consideration. The roughness coefficient recommended by the Japanese design standard is shown in Table 3.3.5.

Table 3.3.5 Roughness Coefficient for Excavated or Dredged Canals

Materials and conditions of canals	Coefficient of roughness		
	Minimum value	Standard value	Maximum value
Earth canals, uniform and straight			
1) No weeds (immediately after completion of the canal)	0.016	0.018	0.020
2) No weeds (after the canal has been exposed to weather)	0.018	0.022	0.025
3) Sand (no weeds)	0.022	0.025	0.030
4) No weeds except some short grasses	0.022	0.027	0.033
Earth canals, non-uniform and bent			
1) No vegetation coverage	0.023	0.025	0.030
2) Some weeds	0.025	0.030	0.033
3) Weeds and aquatic plants are growing densely	0.030	0.035	0.040
4) Earth bottom and rubble at both sides	0.028	0.030	0.035
5) Earth bottom and weedy sides	0.025	0.035	0.040
6) Cobblestones on the bottom and no weeds at either side	0.030	0.040	0.050

(Japanese design standard: Canal works)

e) Inside slope gradient of canal

The inside slopes of canals should maintain their stability without being subjected to sliding, scouring and erosion induced by flowing water and natural conditions. The inside slope gradient is determined by such conditions as texture, the cutting depth and the banking height ground.

The planned canal in the targeted area is small in scale. However, as soil is mainly composed of sand, the slope gradient (vertical: horizontal) is generally determined as follows:

Inside slope of canal by cutting 1 : 1.5
Inside slope of canal by banking 1 : 1.5 ~ 1 : 2.0

When the Namushakende and Lealui Verification Farms were created, the inside slope gradient in the banking area for irrigation canals and the cutting area for drainage canals were as follows:

Table 3.3.6 Inside Slopes of Canals at Verification Farms

	Irrigation canal	Drainage canal	Soil type
Namushakende	1 : 1.5	1 : 1.5	Muck/mucky peat, sandy
Lealui farm	1 : 2.0	1 : 2.0	Sandy

Meanwhile, in the Japanese design standard, standard values are empirically found depending on soil textures, the height of cutting and banking as shown in Table 3.3.7.

When the height of cutting and banking becomes large in scale, slope gradients, which are safe and economical, are usually determined by slope stability analysis based on values obtained from soil tests.

Table 3.3.7 Standard Side Slope Gradients of Canals (1 : s)

Soil type	Cutting	Embankment (inside)		Embankment (outside)	
		less than 3 m	more than 3 m	less than 3 m	more than 3 m
Sandy soil	1.5 ~ 2.0	2.0 ~ 2.5	2.5	2.0	2.5
Sandy gravel	1.0 ~ 1.5	1.5 ~ 2.0	2.0	2.0	2.0
Loam	0.5 ~ 1.0	1.0 ~ 2.0	"	1.5	"
Clayey soil	"	"	"	"	"
Clay contained gravel	"	"	"	"	"
Rock	0 ~ 0.5	-	-	-	-

(Japanese design standard)

f) Freeboard of canal

Freeboard refers to the elevation of a design water level set to maintain safety within the canal against high-water levels and waves tentatively produced within a canal. It is determined after due consideration of such parameters as flow rate in a canal, scale, significance and inflow flood.

Japanese design standard sets the following three parameters as significant freeboard which require consideration.

i) Freeboard against the fluctuation of roughness coefficient
ii) Freeboard against the potential conversion from velocity head to hydrostatic head
iii) Freeboard against the surface oscillation caused by hydraulic facilities (gates, etc.) and wind action in a canal.

Freeboard for a canal constructed with and without lining is computed using the formula below:

$$Fb = 0.05d + hv + 0.10$$

where, Fb: Freeboard (m)
d: Water depth for design discharge (m)
hv: Velocity head (m) = $V^2/2g$
g: Acceleration of gravity (m/s^2)

In case free board value computed from the above formula is below 0.3 m, other empirical formulas should be considered to obtain a minimum freeboard value of 0.3 m.

g) Base width and water-depth ratio of a canal

The following relational expression of base width and water depth is used as a design base width of a canal proportionate to the flow volume in a canal.

$$d = 0.5 \cdot b^{1/2}$$

where, d: Water depth (m)
b: Base width (m)

In the case of a canal with trapezoidal single sections and small flow amounts, the ratio of base width to water depth should be determined within the range of 1:1 - 3:1.

h) Typical cross-section of a canal

After due consideration of the aforementioned conditions, a typical cross-section designed for a branch canal planned in the targeted area is shown in Figure 3.3.4.

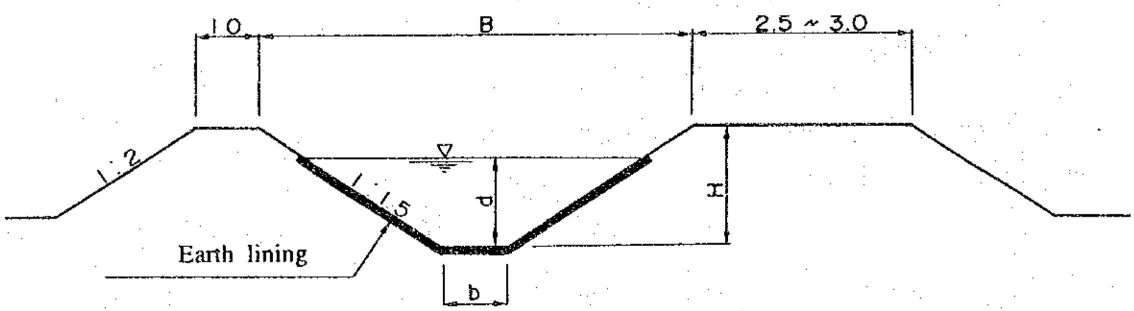

Figure 3.3.4 Typical Cross-section of Branch Irrigation Canal

Table 3.3.8 Typical Dimensions of Branch Canals

Irrigation area (ha)	Discharge Q (m^3/s)	Canal slope I	b (m)	d (m)	H (m)	B (m)
50	0.087	1/1000	0.40	0.31	0.70	2.50
40	0.069	"	0.30	0.30	0.60	2.10
30	0.052	1/500	0.25	0.23	0.60	2.05
20	0.035	"	0.20	0.20	0.50	1.70

Note: 1) Unit water requirements: q = 1.734 ℓ/sec/ha (refer to 3.2.2(4))
2) Results of hydraulic analysis are presented in Appendix III.3.3.

(5) Drainage canal plan

1) Need of drainage

The drainage is equipped aiming at the elimination of surface surplus water caused by heavy rainfall as well as rainwater in the period of upland farming. In the case of a double cropping system, the drainage should fulfill two functions, that is, the elimination of surface water and the elimination of ground water.

2) Classification of drainage canal

The drainage is classified into farm drains which directly discharge water from a farm land, and branch drainage canals which further discharge water off the farming area.

a) Farm drain

The farm ditch drainage canal is equipped downstream in each individual farming area aiming at the elimination of surface water, in which it discharges surface surplus water or storm water off into a branch drainage canal. The farm drain simultaneously serves to eliminate ground water produced by soil moisture or the percolation of stored water in depressions on the farm land surface.

b) Branch drainage canal

The branch drainage canal discharges water from a farm drain off the farming area. A branch drainage canal end is connected to neighboring natural rivers and drainages, if there are any. However, if no nearby rivers and drainage are available, a canal end is drawn to the lower part of outside area to allow subsurface infiltration during the period when the ground water level is low.

3) Structure and cross-section of drainage

The drainage should be constructed without lining and its cross-section should be minimum in scale. An adequate canal depth is 0.3 - 0.5 m when aimed only at the elimination of surface water. However, a depth of 0.7 m or more is required when the elimination of ground water is considered for the prevention of wet injury in dry field farming.

A subsurface water level which does not affect the growth of wheat and maize has been set to 0.4 - 0.5 m and below the ground surface. When considering ground water drainage, a depth and interval of the farm drain should be set, when soil permeability is higher, smaller and wider respectively. Table 3.3.9 shows the relation between soil texture or permeability coefficient and drainage depth and interval.

Table 3.3.9 Relationship between Soil Characteristics and the Depth/Internal of Farm Drains

Soil texture	Soil permeability coefficient (cm/sec)	Farm drainage canal depth (m)	Farm drainage canal interval (m)
Clayey loam	$10^{-4} \sim 10^{-5}$	1.0 ~ 1.2	50 ~ 120
Loam	10^{-4}	0.8 ~ 1.0	100 ~ 150
Sandy loam	10^{-3}	0.7 ~ 0.8	120 ~ 200

(Source: Paddy Field Engineering by F. Yamazaki)

Considering that the targeted area is mainly composed of sandy loam or sand, and its permeability coefficient is between 10^{-3} - 10^{-4} cm/sec, a mean depth of the farm drain is typically set at 0.8 m, in doing so, an effective lowering of the water level to the extent of 50 m - 100 m is expected.

The side slope gradient of the drainage canal is typically determined, considering its depth and primary texture, at 1:1.5. The performance of sodding is desirable to prevent slope erosion caused by rainfall.

The base width of the drainage canal is typically set at 0.3 m. On the farm land side, a ditch border with a width of 0.5 m and a height of 0.3 m is equipped to secure a path within a farming area.

Typical cross-section of the drainage is shown in Figure 3.3.5.

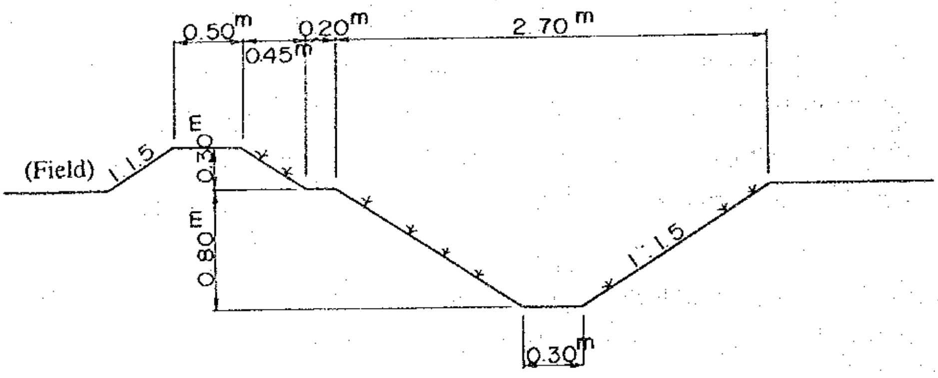

Figure 3.3.5 Typical Cross-section of Drainage Canal

(6) Ancillary facility plan

With the improvement of farm land, such ancillary facilities as water diversion, water level control, road culverts, drainage sluice are required.

The water diversion method includes the diversion from the branch canal to the ditch and from the ditch to a farm lot. For the diversion from the branch canal to the ditch, when the flow amount is small, pipe diversion which is economical and has a simple structure, is used. The equipment of a simple gate at an intake is desirable for water control. Moreover, it is desirable to equip a check gate inside the branch canal in order to maintain adequate water levels required as well as to enable easy diversion.

The simplest diversion from the ditch to a farm lot or canal equipped in a farm is attained by the equipment of a notch at a ditch-side border or burying a pipe and controlling water using sand-bags. In order to perform more strict water control, an intake is desirably to be of a fixed structure, such as concrete blocks, with stop logs or a gate. Each of the above is equipped at an interval of 50 - 100 m.

In the case where a canal crosses a road, a pipe culvert of crossing structure, concrete or asbestos, will be provided.

In order to attain drainage operations covering the entire planned area, sluices are to be equipped on the peripheral road on the branch drainage. The gate of the sluice is opened when discharge from inside the area is required and gravity discharge is possible. It is closed when external water levels are high and the prevention of water invasion is required. The sluices should be of a water tight construction including concrete blocks or reinforced concrete, and be equipped with a simple steel gate or a steel framed wooden gate.

3.4 Standard Land Use in the Mweke Dambo

3.4.1 Characteristics of the Mweke Dambo

The Mweke dambo is located on the sandy high lands approximately 20 km east of Mongu. It is a "coupled dambo" with a natural water reservoir in the plateau, upper dambo, and a swampy depression in the valley, lower dambo.

The lower dambo is a main part of farming in this area, which has a 5 km length, 3 km width, with a maximum relative height of 2.0 m between the edge and center.

In the dry season, maize is cultivated in the central portion of the lower dambo using the available soil moisture and in the wet season, rice is cultivated in the inundated portion, and early maize in the edges of the dambo.

Rice is planted in October to November, and harvested in May to June, but these are variable and depend on the yearly regimes of rainfall and flooding.

Other crops are millet and cassava which are usually cultivated around the sandy plateau.

The soils of the lower dambo are sandy at the edge, mostly silty clay in the central zone, and sandy loam to silty loam in the transitional zone. The thickness of these top soils is around 30 cm, and the subsoils are totally sandy. Values of pH (H_2O) of the soils are 6.0~6.5.

A change in the yearly rainfall is the most serious factor for the agricultural production in the Mweke area where agricultural crops are entirely fed through rain water. Although the soil condition of this area is relatively fertile and suitable for the cultivation of cereals such as rice and maize, the production of these crops is low due to the unstabilities in the rainfall amount and duration, especially the shortage of rainfall.

3.4.2 Standard Land Use Scheme in the Mweke Dambo

(1) Objectives

Select the suitable crops in the Mweke dambo area and determine a standard land use scheme considering topography, hydrology, soil conditions, present planting practices and the results of the agricultural verification trials.

(2) Relation of topography and soil distribution in the dambo

Relation of topography and soil distribution in the lower dambo of Mweke is shown in Figure 3.4.1 (Plan) and Figure 3.4.2 (Section).

These figures show that silty clay loam soils dominate vastly in the lower part of the dambo where temporary elevations (in reference with established B.M.) are between 7.5 and 8.0 m.

(3) Water level mechanism of the dambo

Water level fluctuations in the central lower part of the Mweke lower dambo, measured during the AVS are shown in Figure 3.4.3. According to the curves recorded from January 1989 to April 1992, the water level of the central portion of the dambo shows a rise above the ground surface from January and reaches a peak in April after the rains. It drops gradually after the peak and reaches below ground in September, and the lowest level appears in November to December just before the beginning of the rains.

The water level in 1989 was exceptionally high and inundated the area almost throughout the year due to the extremely heavy rains recorded during that year, which were the biggest rains recorded in the last 10 years. On the contrary, rainfall in 1992 was 2nd smallest in the last 10 years, resulting in a water depth, duration and inundated area extremely limited compared to ordinary years.

Figure 3.4.4 shows the relationship between inundation levels and inundation areas in the Mweke lower dambo.

(4) Cropping plan

Considering the above described topography, hydrology, and soil conditions of the dambo, and also the present cropping patterns, cropping programs concerning rice and maize, main crops of the area, were explained.

1) Rice

Based on the actual cropping patterns in the area and also the results of the verification study, the suitable planting period of rice can be estimated from middle November to early December, and the harvesting period will be from early to middle April in the case of early varieties and from late April to middle May in the case of late varieties. The deep water varieties are desirable because they are more adapted to yearly variable depths. Based on a standard maximum water depth, an area with the appropriate altitude should be selected.

2) Maize

As the planting period is desirable from middle to late July, an area with an underground water level of about 15 cm below the soil surface should be selected. The harvesting period will be aimed for late November.

As the heading period (from middle to late October) falls during the low groundwater period in general, it is important to secure supplemental water.

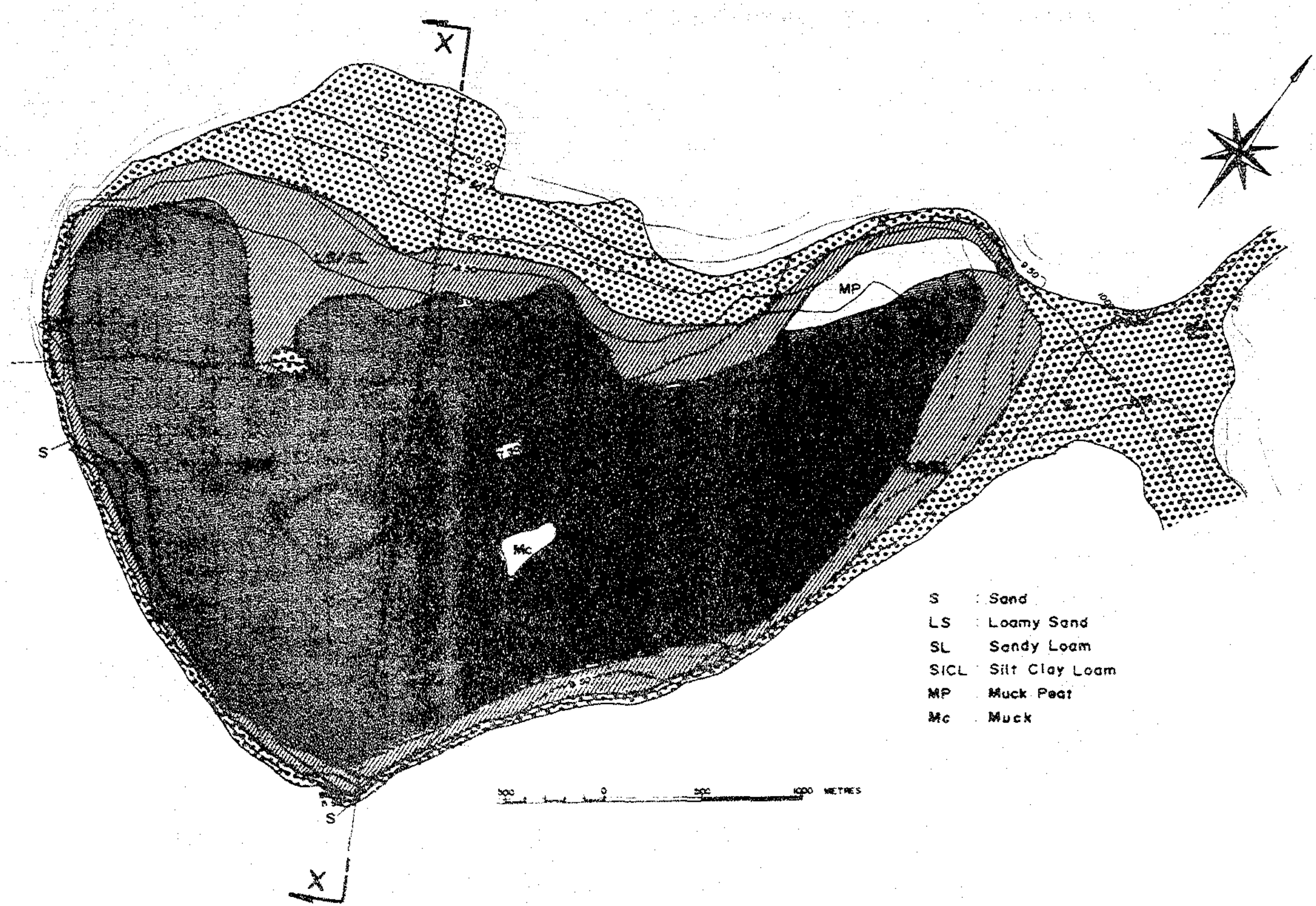

Figure 3.4.1 Topographical Map at Mweke Lower Dambo

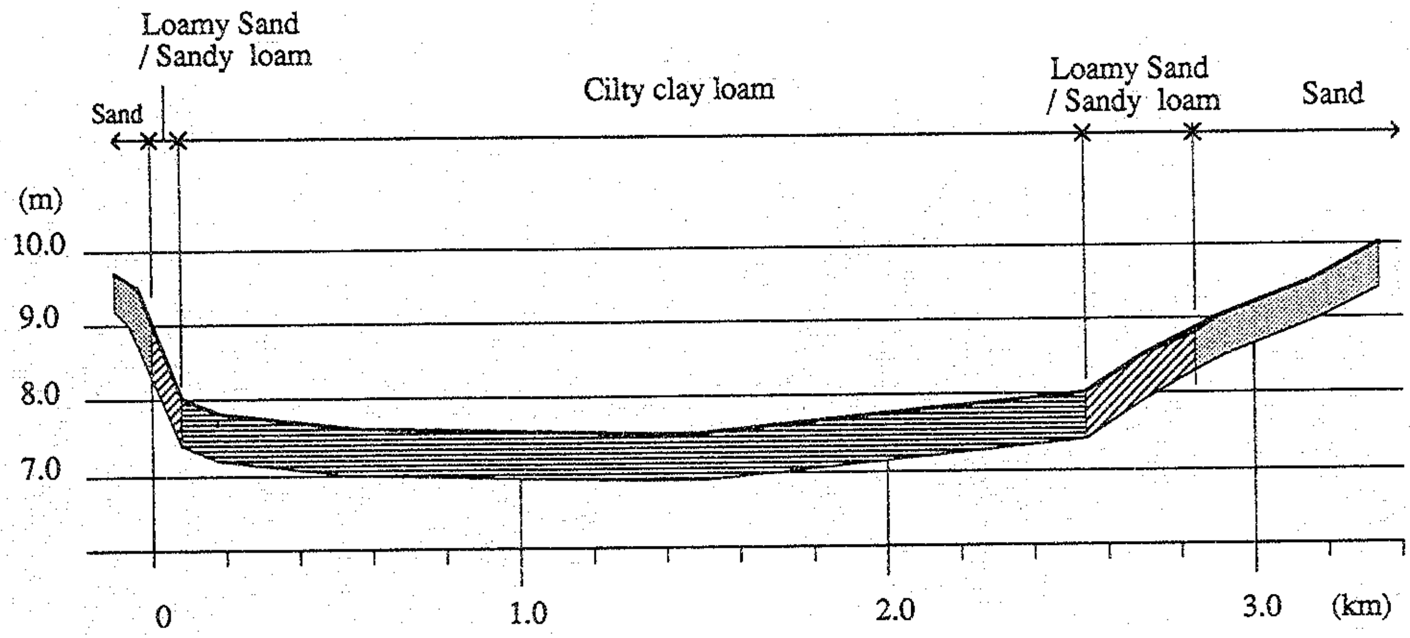

Figure 3.4.2 Topographical Cross Section at Mweke Lower Dambo

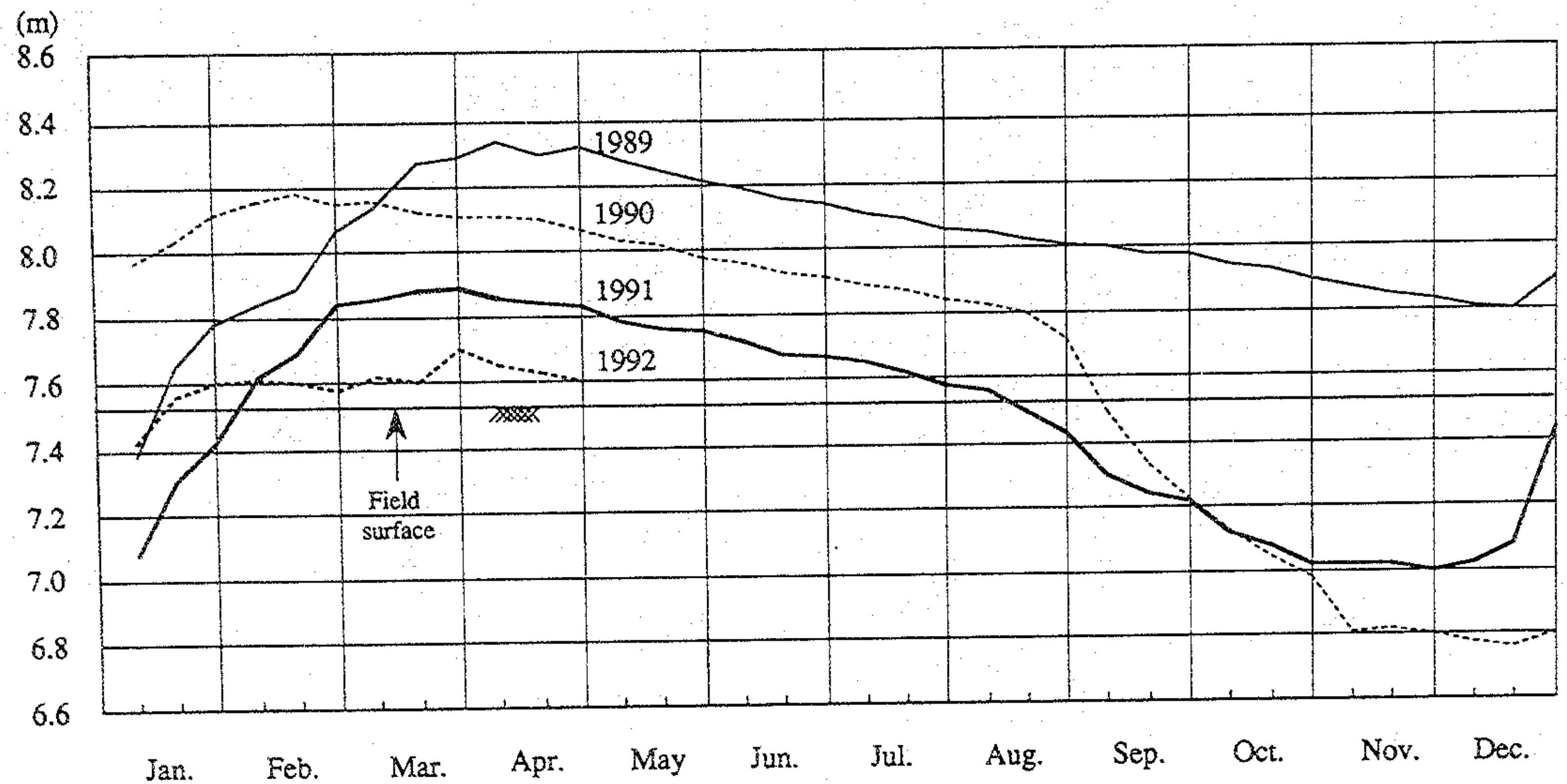

Figure 3.4.3 Water Level Fluctuations at Mweke Lower Dambo (Lower Central Part)

Jan. 1989 ~ Apr. 1992

Ground Level (m)	Area (ha)	Cumulative Area (ha)
~ 7.5	120	120
7.5 ~ 8.0	580	700
8.0 ~ 8.5	180	880
8.5 ~ 9.0	160	1,040
9.0 ~ 9.5	140	1,180

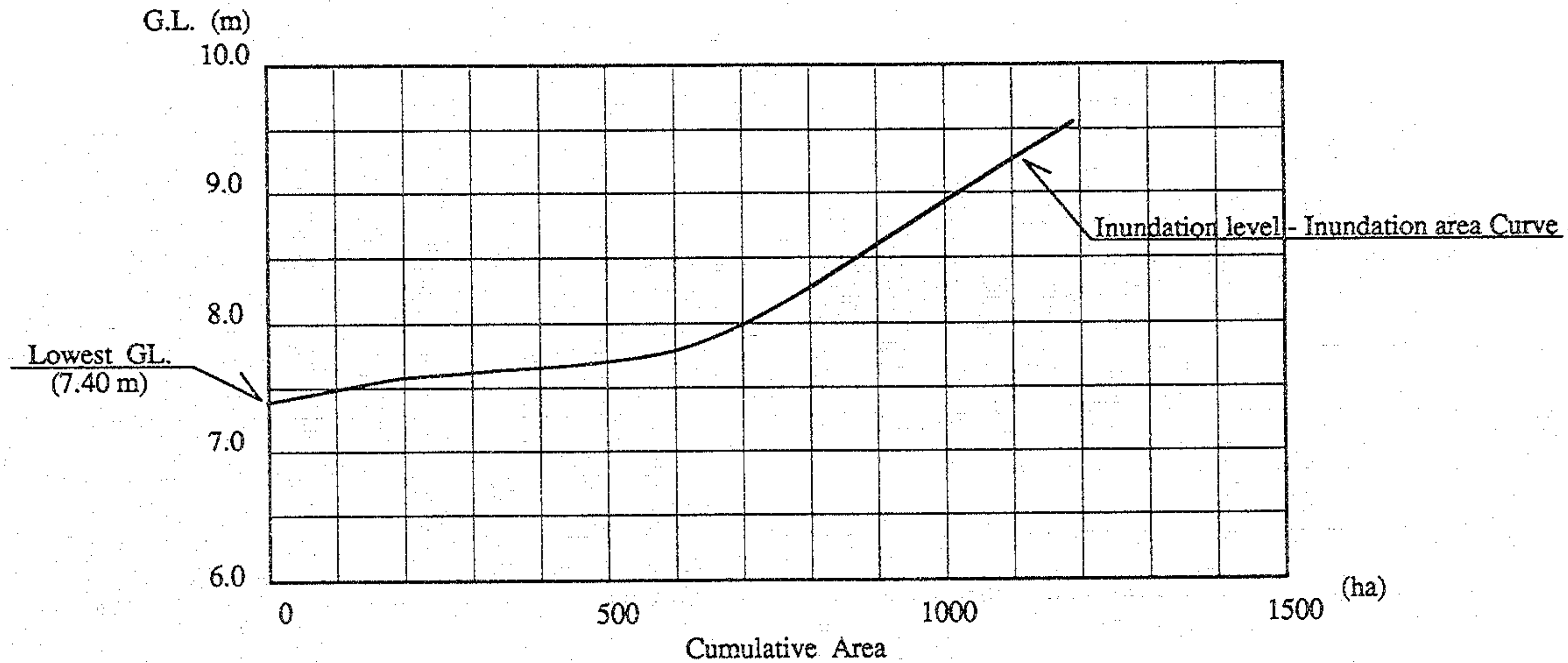

Figure 3.4.4 Inundation Level - Inundation Area Curve for Mweke Lower Dambo

CHAPTER 4.

CONCLUSION AND RECOMMENDATION

CHAPTER 4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

As already described, the Western Province is the broad sandy high land with an altitude ranging from 1,200 m in the northeast to 800 m in the south-west. The Zambezi river streams the center of the province from north to south and the large flood plain of the Zambezi and its tributaries located about 40 m below the high lands lays linking them with a gentle slope. The soil bed of the flood plain is Kalahari sand; however, there are many kinds of surface soils with many characteristics originating from different sediments owing to the difference of altitude, groundwater level, topography, etc...The main agricultural area in Mongu is the flood plain which also constitutes the main target of the verification study. At present, there are no artificial facilities in the flood plain and rice is grown as a main crop by traditional small farms.

Owing to a large variability in the rainfall pattern, crop production is unstable resulting in a wide fluctuation of planted areas and yields. However, there are places in the flood plain with somewhat good fertility, which are barely influenced by floods and have the advantage of getting irrigation water during the dry season. In these areas, stable agricultural production can be expected if an appropriate technology and the necessary minimum land consolidation conditions are applied for the small scale farms.

Studies and surveys have been carried out in the verification farms and surrounding areas for four years. Based on the results of these studies and surveys, the guideline involving farming systems, useful component technologies, irrigation and water management, and farm land consolidation were decided. The points of these guidelines are as follows :

(1) Farming systems

The guideline refers to the cropping systems involed and shows details of related cultural operations. By following the guideline, a given farming system can be practiced. The actual farming systems are (1) Early rice single cropping, (2) Late rice single cropping, (3) Early rice - Wheat double cropping, (4) Early rice - Onion double cropping, (5) Early rice - Cabbage double cropping, (6) Late rice - Maize double cropping, and (7) Late rice - Tomato double cropping.

In the actual farmer's field, depending on the conditions of the field and labor, the above mentioned systems are practiced in combination with each other. One example is shown as a model.

(2) Useful component technologies

During the conduct of the verification study some technologies which have been approved as being useful, were proposed as individual or separate technologies not as main system technology. These are (1) Line makers and drill seeders for rice, (2) Effective sowing and effective fertilizer application methods in sandy soil, (3) Use of grass ash and straw ash in peat muck soil, (4) Rice straw incorporation on paddy field.

(3) Irrigation and water management

Relevant irrigation factors for paddy rice and dry season upland crops in a double cropping system with rice are determined depending on the AVS findings and the farming plan adopted in the guideline. A water requirement plan and planning procedures for the Mataba seepage zone in the flood plain edge area are also determined.

A farmer's organization establishment is recommended in relation to irrigation practice, on-farm irrigation facilities, maintenance and management.

(4) Farm land consolidation

A farm block of 2 to 5 ha is selected as a basic unit of farming scale, and a typical farming system which groups several farm blocks with the size of 10 to 50 ha is recommended. A farm road is planned around the farm land and is designed to protect the latter from the influence of the flood as well as to serve as a means of transportation for farming inputs and harvests.

In the farm land, minimum land grading and leveling are recommended considering that direct seeding of paddy rice in dry conditions is adopted. Gravity irrigation is introduced and branch irrigation canal and farm ditches are proposed in the farm land with plot-to-plot irrigation to be applied in each farm block.

Finally, standard consolidating plans for farm roads, land readjustment, irrigation and drainage canals, and ancillary facilities were shown in this guideline.

Due to these guidelines, more stable farming systems with a higher percentage of land use and higher income compared to the present systems, are expected to be achieved.

4.2 Recommendation

The agricultural verification survey resulted in the elaboration of technical guidelines for crop production and production infrastructure improvements. In order to achieve a stabilized production at the edge of the flood plain of the Zambezi River as well as in similar areas throughout Zambia, it is necessary, based on the above guidelines, to make agricultural technology available in the areas and further to spread and strengthen training systems for the enhancement of technology transfers. It is also required, along with the above, to establish a development plan for the project area and to implement the project. It is desirable that a development plan includes, in addition to the items included in the agricultural verification survey, social and financial surveys in the project area to examine necessary facilities and organizations for obtaining a post harvest that adds value to the negotiability of the harvest and the harvest itself. It is also desirable that the plan is such that it serves for the organization of infrastructures in farming villages as well as for the establishment of continuous agriculture. It is desirable that the implementation of the development project of agriculture and farming villages be accomplished through the effort of the government of Zambia, and aid from foreign countries. We also propose to the government of Zambia to immediately start studies on the operation of the project after implementation and maintenance of facilities along with the establishment of a guiding system.

These guidelines were made based on the results obtained from surveys and studies included in the agricultural verification tests performed over a period of four years. However, as surveys and experiments were limited to the aforementioned two farm areas, further surveys into expanded areas are required. It is strongly recommended that the proposed guidelines be revised based on added surveys.

The issues to be dealt with are categorized in the following two groups:

(1) Issues requiring short or middle-term review

1) The selection of paddy varieties adaptable for flood plain soil (depending on the soil types).

2) The selection of such varieties as wheat, maize and tomatoes that are adaptable for double-cropping with paddy in the flood plain soils.

3) The promotion of hydrological and soil surveys for farmland improvements.

4) The development of simple apparatus including man-operated threshers and transporters.

5) The spread of agricultural technology and the strengthening of training systems.

6) The promotion of the creation of farmers organization.

(2) Issues requiring middle or long-term reviews

1) The breeding of excellent varieties of paddy and that of field crops that constitute two-crop systems with paddy.

2) The grading and evaluation of potential areas for development.

3) The promotion of farmers organizations and the establishment of reinforcement systems.

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