ANNEX-K

IRRIGATION AND DRAINAGE

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IRRIGATION AND DRAINAGE

1. INTRODUCTION

This ANNEX details the development plan on irrigation, drainage, flood protection dike, farm roads along canals, and on-farm works plans which has been worked out based on the results of the study and analysis on data and information collected through inventory survey, field inspection, interview with farmers and the government agencies concerned, and also the results of field measurements executed by JICA Study Team himself. Design concept for project facilities has followed that for the Lower Moshi Project Area since these project facilities have functioned well.

Chapter 2 shows the present conditions of irrigation and drainage facilities, flood dikes and farm roads including on-farm facilities which have been examined mainly through inventory survey. The problems envisaged with the existing project facilities have been also clarified and mentioned in this chapter.

Chapter 3 presents the study results on irrigation water requirement based on the proposed attractive cropping pattern and irrigation efficiencies, and the required rehabilitation works which have been planned based this irrigation water requirement and results of inventory survey.

Chapter 4 relates the development plan of drainage works, which has been formulated mainly based on the study results on the drainage system provided for the Existing Lower Moshi Project Area. The Plan includes not only the drainage system for the Expanded Area and the New extension Area, but also the rehabilitation plan for the existing drainage system for the Existing Lower Moshi Project Area.

Chapter 5 discusses the flood protection work for the Mandaka Mnono area in the Expanded Area. There are two flood protection dikes: One is against the Rau river, and the other against floods from some small steams flowing from hilly area. The design concept for flood protection works has also followed that for the Existing Lower Moshi Project Area because the existing flood protection work has worked satisfactorily.

Chapter 6 gives the farm road development plan for the Project area including a diversion channel. The rehabilitation of the existing farm roads in the Existing Lower Moshi Project Area is also included in this chapter.

Chapter 7 mentions the on-farm work development plan for the Expanded Area, New Extension Area, and also the upland crop area of the Existing Lower Moshi Project Area which will be changed into paddy field area.

2. PRESENT CONDITIONS

2.1 General

The Project area is divided into three areas: the Existing Lower Moshi Project Area, Expanded Area and New Extension Area. Out of them, irrigation activities are executed only for the Existing Lower Moshi Project Area and Expanded Area. Therefore, a review on irrigation and drainage systems has been concentrated upon these areas.

2.2 Irrigation System

2.2.1 Water Source for Irrigation

(1) Existing Lower Moshi Project Area

A water source for the Existing Lower Moshi Project Area is the Njoro and Rau rivers. As mentioned in ANNEX-A, the river discharge has decreased year by year. This tendency is remarkably observed on the Rau river. The average monthly discharge in the dry season in 1994 became to 0.56 m^3/s which is so lower than 1.13m^3/s of the authorised water right. The reason of discharge decrease is due to unplanned water tapping at upstream area where paddy cultivation has been vigorously conducted by observing the success of the Existing Lower Moshi Project Area. The Existing Lower Moshi Project Area has subsequently envisaged severe water shortage and was consequently involved in the serious water conflict in 1995. In order to cope with such severe situation, it is essential to exploit a new additional water source urgently. The Kikuletwa river, a tributary of Pangani river, is expected as a new additional water source which has a high potential according to a hydrological analysis. 80% dependable flow of the Kikuletwa river at IDD54 is calculated as follows:

(Unit : m^3/s)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
10.4	10.5	10.6	13.2	16.4	11.8	11.1	11.0	10.7	10.9	10.4	10.3

A possibility of the Kikuletwa river as a new additional water source is discussed in ANNEX-J.

(2) Expanded Area

The Expanded Area is divided into two areas: Kaloleni area and Mandaka Mnono area. The Kaloleni area is further divided into three areas by the Njoro and Mamba rivers, that is Northern Kaloleni area, Western Kaloleni area, and Southern Kaloleni area. The existing water sources for these areas are as follows:

(a) Northern Kaloleni area : Three springs
(b) Eastern Kaloleni area : Spring
(c) Southern Kaloleni area : Goa spring and Njoro river.

As the results of field inspection of these springs and interview with farmers concerned, it has been confirmed that these water sources have been enough for irrigation to these areas.

On the other hand, a water source for irrigation of the Mandaka Mnono area is the Mwanangurawe spring. According to the discharge measurement for the spring, its discharge is approximately 300 l/s which is not enough to irrigate all the Mandaka Mnono area of 360 ha in net. Therefore, supplemental water source is essential. The Mamba river is considered as a supplemental water source, whose details are discussed in ANNEX-J.

(3) New Extension Area

As mentioned above, no irrigation activities are conducted for this area. All crop cultivation, mostly maize cultivation, is made under rainfed condition.

2.2.2 Irrigation Method

Out of the Project area, the Existing Lower Moshi Project Area and the Expanded Area are covered with the irrigation canal system. The former area is provided with sophisticated canal system, but the latter area with a primitive one. The both systems are designed to supply irrigation water to each field by gravity. In the former area, water continuously flows down to tertiary canals through main and secondary canals, and then delivers to respective field plots by rotation. In the latter area, water supply is continuously made to each field on the farmers'demand basis. Details of irrigation method are discussed in ANNEX-N.

2.2.3 Field Water Requirement

Data for field water requirement of paddy is available only for the Existing Lower Moshi Project Area, where many field tests on water requirement for paddy were carried out by KADC, KADP and KATC. In order to make a cross check for the test results, JICA Study Team has also made field tests using paddy fields in the Existing Lower Moshi Project Area. These test results have been analysed as follows:

(1) Field Measurement by KADC at Pilot Farm

The pilot farm of 10 ha located in the Chekereni area was completed in 1981. Out of 10 ha, 2.4 ha was cultivated with paddy. A field test was executed by KADC in 1982 and 1984 using this paddy field. The results are given in Table K.2.1. As can be seen in this table, evapo-transpiration and percolation measured in 1982, say field water requirement ranges from 11.0 mm to 18.0 mm, and its average is 16.3 mm. These figures are slightly higher to those in Chekereni area measured by KADP which are discussed below, due mainly to just reclaimed paddy field.

Measurement data in 1984 is equivalent to about 70% of those by KADP in Chekereni area. The reason of lower values in 1984 is deemed to be due to creation of pan by continuous cultivation.

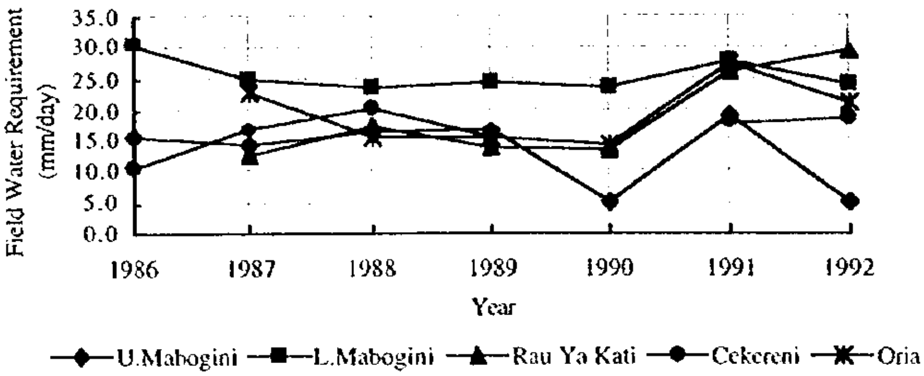
(2) Field measurement by KADP at Existing Lower Moshi Project Area

In parallel to commencement of water supply to fields, KADP has started the measurement of field water requirement for the selected field plots in five areas such as Upper Mabogini, Lower Mabogini, Rau Ya Kati, Chekereni and Oria areas including pilot area in 1986, and has substantially continued by 1992.

(a) Yearly variation

Table K.2.2 shows the average field water requirements observed from 1986 to 1992. From this table, a yearly tendency for respective areas is graphed below:

Yearly Variation of Field Water Requirement



The graph indicates the different tendency for respective areas.

1) Upper Mabogini area

The field water requirements observed at the Upper Mabogini area show an almost constant tendency although those sharply fell in 1990 and 1992.

2) Lower Mabogini area

The field water requirements measured at the Lower Mabogini area range from 23.5 mm/day to 30.5 mm/day. It would approach to 24 mm/day.

3) Rau Ya Kati area

The field water requirements measured at the Rau Ya Kati area present a small change from 12.8 mm/day to 17.6 mm/day in four years from 1987 to 1990, but those in the remaining two years of 1991 and 1992 show a large increase.

4) Chekereni area

The field water requirements measured at the Chekereni area present a gradually increase with small variation, and would come to around 19 mm/day.

5) Oria area

The field water requirements measured at the Oria area present a gradually decrease in the first four years from 1987 to 1990, but thereafter a sudden increase for two years of 1991 and 1992.

As a general tendency in all five areas, it was observed that the field water requirements in the first four years from 1988 to 1990 showed a small fluctuation, but those in the first year of 1986, and latter two years of 1991 and 1992 a large fluctuation. It was deemed that such general tendency would be due to occurrence of cracks in soils which were brought by long fallow period caused by water shortage.

(b) Seasonal variation

As can be seen in Table K.2.2, there are no remarkable difference in the average field water requirements in three seasonal paddy cultivation.

- 1st season paddy from Jan. to Jun. : 8.9 mm/day to 24.5 mm/day
- 2nd season paddy from May to Oct. : 8.2 mm/day to 30.7 mm/day
- 3rd season paddy from Sept. to Feb. : 9.1 mm/day to 25.6 mm/day

(c) Areal variation

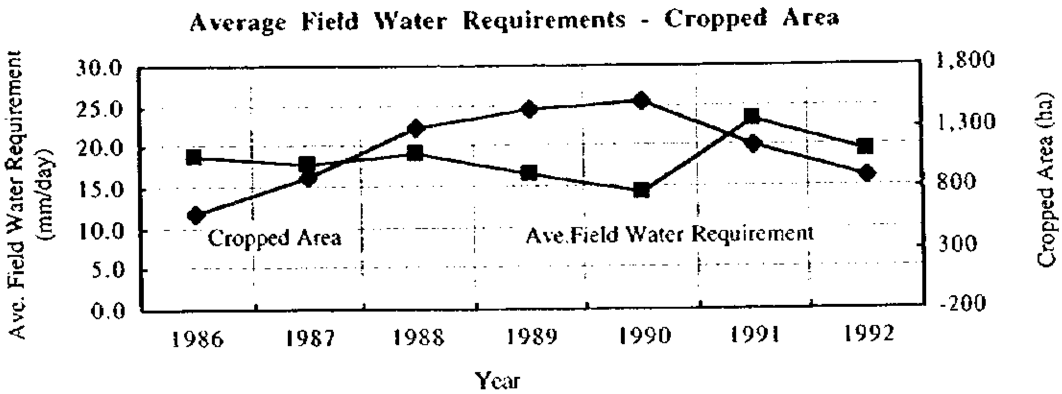
On the other hand, some difference have been found in the average field requirements among five areas:

- Upper Mabogini : 8.2 mm/day to 19.5 mm/day
- Lower Mabogini : 16.6 mm/day to 30.7 mm/day
- Rau Ya Kati : 11.2 mm/day to 21.4 mm/day
- Chekereni : 13.1 mm/day to 20.9 mm/day
- Oria : 12.0 mm/day to 20.0 mm/day

The Lower Mabogini presents the highest field water requirement among them, whereas the Upper Mabogini shows the lowest one. The Rau Ya Kati, Chekereni and Oria, which are covered by the Rau canal system, show the similar field water requirement. The reason of the lowest field water requirement in the Upper Mabogini would be considered to be mainly due to the high ground water table. Other factor would be soil texture in difference of field water requirement because the Rau Ya Kati, Chekereni and Oria areas are covered with finer soil texture than the Lower Mabogini.

(d) Relation between cropped area and field water requirement

Of the 7-years observation data recorded by KADP for the 5 areas, those of the 4 years from 1987 to 1990 show a tendency of smaller fluctuation than in 1986, 1991, and 1992. On the other hand, the cropped area was 94 ha in 1985. It has increased year by year and reached the maximum area of 1,508 ha in 1990. Thereafter, it has decreased until 1994 due to water shortage. The graph below shows the relation between average field water requirement and cropped area from 1986 to 1992.



From this graph, it is likely, as a general tendency, that the larger the cropped area becomes, the smaller the field water requirement becomes. In 1991 and 1992, one crop season was totally in fallow as shown in Table K.2.3. This might bring about larger percolation due to the dry condition of paddy fields. In particular, a large percolation was observed in 1991, because a fallow period was due in the dry season so that paddy cultivation was started in completely dry condition. Such phenomenon can also be explained from another side where KATC's field measurement under continuous cultivation presents lower values as mentioned above. Thus, it is proposed that the field data for 4 years from 1987 to 1990 shall be used for estimating the well-fitted field water requirements for paddy.

(3) Field Measurement by KATC at Experimental Farm

KATC has also measured the field water requirement for paddy using the experimental farm for the 1st season paddy in 1997 by an automatic and a manual apparatus. The results are tabulated as follows:

(Unit : mm/day)

Instruments	Feb.	Mar.	Apr.	May
Automatic	14.4	17.2	14.7	14.4
Manual	10.0	8.2	6.0	6.8

The field water requirements measured by the automatic apparatus are in a lower position as compared with those of the 1st season paddy for all areas. A difference between those at the experimental farm and the Chekereni area would be mainly due to cultivation condition because the experimental farm is presently cultivated with paddy twice a year without any long fallow period. Meanwhile, other areas are cultivated by rotation of three crop seasons in a year, which would lead to a high possibility on crack occurrence. In fact, the field water requirements at all areas in 1989 and 1990, are within a similar range with those at the experimental farms, because cultivation areas in these two years, attained at 1,434 ha and 1,508 ha respectively. On the other hand, the reason why the observed field water requirements at the Upper Mabogini is lower than the experimental farm, is due to high ground water table mentioned above.

(4) Field Measurement by JICA Study Team in 1997

A field water requirement of paddy has been measured for the following four plots from June to October, 1997, using one automatic and three manual instruments:

(a) Measurement by automatic instrument

An automatic instrument was installed at Plot No.202 of RS 4-1 tertiary block at Chekereni area. The results of measurement are given in Table K.2.4. Average field water requirements except unreasonable high values, are calculated at 8.3 mm/day for June, 11.0 mm/day for July, 12.3 mm/day for August, 14.1 mm/day for September and 15.9 mm/day for October. These values are about 30% lower than those by KADP.

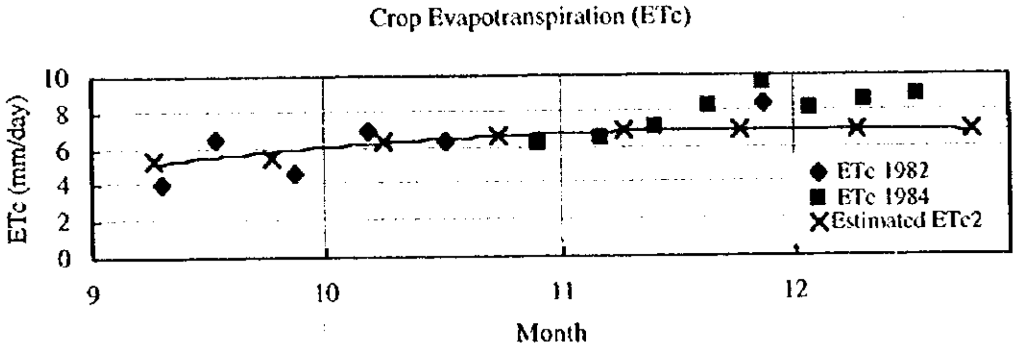
(b) Measurement by manual instrument

A field water requirement of paddy has also been measured for Plot No.317 of MS 5-1 tertiary block at Lower Mabogini area, Plot No.215 of RS 1-2 tertiary block at Rau Ya Kati area, and Plot No.214 of tertiary block at Oria area using a manual instrument. It is composed of three tanks such as a bottomless tank with paddy, a bottomless tank without paddy and a bottom tank without paddy, so as to be able to calculate evapotranspiration (ET) and percolation (P) separately.

Table K.2.5 presents the measurement results for respective plots from June 1997 to October 1997. These results also show very low values as compared with those measured from 1986 to 1992 by KADP. In particular, such a remarkable tendency is seen in Lower Mabogini area where the highest field water requirement is observed among five areas according to the said KADP data, because field water requirement observed at Lower Mabogini area gives the lowest among three measurement plots.

(5) Comparison of Measured and Estimated Consumptive Use of Paddy (ETc)

A consumptive use of paddy (ETc) for dry season paddy was measured by KADC in 1982 and 1984 as shown in Table K.2.1. These values except largely deviated ones, have been compared with the estimated ones by the modified Penman method. The estimated consumptive use of dry season paddy is given in Table K.3.1. The comparison graph is drawn below:



A consumptive use measured in 1997 which ranges from 4.1 to 9.2 mm/day for two months of September and October, is not largely deviated from this estimated consumptive use curve although the crop growing stage is slightly different. From this comparison study result, it was judged that the estimated consumptive use curve by the modified Penman method was applicable for the Project.

2.2.4 Irrigation Efficiency

The irrigation efficiency consists of conveyance and operation efficiencies in canals and structures, and application efficiency in fields. In design of irrigation canals provided in the Existing Lower Moshi Project Area, the overall irrigation efficiency applied are 72% for paddy and 53% for upland crops, breakdown of which are as follows:

Efficiencies	Paddy field	Upland crops field
Application efficiency	95%	70%
Operation efficiency	85%	85%
Conveyance efficiency	90%	90%
Overall efficiency	72%	53%

Out of these efficiencies, conveyance efficiencies for secondary canal, tertiary canal and watercourse have been measured by a ponding method. As a result, a conveyance efficiency for lined canals has been measured at 97% to 98%, and that for unlined canal, say watercourse at 90%. The details of measurement are given in Section 2.8. The conveyance efficiency for the lined canals was still in good range, but that for watercourse was low due to much leakage. Therefore, the same watercourse was tested again after certain repairing, which was regarded as one of maintenance work to be conducted by farmers. The test result which details later too, showed 94% of conveyance efficiency.

2.2.5 Irrigation Canal Network

(1) Existing Lower Moshi Project Area

Two irrigation canal systems commanding 2,300 ha of the Existing Lower Moshi Project Area including 150 ha of pilot farm and sugar estate, were constructed in 1987 under the financial assistance of the Government of Japan (OECF). One is the Mabogini canal system and the other is the Rau Ya Kati canal system. The Mabogini canal system serves irrigation water to 155 ha of the upper Mabogini area and 800 ha of the Mabogini area. Irrigation water is tapped from the Njoro river by the Mabogini intake structure, and is delivered to field plots by gravity through a main canal, secondary canals, tertiary canals and watercourses. The Rau Ya Kati canal system supplies irrigation water to 600 ha of Rau Ya Kati area and 745 ha of Chekereni area in the same manner with the Mabogini canal system. A concrete block lining was provided for the main, secondary and tertiary canals, but watercourses are unlined although those in Chekereni area are partially given a concrete block lining by the beneficial farmers at their own finance. The constructed irrigation canals and structures are tabulated below:

Irrigation Canals	Mabogini Canal System	Rau Ya Kati Canal system	Total
Main canals	4.8 km	5.3 km	10.1 km
Secondary canals	6.5 km	18.1 km	24.6 km
Tertiary canals	27.8 km	37.8 km	65.6 km

At present, these canals are generally in good conditions so that minor repairs such as small-scaled embankment and replacement of damaged concrete blocks and filling of joints between concrete blocks will be only required as shown in Tables K.2.6 and K 2.7.

(2) Expanded Area

The Expanded Area is located upstream of the Existing Lower Moshi Project Area, and is mostly cultivated with paddy by making reference with farming practice executed in the Existing Lower Moshi Project Area. The Expanded Area is irrigated by illegally tapping water from the Njoro and Rau rivers flowing nearby.

In the Expanded Area, there are three existing irrigation systems namely; the Njoro Kwa Goa irrigation system in the upper stream of Njoro, administratively located in Kaloleni ward, Moshi urban district, 9 farmers' built irrigation systems in the same ward, and the Mandaka irrigation system located in Mandaka Mnono village.

(a) Njoro Kwa Goa Irrigation System

The irrigation facilities of Njoro Kwa Goa irrigation system were constructed by farmers themselves voluntarily without any governmental financial assistance. At the beginning time of 1980s, about 180 ha of paddy fields have been already developed in Kaloleni ward with water sources of Njoro Ya Dobi and Goa springs, and after that the irrigation area expanded gradually in particular shortly after the development of the Existing Lower Moshi Project Area. The area is obtaining irrigation water from Njoro Ya Dobi spring and Goa spring, respectively. There are three major irrigation canals. These are of excavated canals, and a few poor concrete structures only are provided.

(b) Nine Farmers' built Irrigation Systems

Out of 9 farmers' built irrigation systems, 7 systems are located between the Goa spring and the Mabogini weir, and 2 systems are located downstream of the Dobi spring. The former 7 systems have been made by farmers themselves due to successful paddy cultivation in the Existing Lower Moshi Project Area, which has resulted in the present constant water shortage in the Existing Lower Moshi Project Area. All canals are unlined, and 2 simple concrete structures serve as intake structures. The remaining 2 systems have also been constructed by farmers for vegetable cultivation in the dry season. The canals are of excavated type and no permanent structures are provided.

(c) Mandaka Irrigation System

As well, about 330 ha of paddy fields in the Mandaka Mnono village were developed by the farmers concerned in the beginning of 1980s, with water sources of the Mwananguruwe spring and the Rau river, and then the irrigation area expanded gradually in particular shortly after the development of the Existing Lower Moshi Project Area.

The Mandaka Mnono village has 3 paddy blocks, namely the Makarare, Mwananguruwe and Uswahilini blocks. These blocks are irrigated by 2 major canals; Saningho and Cenema canals. The Saningho canal is supplying water to the Uswahilini block which is further divided into 2 sub-blocks of the Upper Uswahilini and the Lower Uswahilini. The Cenema canal is supplying water to the Makarare and Mwananguruwe blocks.

(3) New Extension Area

The potential area is located at western side of the Existing Lower Moshi Project Area. Since there are no water sources, only upland crops such as maize, beans and sunflowers are cultivated under rainfed condition, and no crop cultivation is executed in the dry season. Any irrigation canals and structures are not provided in this Area.

2.2.6 Canal Capacity

(1) Existing Lower Moshi Project Area

Main and secondary irrigation canals are designed using the unit design discharges of 1.34 lit./s/ha and 1.85 lit./s/ha, respectively, and tertiary irrigation canals for the following design capacities, aiming to ensure flexible operation of canal systems:

Main irrigation canal	:	1.34 lit./s/ha
Secondary irrigation canal	:	1.85 lit./s/ha
Tertiary irrigation canal	:	46 lit./s for up to 25 ha
		92 lit./s for 25 ha to 50 ha
		138 lit./s for 50 ha to 75 ha
		184 lit./s for 75 ha to 100 ha

On the other hand, watercourses commanding about 10 ha are designed and constructed for 46 lit./s. These canals have a freeboard ranging from 0.17m to 0.35m mostly depending on flow discharge.

(2) Expanded Area

There are no data for the flow capacity of the existing canals. According to the field investigation, the flow capacity of existing canals in the Kaloleni ranges from 10 lit/s to 40 lit/s, and that for the Mandaka Mnono from 10 lit/s to 200 lit/s.

2.2.7 Structures

(1) Existing Lower Moshi Project Area

In order to operate these canal systems, numerous structures are also provided in the Existing Lower Moshi Project Area. These are headworks, turnouts, check drops, drops, culverts, spillways, siphons and division boxes which are made of reinforced concrete. Number of canal structures provided is given in Table K.2.8. As a measuring device, a Parshall flume was constructed at the headworks, and a rectangular weir at respective turnout gates.

According to an inventory survey, these as well as the canals are mostly in working conditions. However, there have found damages in gates installed at turnouts especially in the upland crop area, and missing of covering soils for concrete pipes on culverts. In addition, it has been found that both Parshall flumes installed at the Mabogini and Rau Ya Kati intakes have been sensitive to backwater effect caused by control of a check gate at No. 1 turnout. Measurement of intake discharge shall be therefore conducted paying care upon the check gate control. Some foot bridges would be required on major canals running around village area.

(2) Expanded Area

There are a few permanent structures in both Kaloleni and Mandaka Mnono areas. Quality of them is also poor. These structures shall be replaced totally.

2.3 Drainage System

2.3.1 Drainage Condition in Each Area

(1) Existing Lower Moshi Project Area

In the Project area, the Existing Lower Moshi Project Area only were provided with well-planned drainage system consisting of main, secondary , tertiary and field drains, and related structures, to eliminate the excess water from the Project are to rivers flowing nearby. In addition, flood protection dikes were constructed along the Njoro and Rau rivers, to protect the Project area and facilities from floods. The dikes were provided with flap gates so as to drain the internal excess water to the rivers when water level in the rivers are lower.

(2) Expanded Area

There are no drainage system in the Expanded Area. Some areas become swampy in the rainy season every year. In particular, such swampy condition is remarkably observed in the Kaloleni area. In order to improve the swampy condition, it is indispensable to construct the proper drainage network in the Kaloleni area. The proper drainage network can be also expected to produce certain return flow.

(3) New Extension Area

In the New Extension Area, any drainage network as well as the irrigation canal network has not been established. The southern part of the New Extension Area is suffering from poor drainage condition and salinity accumulation is observed as discussed in ANNEX-D.

2.3.2 Drainage Method

In the Existing Lower Moshi Project Area, excess water is drained by gravity, any mechanical drain is not applied. This drainage method has not envisaged with any problem so far.

2.3.3 Drainage Requirement

There are two drainage requirements: one is for upland crop field and the other for paddy field. The former is so estimated as to remove the excess runoff from 5-year, one hour storm rainfall, say 30 mm/h. The latter is estimated at 5 l/s/ha on the conditions that 5-year, 24-hour storm rainfall is to be evacuated from paddy field within 48 hours.

As mentioned above, the drainage system designed and constructed using these drainage requirements, has not presented any drainage problems on its network and capacity since its construction in 1986. From this fact, it is deemed that the applied drainage requirement is quite satisfactory.

2.3.4 Drainage Canal Network

Drainage canal network in the Existing Lower Moshi Project Area was provided considering the irrigation canal network. Drainage canals provided are of unlined type and are classified into main drains, secondary drains, tertiary drains and field drains.

Length of respective drains are tabulated below:

Drainage Canals	Mabogini Drainage System	Rau Ya Kati Drainage system	Total
Main drains	12.2 km	4.4 km	16.2 km
Secondary drains	14.7 km	17.3 km	32.0 km
Tertiary drains	17.1 km	23.8 km	40.9 km

The drainage network provided has technically functioned well and any severe drainage problem has not been observed. But regular removal of grasses and sediments in drains should be made as a routine of maintenance work, in order to keep smooth elimination of excess water from fields to the parent drain and also to prevent salinity problem.

2.3.5 Structures

The drainage system constructed were also provided with many structures. These structures are 319 pipe culverts, 12 box culverts, 71 junction structures and 3 drainage sluices. The inventory survey results show that these structures are in working condition and any major repairs will not be required accordingly.

2.4 Problems in Irrigation and Drainage Systems

Irrigation and drainage activities by KADP and farmers' organisation have been examined through inventory survey, discussion with government agencies, and interview with farmers. From the results of examination, the following problems have been clarified:

(1) Existing Lower Moshi Project Area

(a) Shortage of irrigation water
(b) Damage of intake and turnouts
(c) Much leakage from watercourses
(d) Water stagnant due to enclosure by RS5-4 and MR-3

(2) Expanded Area

(a) Poor canalization system
(b) No drains
(c) Poor access roads
(d) Damage by floods

(3) New Extension Area

Construction of irrigation and drainage facilities is highly expected by farmers.

These problems will be sufficiently reflected upon the formulation of irrigation and drainage development plan.

2.5 Flood Protection Dike

Before completion of the Lower Moshi Agriculture Development Project, the Existing Lower Moshi Project Area had been periodically inundated due to seasonal floods from the Rau river and its tributaries, and 430 ha or about 20% of the Existing

Lower Moshi Project Area had been suffered from inundation every year. In order to protect the Area from such inundation, flood protection dikes were constructed on the right bank of Njoro and Rau rivers. The dikes were designed against the 20 years probable flood discharge. The constructed dikes are of earthen embankment with trapezoidal section. The crest width is 2.5m and side slopes are 1:2.0 for outside and 1:1.5 for inside. Its total length is 15.4 km.

After completion of the dikes, a part of the dikes between the railway and No.1 aqueduct was once damaged by the flood occurred in April 1995. Except this, the dikes have not faced any problem and have well protected the Area from floods so far.

2.6 Farm Roads

In the Existing Lower Moshi Project Area, four types of farm roads are provided for execution of operation and maintenance of project facilities and carry of agriculture inputs and outputs. These are trunk road, main farm road, secondary farm road and tertiary farm road of which features are tabulated below:

Class	Effective width (m)	Number	Length (km)	Pavement
Trunk road	9	1	16.1	Gravel
Main farm road	6	3	17.7	Laterite
Secondary farm road	5	12	38.6	Unpaved
Tertiary farm road	3	76	55.6	Unpaved

The conditions of the roads cited have been also surveyed, and the results are summarised as follows:

(a) Trunk road:

1) Very rough surface with deep ruts and holes with standing water,
2) Zigzag traffic course,
3) Muddy and slipping condition after rainfall,
4) Poor drainage condition,
5) Partially gravel pavement

(b) Main and secondary farm roads:

1) Narrow road width due to grass growing which obstruct smooth traffic,
2) Rainfalls draining into irrigation canals at several places due to reverse gradient of road surface caused by less maintenance,

(c) Tertiary farm road:

1) Road surface covered with many grass which bring about a difficulty in passing of vehicles and tractors,

(d) Others:

1) exposure of pipes in culvert due to erosion of road surface by rainfalls

2.7 On-farm Works

The on-farm irrigation block size is about 40 ha. The size and shape of a field plot is 0.3 ha (100m x 30m). The on-farm works comprises watercourses, field drains, field roads, ,their related structures and land levelling works. The constructed on-farm works are watercourses of 72.9 km, field drains of 64.4 km, field drains of 77.8 km, and related structures of 10,142 nos. The levelling works were executed with a tolerance of ± 7.5 cm. At present, these on-farm works function well, and size of a field plot has not offered any problem on on-farm activities such as land preparation by a tractor and water distribution. And also, land levelling has not indicated any crop yield reduction so far.

2.8 Field Measurements

(1) General

In addition to the measurement of field water requirement of paddy mentioned in Sub-section 2.2.3, canal seepage loss and return flow have been measured in the Existing Lower Moshi Project Area, to confirm the exiting irrigation efficiencies and also whether water distribution is properly executed or not.

(2) Canal Seepage

Canal seepage loss is one of important factors for determination of proper diversion requirement. Previously, canal seepage loss for watercourse (lined and unlined) has been measured using a current meter by KADP. At this time, the measurement has been made for the secondary canal (RS-4), tertiary canal (RS-4-2), and watercourse (RS-4-7, No.1), by a ponding method. As a result, conveyance loss for secondary canal, tertiary canal and watercourse is measured to be 3%, 2% and 10% respectively. In addition, the same watercourse has been tested again in the same manner, but after repairs which have been regarded as one of routine maintenance work by farmers. The test result shows the seepage loss of 6%. The details of measurement and calculation are shown in Tables K.2.9 to K.2.12.

(3) Return Flow

In order to know whether water supply is effectively executed, and also to grasp approximate water supply discharge, a return flow measurement was carried out using the RS 4-3 tertiary block. The RS 4-3 tertiary area has 41ha, and its drainage system serves within its area only. Water supply discharge has been measured using a tertiary turnout with a measuring device. Outflow from the tertiary area has been measured using a triangular weir installed at the end of tertiary drain.

A measurement was carried out for one cropping season from June 1997 to October 1997 when water supply was discontinued. Table K.2.13 shows the results of return flow measured. As can be seen in this table, about 4% of supplied water has been released into drain throughout one cropping season. It was deemed that this water management was satisfactorily executed if judging from this value. A peak water supply was 2.6 l/s/ha in June when a puddling time occurred, and followed by 2.4 l/s/ha in August when no rain was observed.

2.9 Review on Relevant Projects

(1) Traditional Irrigation Projects

There is a rehabilitation project of traditional irrigation projects in the Kilimanjaro region which is financed by UNDP, NORAD and GOT. The project aims at contribution to achievement of food security and increase in self-sufficiency of food through increase and stabilisation of crop production. This project covers the traditional projects of Musa, Kikafu Chini, Mougini and Shango. Out of them, Musa and Kikafu Chini are located in Hai district which is included in the Study Area. The Kikafu river is a water source for the Musa and Kikafu Chini rehabilitation projects. An irrigation water is tapped by an intake weir and is supplied to the field by gravity.

The Musa rehabilitation project commands 676 ha, and crops to be irrigated are paddy, maize, beans and onions. The project facilities to be rehabilitated are an intake weir, main canal of 2.07 km and canal structures consisting of 8 drops, 5 turnouts, and 2 culverts. Construction cost for the weir, main canal and structures are US$ 100,000, and construction is on-going. On the other hand, design of drainage canals and roads has not yet been made so far.

The Kikafu Chini rehabilitation project covers 641 ha of Irrigable area for cultivation of paddy, maize, beans and onions. The Kikafu Chini project has been originally irrigated by pump system, but has been failed due to lack of proper maintenance of pumps. Under the rehabilitation project, rehabilitation and/or construction is made for one intake weir, main canal of 1.35 km, secondary canal of 0.8 km, and 15 canal structures such as 2 culverts, 5 drops, 4 offtakes, 3 cross-drains, and one bifurcation structure. Construction of 270 m pipeline is also included in the project. Construction cost is US$ 223,000, and these facilities are under construction.

The site inspection has clarified that construction work including quality control has not been made well due to lack of construction equipment although it has been in due course of the rainy season. In the Kikafu Chini rehabilitation project, a weir is constructed by combination of concrete weir and gabion weir. At present, it is functioning well, but careful observation is required whether smooth water intake can be ensured or not in the dry season when river discharge extremely decreases. Judging from the river condition and the required scale of the weir, it is difficult to apply such combination system to the Project.

(2) Ndungu Agriculture Development Project

A site visit has been made for the Ndungu Agriculture Development Project (NADP) located in Ndungu division, Same district, Kilimanjaro region. NADP was completed in February 1990 as a Japanese grant aid project. The irrigable area developed are 680ha. At present, a double cropping pattern is introduced into NADP, that is, 1st season paddy from January to May, and 2nd season paddy from September to January.

The irrigation and drainage canal system is just the same with the Existing Lower Moshi Project . The different points are that flood protection facilities such as floodway, intercepting drains and gated flood dikes were constructed in a large scale, to protect NADP area from flood.

An irrigation water supply has been made since 1990, and is presently executed well. Major problems encountered are choking of intercepting drain, siltation of floodway and internal drain. Especially, flap gates installed at the flood dikes, do not function because the downstream area which is out of NADP area, is cultivated with paddy using drainage water dammed up in downstream reach of floodway. As a result, there occurs water stagnant in the lower portion of NADP area.

NADP is administratively under KADP. NADP has three sections under a project manager: Water Management and Facility Maintenance Section, Tractor Hire Service Section and Extension Service Section, which has Project staff under a project manager are six in total, consisting of one O & M staff, three tractor services staff and two extension staff.

3. IRRIGATION WORKS

3.1 Basic Approach to Establishment of Irrigation Plan

An irrigation development plan for the Project will be formulated taking into consideration the lessons learnt from the Existing Lower Moshi Project and the currently envisaged problems and constraints to the Study Area, aiming to establish a sustainable irrigation system. In the plan formulation, a special focus shall be given to the following matters:

(a) Application of irrigation water requirement estimated based on the actual measurements, soil conditions, and irrigation method.

(b) Design of irrigation canal system, paying attention to the introduction of administrative boundary into canal layout for easy establishment of farmers' organisation.

(c) Design of canal system which conveys irrigation water from main canal to respective field plots through secondary canal, tertiary canal and watercourse in turn as much as possible, for easy water distribution.

(d) Provision of simple irrigation facilities including measuring device, considering easy operation, maintenance and water management.

3.2 Basic Figures for Irrigation Plan

3.2.1 Field Water Requirements

(1) Paddy

(a) Study results on field water requirements measured by KADC, KADP, KATC and JICA Study Team

The field water requirements measured by KADC, KADP, KATC and JICA Study Team were discussed as mentioned in Sub-section 2.2.3. As a result, the following have been clarified:

1) As for KADP's data, each area shows the similar tendency in yearly and seasonal variation except areal variation. The Lower Mabogini area presents the highest field requirement , whereas the Upper Mabogini area shows the lowest one. The average values of the Lower and Upper Mabogini areas are similar to the field water requirements for other areas.

2) Of the seven-years observation data recorded by KADP from 1986 to 1992, those for four years from 1987 to 1990 are proposed to be used for estimating field water requirements for paddy.

3) The field water requirements measured by automatic instrument (KATC and JICA Study Team) are in lower position as compared with those by KADP.

4) The estimated crop evapotranspiration (Etc) is applicable for the Project because its curve is not largely deviated from the measured values.

(b) Adopted calculation procedure of field water requirements of paddy

Taking into due consideration the above study results, it is proposed that the field water requirement of paddy shall be estimated in the following procedure:

1) Crop evapotranspiration of rainy and dry season paddies are estimated using the modified Penman method.

2) Percolation rates for rainy and dry season are calculated by deducting the estimated crop evapotranspiration from the measured data of KADP for 4 years from 1987 to 1990, and then the averaged ones are determined In this procedure, percolation rates measured by KADC in 1982 and 1984 and by KADP in 1997 are also taken into account.

3) Field water requirements of rainy and dry season paddies are calculated adding the estimated crop evapotranspiration and the determined percolation rates.

(c) Determination of field water requirements of paddy

In line with the calculation procedure mentioned above, the field water requirements of rainy and dry season paddies are determined as follows:

1) Crop evapotranspiration of rainy and dry season paddies

Tabulated below are the potential evapotranspiration estimated by the modified Penman method.

(mm/day)

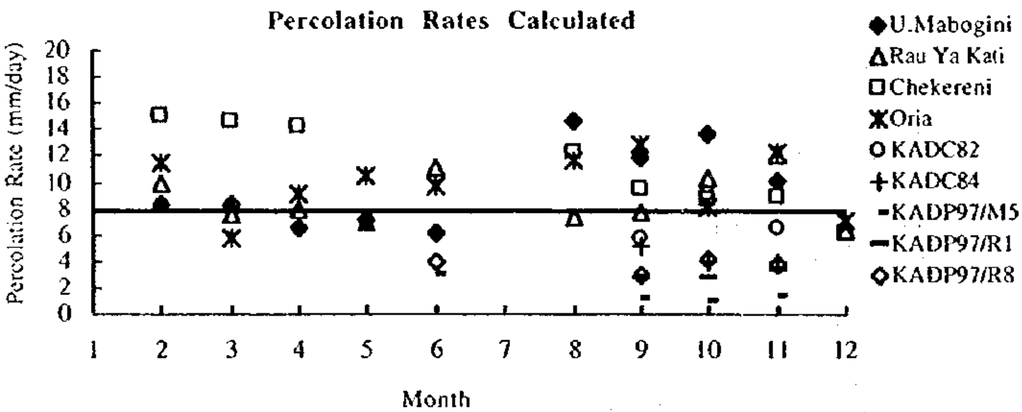
Station	Elev.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Moshi	813m	6.5	6.6	6.7	4.8	3.6	3.4	3.6	4.2	5.7	7.1	6.8	6.1
TPC	701m	5.9	6.0	5.6	4.6	3.8	3.4	3.5	4.0	4.9	5.5	5.6	5.6

As the elevation of the Study Area ranges from 715m to 760m, the potential evapotranspiration estimated using data observed at TPC is applied to this Study.

Using these potential evapotranspiration and crop coefficient, crop evapotranspiration of rainy and dry season paddies are determined as shown in Table K.3.1.

2) Determination of percolation rates

Percolation rates for rainy and dry season paddies are calculated by deducting the said crop evapotranspiration from the measured data of KADP. The results are given in Table K3.2. The calculated percolation rates and the measured ones by KADC in 1982 and 1984 and by KADP in 1997 are plotted as shown below:



In general, a percolation rate in the dry season is higher than in the rainy season. But, in these data, percolation rates in the rainy season are in slightly higher tendency rather than those in the dry season. From these plotted positions, and also taking it into consideration that percolation rate would lower if continuous cultivation is realised, a percolation rate was conservatively determined at 8 mm/day for all areas throughout a year.

3) Determination of field water requirements of rainy and dry season paddies

Field water requirements of rainy and dry season paddies are estimated by adding the estimated crop evapotranspiration and the percolation rate of 8 mm/day as follows:

- Rainy season paddy

Description	Feb.		Mar.		Apr.		May		Jun.		Jul.	
Crop ETc (mm/day)	6.4	6.8	6.2	6.3	5.4	5.6	4.7	4.7	4.2	4.2	4.2	-
Percolation (mm/day)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	-
FWR (mm/day)	14.4	14.8	14.2	14.3	13.4	13.6	12.7	12.7	12.2	12.2	12.2	-
FWR (mm/month)	409		442		405		394		366		378	-

- Dry season paddy

Description	Aug.		Sept.		Oct.		Nov.		Dec.		Jan.	
Crop ETc (mm/day)	4.2	4.5	5.4	5.5	6.4	6.7	7.0	7.0	6.9	6.9	7.0	-
Percolation (mm/day)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	-
FWR (mm/day)	12.2	12.5	13.4	13.5	14.4	14.7	15.0	15.0	14.9	14.9	15.0	-
FWR (mm/month)	383		404		451		450		462		465	-

The details of calculation are given in Table K.3.3.

(2) Upland Crop

In the Project area, alfalfa was proposed as the upland crop as discussed in ANNEX-C. Since no actual measurement data are available, crop water consumption was estimated as a product of potential evapotranspiration calculated from climatic data and crop coefficients relating to crop growth stages. The modified Penman method was employed because the climatic data necessary for applying it is adequate in and around the Study Area. The crop coefficient of alfalfa was cited from the FAO Publication No.24, and then consumptive use was calculated as follows:

	Oct.		Nov.		Dec.		Jan.		Feb.	
Potential Eto (mm/day)	5.5	5.5	5.6	5.6	5.6	5.6	5.9	5.9	6.0	6.0
Kc	0.40	0.45	0.60	0.80	1.00	1.13	1.12	0.98	0.74	0.60
Cu (mm/day)	2.2	2.5	3.4	4.5	5.6	6.3	6.6	5.8	4.4	3.6

Note: Kc = Crop Coefficient, Cu= Consumptive Use (mm/half month)

Table K.3.4 presents the details of calculation of consumptive use of upland crop.

3.2.2 Effective Rainfall

Effective rainfall varies with rainfall intensity and distribution, permeability and water holding capacity of soils, amount of irrigation water supply, irrigation management practices, type of field plot and topography of land, etc. In this Study, the effective rainfall in paddy fields and upland field is calculated separately as explained in the following paragraph :

(1) Paddy Fields

Effective rainfall in paddy fields is calculated on the basis of the daily water balance using daily rainfall data observed at the Chekereni Station. A daily balance study is made on the following assumption :

- Ineffective rainfall : less than 5 mm/day
- Maximum depth of tank : 80 mm

Based on the results of daily water balance study, correlation between the 10-day rainfall and effective rainfall is estimated for the purpose of calculating the long term assessment as shown in Figures K.3.1.

(2) Upland Crop Fields

The U.S. Department of Agriculture Soil Conservation Service has developed a procedure for estimating effective rainfall by processing long term climatic and soil moisture data from 50 years of rainfall records at 22 experimental stations. A study on daily balance in the soil profile is carried out, and the following relationship is derived from monthly rainfall and crop consumptive use.

$$ER = 0.2 \times R^{0.95} \times ETc^{0.31}$$

Where,

ER : Average monthly effective rainfall in mm
R : Monthly rainfall in mm
ETc : Monthly crop evapotranspiration (consumptive use water) in mm

Table K.3.5 presents the effective rainfall calculated for Alfalfa, using the above equation.

3.2.3 Puddling, Nursery and Pre-irrigation Water Requirements

(1) Puddling Water Requirement for Paddy

Puddling water requirement for paddy depends on soil type, moisture content, etc. and varies from time to time. Table K.3.6 gives soil physical properties in the Study Area. According to this table, porosity of soil in the cultivable layer (approximately 0 to 30 cm) is estimated to be about 40% on an average. The observed evaporation in February and March for rainy season paddy is 7mm/day, and that for dry season paddy is 5 mm/day. On the other hand, percolation is 8mm/day as discussed above. From these figures, the puddling water requirement is calculated as follows:

Description	Unit	Rainy Season Paddy	Dry Season Paddy
Soil depth	mm	300	300
Porosity	%	40	40
Soil vapour phase	%	5	5
Soil moisture before water supply	%	25	20
Water to be supplied:			
Saturation of soil profile	mm	30	50
Evaporation	mm	70	30
Percolation	mm	80	80
Standing water	mm	40	40
total	mm	220	215
say	mm	220 for both paddies	

Table K.3.7 shows the puddling water requirement schedule.

(2) Nursery Water Requirement

Nursery water requirement for paddy is composed of puddling water for nursery bed, consumptive use and percolation during nursery period. The nursery water requirement was estimated under the following conditions, and details are given in Table K.3.7:

- Area required for nursery bed : 1/20 of paddy field area
- Nursery period : 25 days
- Required water for 25 days
  - Preparation of nursery bed : 220 mm
  - Consumptive use : 7 mm/day
  - Percolation : 8 mm/day

(3) Pre-irrigation Requirement for Upland Crop

Pre-irrigation will be required just before commencement of upland crop cultivation in case of dry field condition. Table K.3.6 shows the average field capacity of 32 % for the necessary layer for germination assumed to be 20 cm. From these figures, the pre-irrigation water requirement was estimated at 64 mm, say 60 mm.

3.2.4 Irrigation Efficiency

The Existing Lower Moshi Project applies the overall irrigation efficiency of 72% for paddy and 53% for upland crops. In this Study, the Kikuletwa river was planned as an additional water source in addition to the Njoro and Rau rivers. According to the water source development plan, the New Extension Area and the Existing Lower Moshi Project Area, except the Upper Mabogini Area and a part of the Lower Mabogini Area, are planned to be supplied with water from the Kikuletwa river by constructing headworks and a diversion channel of about 22 km. On the other hand, the Expanded Area and the remaining Existing Lower Moshi Project Area will be irrigated with the Njoro and Rau river water. In consideration of such water source development plan and the results of field measurements of canal seepage loss, the following irrigation efficiencies were estimated:

Efficiencies	Water Supply by Kikuletwa		Water Supply by Njoro and Rau	
	Paddy field	Upland crops field	Paddy field	Upland crop field
Application efficiency	95%	70%	95%	70%
Operation efficiency	85%	85%	85%	85%
Conveyance efficiency	85%	85%	90%	90%
Overall efficiency	69%	51%	72%	53%

3.2.5 Unit Irrigation Water Requirement

Unit irrigation water requirement for paddy and was estimated based on the field water requirements mentioned above, effective rainfall, and irrigation efficiency. Since there are two irrigation efficiencies depending on water sources as mentioned above, the following 2 unit irrigation water requirements at water abstraction points are proposed:

(1) Area to be supplied from Njoro and Rau Rivers

(Unit : l/s/ha)

Crop	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Rainy Season Paddy	0.1	1.2	2.2	1.9	1.8	1.0	0.1	-	-	-	-	-
Dry Season Paddy	0.2	-	-	-	-	-	0.1	1.6	2.1	2.3	2.2	1.2
Upland Crop (Alfalfa)	1.3	0.4	-	-	-	-	-	-	-	0.3	1.0	1.2

(2) Area to be supplied from Kikuletwa River

(Unit : l/s/ha)

Crop	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Rainy Season Paddy	0.1	1.4	2.3	2.0	1.8	1.0	0.1	-	-	-	-	-
Dry Season Paddy	0.2	-	-	-	-	-	0.1	1.2	2.3	2.4	2.3	1.2
Upland Crop (Alfalfa)	1.4	0.5	-	-	-	-	-	-	-	0.3	1.0	1.2

(3) Cross-Check of Unit Irrigation Water Requirement with Return Flow Analysis

As mentioned in Section 2.8, a return flow measurement was executed for one cropping season from June to October 1997, the results of which are given in Table K.2.14. The table shows that a peak water supply was 2.6 l/s/ha with 12% surplus water in June when a puddling time occurred, and followed by 2.4 l/s/ha with surplus water 3% in August when no rain was observed. This means that used water amount at field would be around 2.3 l/s/ha. On the other hand, the unit water requirement at the head of tertiary canal would come to 2.1 l/s/ha after deducting the operation and conveyance losses to occur at the diversion channel, main canal and secondary canal from the estimated unit irrigation water requirement of 2.4 l/s/ha at the water abstraction point. Since the estimated unit irrigation water requirement is deviated from the measured one within a 10 % range, it is deemed that the estimated irrigation water requirement is still applicable.

3.2.6 Design Discharge

As mentioned above, two unit irrigation water requirements were proposed depending on water sources. These were used for water balance study, to determine the irrigable area to be supplied from respective water sources: Njoro, Rau and Kikuletwa river. Finally, the irrigable area was determined at 4,700 ha in net excluding 150 ha of pilot farm and sugar estate, by supplying additional water of 9m^3/s in the rainy season and 5 m^3/s in the dry season from the Kikuletwa river.

Taking into consideration two unit irrigation water requirements, the results of water balance study, water supply method, and simplification of design, design discharge for each irrigation canal is proposed as follows:

(1) Diversion Channel

A diversion channel will be operated on a 24-hour basis. Its flow capacity will be the same from the intake point to the release point at the Rau river in consideration of maintenance of branched main/secondary canals and more effective use of limited water. Design discharge of the diversion channel was therefore proposed to be 9m^3/s.

(2) Main Irrigation Canal

A peak water requirement in the rainy season are 2.2 l/s/ha and 2.3l/s/ha. Judging from small difference in these peak requirements, a unit design discharge for main irrigation canal was proposed to be 2.3 l/s/h for both areas.

(3) Secondary Irrigation Canal

As well, a unit design discharge for secondary irrigation canals was proposed to be 2.4 l/s/ha in the same consideration above and also taking into account a possibility of whole area commanded by one secondary irrigation canal being cropped with the dry season paddy at one time.

(4) Tertiary Irrigation Canal

The design capacity of tertiary irrigation canal is determined in view of rotational irrigation along tertiary canal. The applied design capacities are as follows:

Command Area of Tertiary Canal	Design Capacity of Tertiary Canal
Less than or equal 25 ha	60 l/s
More than 25 ha, but less than or equal 50 ha	120 l/s
More than 50 ha, but less than or equal 75 ha	180 l/s

(5) Irrigation Water Distribution Diagram

Based on the unit design discharge, the irrigation water distribution diagrams for respective areas are shown in Figure K.3.2.

3.3 Irrigation Method

(1) Paddy

In the Existing Lower Moshi Project Area, water is continuously supplied down to tertiary canals. In the tertiary block, a rotational water supply is made for 2 watercourses at a 10-day interval at puddling time and at a 5-day interval at the remaining crop growing time. Continuous water supply down to tertiary canals is executed by KADP, and rotational water supply in the tertiary block by the farmers' organisation, say CHAWAMPU. On the other hand, in the Expanded Area, water is delivered on farmers' demand basis. In this plan, water supply is planned by combining the continuous supply and rotational supply systems, of which details are discussed in ANNEX-J.

(2) Upland Crop

(a) Water supply method

Alfalfa is proposed as a main upland crop after rainy season paddy. According to the proposed cropping pattern, alfalfa will be rotationally cultivated for 20% of the Project area from the middle of October to the end of February since the dry season paddy is grown for 50% of the Project area.

Alfalfa as well as other upland crops, will be intermittently supplied with irrigation water. The basin irrigation method is proposed for alfalfa, using a field plot for paddy although further field ridges are required for effective water use.

(b) Water supply amount at one time

Water supply amount at one time is calculated on the following conditions in this study:

- Effective root depth : 60 cm
- Soil moisture extraction pattern : Standard type (4 layers of 15 cm each)
- Available moisture : 10%

From these conditions, Total Readily Available Moisture (TRAM) is calculated at 56mm, which corresponds to water amount at one time.

(c) Irrigation interval

Daily consumption use is computed at 6.6 mm/day at peak time as shown in Table K.3.4. With this daily consumption use and TRAM mentioned above, an irrigation interval at peak time is calculated at 8.5 days. For easy operation of water supply, it is proposed to apply 7 days irrigation interval at peak time and its multiple days at other growing stage, in the light of calendar week.

3.4 Irrigation Canal System

The Study Area is planned to be covered by the following 4 irrigation divisions: Headworks and diversion channel division, Expanded Area division, Existing Lower Moshi Project Area division, and New Extension Area division.

(1) Headworks and Diversion Channel Division

In the headworks and diversion channel division, no irrigation will be made, and only domestic water supply to villages people living nearby will be taken into consideration as mentioned in ANNEX-L.

(2) Existing Lower Moshi Project Area Division

At present, the Existing Lower Moshi Project Area consists of the Mabogini canal system and the Rau Ya Kati canal system. Since these systems are currently functioning well, no large modification will be required and the existing system will be used as it is. According to the result of water balance study for the rainy season paddy, the Upper Mabogini area (257 ha) including 70 ha of sugar estate, and a part of the Lower Mabogini area (59 ha) will be irrigated using water from the Njoro river, and a part of the Rau Ya Kati area (160 ha) from the Rau river. And then the remaining area of 1,733 ha including 80ha of the pilot farm will be supplied from the Kikuletwa river as discussed in ANNEX-J. From this change of water source, a special attention shall be paid to the junction structure on the diversion channel for realising smooth the distribution.

As mentioned in Sub-section 3.2.6, design discharges for canals were largely increased as compared with present ones, details for which are given below:

Canal		Present	Modified	Ratio
Main canal		1.34 l/s/ha	2.3 l/s/ha	72 %
Secondary canal		1.85 l/s/ha	2.4 l/s/ha	30 %
Tertiary canal,	below 25 ha	46 l/s	60 l/s	30 %
	25 ha to 50 ha	92 l/s	120 l/s	30 %
	50 ha to 75 ha	138 l/s	180 l/s	30 %

Using the modified unit design discharges, the increased water depth and the required canal height were calculated as shown in Table K.3.8. As can be seen in this table, the water depths in the main canals were mostly increased by more than 15 cm, but less than 30cm. On the other hand, those in the secondary canals were increased by less than 15 cm for all canals, but mostly less than 6 cm. As for tertiary canals, the increased water depths were below 5 cm. The required work volume for heightening of canals was estimated based on this table.

(3) New Extension Area Division

The New Extension Area (2,090 ha in net) is located around the Existing Lower Moshi Project Area. Irrigation water is planned to be supplied from the Kikuletwa river through a diversion channel. The irrigation system in this Area will be designed independently as much as possible, so as not to interfere with that of the Existing Lower

Moshi Project Area although the same system design criteria is applied. The irrigation canal layout is planned taking into consideration not only the topographic condition but also the village boundary, for easy operation and maintenance by farmers' organisations.

In the New Extension Area, three irrigation canal systems are planned according to the feasibility level canal layout on 1/5,000 topo-maps. These are System-A, System-B and System-C. Each system will be composed of main, secondary and tertiary canals. Irrigation water will be delivered to each field through these canals in respective order, that is not main to tertiary canals or the fields and secondary canals to fields, taking into due account easy water management.

(4) Expanded Area Division

The Expanded Area consists of the Kaloleni ward and the Mandaka Mnono village, located separately from each other. These ward and village are partly covered by the existing farmers' irrigation system. Accordingly, the irrigation system plan is worked out by following this existing system as much as possible. The proposed canal systems for Kaloleni and Mandaka Mnono areas which have been also planned using the topo-maps of 1/5,000, is as follows:

(a) Kaloleni area

As explained previously, the Kaloleni area is divided into three areas by the Njoro and Mamba rivers. These are Northern Kaloleni, Western Kaloleni and Southern Kaloleni areas. The present water sources for these areas are as follows:

- Northern Kaloleni area	:	Three springs
- Eastern Kaloleni area	:	One spring
- Southern Kaloleni area	:	Goa spring and Njoro river

Through the site inspection and interview with farmers, it has been found that Northern and Western Kaloleni areas have been supplied with enough water from these springs. Meanwhile, Southern Kaloleni area requires irrigation water from not only the Goa spring, but the Njoro river. Taking into account such water source planning, irrigation canal system for each area has been planned as follows:

- Northern Kaloleni area

The Northern Kaloleni area has a small irrigable area of 4ha. At present, this area is irrigated from three springs. Since the spring water is enough to irrigate the area, two small supply irrigation canals will be so constructed as to connect with them. In this case, there is no application of canal classification such as main, secondary and tertiary canals.

- Eastern Kaloleni area

The Eastern Kaloleni area has an irrigable area of 27 ha. This area is presently irrigated from a large spring using small excavated canals. Since the spring water has sufficient discharge for irrigating this area using the existing irrigation system, the proposed irrigation canal system will follow this system as much as possible. The proposed irrigation canal will consist of two small supply canals.

- Southern Kaloleni area

The Southern Kaloleni area has a irrigable area of 69 ha. This area is presently irrigated from a Goa spring and the Njoro river. Taking into account water volume of the spring which is about 100/s, this area is divided into two areas: one is 32 ha to be supplied from the Goa spring, and the other is 37 ha to be irrigated from the Njoro river. The former is provided with one small supply canal, and the latter with two small supply canals.

(b) Mandaka Mnono area

The Mwananguruwe spring is a water source for the Mandaka Mnono area of 360 ha in net. The discharge of this spring was measured to be less than 300 l/s, which could not cover all the Mandaka Mnono area. Accordingly, The deficit water will be supplied from the Mamba river by constructing intake facility and a supply canal. The existing canal will be improved and linked with this supply canal. The proposed canal system consists of one main canal, two secondary canals and twenty seven tertiary canals.

3.5 Required Irrigation Facilities

(1) Basic Approach to Irrigation Facility Plan

It was observed that the irrigation system in the Existing Lower Moshi Project Area has been well operated. Therefore, in this study, the basic principle of irrigation facilities plan will follow that of the Existing Lower Moshi Project.

(2) Existing Lower Moshi Irrigation Area

An inventory survey on the existing irrigation facilities was carried out during the Phase I field investigation. The survey concluded that any major rehabilitation works would not be required, except for minor ones such as replacement of damaged small gates, re-filling earth for culvert, provision of measuring gauge, etc. Details of required works for the Existing Lower Moshi Project Area are shown in Table K.3.9.

(3) Expanded Area

There are simple irrigation systems established by farmers themselves in Kaloleni and Mandaka Mnono areas. There are no permanent irrigation facilities in these systems. The basic principle for irrigation facility plan of this Area is that the existing system will be incorporated into the new system as much as possible. As mentioned above, the Expanded Area has plural small water sources. Therefore, the required major works are planned according to these water sources as follows:

(a) Kaloleni area

1) Northern Kaloleni area

- Intake facility for three springs
- Inlet structures
- Small supply canals
- Division boxes
- Measuring device

2) Eastern Kaloleni area

- Intake facility for a spring
- Small supply canals
- Division boxes
- Measuring device

3) Southern Kaloleni area

- Intake facility for the Goa spring
- Intake facility for the Njoro river
- Small supply canals
- Division boxes
- Measuring devices

(b) Mandaka Mnono area

- Intake facility for the Mwananguruwe spring
- Intake facility for the Mamba river
- Supply canal
- Main, secondary and tertiary canals
- Inlet structure
- Turnouts
- Division boxes
- Measuring devices
- Culverts

The details of the required irrigation facilities are given Table K.3.10.

(4) New Extension Area

As discussed above, the canal system covering the New Extension Area is planned to be divided into three irrigation canal systems such as System-A, System-B and System-C. The respective systems consist of main, secondary, and tertiary canals and related structures. The main, secondary and tertiary canals will be lined with concrete in the same way with that of the existing Lower Moshi Project Area. As related structures, turnouts, checks, spillways, and culverts would be provided. Either a Parshall flume or broad crested weir is planned as a measuring device on the main canal. Gates with staff gauges are planned to be provided in turnouts at the heads of secondary and tertiary canals. The required length of them and number of structures are estimated as follows:

(a) System-A (181 ha in net)

Main canal	:	0.1km
Secondary canals	:	3.1km
Tertiary canals	:	7.2km
Related structures	:	111 nos.

(b) System-B (1,569 ha in net)

Main canal	:	7.4 km
Secondary canals	:	18.9 km
Tertiary canals	:	52.2 km
Related structures	:	779 nos.

(c) System-B (340 ha in net)

Main canal	:	2.1 km
Secondary canals	:	3.0 km
Tertiary canals	:	10.9 km
Related structures	:	161 nos.

The details of them are given in Table K.3.11.

3.6 Design of Irrigation Facilities

(1) Design Criteria

The irrigation facilities are in principle designed at a feasibility level based on the design criteria employed for that for the Existing Lower Moshi Project and irrigation distribution diagram. The executed design for them are explained hereinafter.

(2) Irrigation Canals

(a) Canal lining

The water sources for the Project should be used most efficiently, because the high cost would require the exploitation of additional water source. The irrigation canals constructed under the Existing Lower Moshi Project were provided with the precast concrete block lining from the technical and economical viewpoints, especially considering the effective use of limited water sources. According to the results of inventory survey for the canals, these lined canals are in satisfactory condition even after 10 years use and also offer the less maintenance cost as having been planned. From these facts, it is proposed that the main, secondary and tertiary canals to be constructed under the Project should be lined with the precast concrete block lining.

(b) Flow formula

The Manning formula is employed for hydraulic calculation of irrigation canals. In the formula, the roughness coefficients to be used are as follows:

1) For lined canal, concrete flume and concrete pipe : 0.015

2) For unlined canal : 0.030

(c) Allowable flow velocity

The allowable flow velocity used for design of canals are as follows:

1) Maximum velocity

- Lined canal : 1.2 m/sec
- Unlined canal : 0.8 m/sec

2) Minimum velocity

- All canals : 0.3 m/sec

(d) Free board

The required free board for the canals, which aims to protect the canal bank from the overflowing, are determined as follows:

1) For lined canal, concrete flume and concrete pipe:

$Fb = 0.05d + hv + 0.15$

where, Fb: Free board (m)
d : Design water depth (m)
hv: Velocity head (m)

2) For unlined canal:

more than 0.20 m

(e) Side slope

The following canal side slope is proposed considering the slippage of canal lining and stability of its sub-grade:

1) For up to and equal 0.6 m canal height : 1: 1.00
2) More than 0.6 m canal height : 1: 1.25

(f) Canal banks

Taking into consideration the bank width of existing canals for the Existing lower Moshi Project, the following berm width and bank height above the top of lining are used:

Canal	Berm width (m)	Bank height (m)
Main	1.0	0.3
Secondary	0.5	0.2
Tertiary	0.3	-

(3) Structures

As mentioned above, lots of canal structures will be required for smooth operation and protection of canals. These are diversion structure, turnout, checkdrop, drop, culvert, spillway, syphon, aqueduct and measuring device. The structures will be of reinforced concrete type. The diversion structure will be accompanied with a measuring device such as Parshall flume. The turnout will be also equipped with a movable weir type slide gate for easy operation and accurate water distribution.

4. DRAINAGE WORKS

4.1 Basic Approach to Establishment of Drainage Plan

As mentioned previously, there has not found any technical problem in the drainage system provided in the Existing Lower Moshi Project Area. Accordingly, the same approach to the drainage plan including calculation of drainage requirement, was applied to this Study although the rainfall data were updated.

4.2 Proposed Drainage Method

According to topographic conditions, excess water can be eliminated by gravity from the Project area to the rivers/streams flowing nearby. In the Existing Lower Moshi Project Area where gravity type of drainage system was constructed, there has not found any technical problem since 1986. Accordingly, the same gravity drainage system will be applied to the other areas, too.

4.3 Rainfall Analysis

(1) Hourly Rainfall

Two drainage water requirements are estimated: one is for paddy field and the other for upland crop fields. These drainage water requirements are calculated based on the 5-year probable 24-hour storm rainfall for paddy fields and the 5-year probable 1-hour storm rainfall for upland crop fields. The hourly rainfall is obtained by converting the daily maximum rainfall using the following equation:

$$R_1 = R_{24} (1/24)^{1/3} = 0.347 R_{24}$$

where, R_1 : hourly rainfall (mm/hr)
R_{24} : daily maximum rainfall (mm/day)

(2) Design Rainfall

Design rainfall for drainage is determined from the daily maximum rainfall - altitude relation shown in Figure K.4.1. The Study Area extends from El.765m to El.715m. The design rainfall is thus estimated at 82 mm/day for the average altitude of El.740m. This design rainfall is almost the same as the previous one of 87mm/day. Accordingly, the following previous design rainfalls are applied for this Study:

Paddy fields : 87 mm/day
Upland crops fields : 30 mm/hr

4.4 Estimate of Drainage Requirements

(1) Drainage Water Requirement for Paddy Fields

The drainage water requirement for paddy field is estimated under condition that a 5-year probable daily rainfall could be drained allowing 48 hours retardation in the fields. The following equation is employed for calculation:

$$Q = q \times A$$
$$q = (R_{24} \times 10^{-3} \times 10^{4})/(3,600 \times 48)$$

where, Q : design drainage requirement (l/s)
q : unit drainage requirement (l/s)
A : drainage area (ha)
R_{24} : 5-year probable daily rainfall (mm/day)

Since the 5-year probable daily rainfall is 87mm/day, the unit drainage requirement for paddy fields is estimated at 5 l/s/ha.

(2) Drainage Water Requirement for Upland Crop Fields

The drainage water requirement for upland crop fields is estimated based on the 5-year probable hourly rainfall of 30mm/hr, using the McMath formula:

$$Q = 2.3 \times C \times R_1 \times S^{1/5} \times A^{4/5}$$

where,
- Q : flood discharge (l/s)
- C : coefficient representing the basin characteristics (= 0.3)
- R_1 : hourly rainfall (mm/hr)
- S : fall of main drain between the farthest point and the connection point
- A : drainage area (ha)

Since the hourly rainfall is 30mm/hr, the above formula is expressed as follows:

$$Q = 20.7 \times S^{1/5} \times A^{4/5}$$

(3) Drainage Water Collection Diagram

Based on the unit drainage water requirement mentioned above, the drainage water collection diagrams for respective areas are prepared as shown in Figure K.4.2.

4.5 Drainage Canal System

A drainage system of gravity type will be employed in the Study Area, and any mechanical drainage system will not be required as mentioned above. The proposed drainage canal system will consist of tertiary, secondary and main drains in principle. All these drainage canals will be unlined. A specific drainage plan for the respective areas is discussed below:

(1) Existing Lower Moshi Project Area

No major repairs and/or rehabilitation will be needed for the constructed drainage canal system. Regular maintenance work such as removal of grasses and sediments from drains will be necessary for keeping a smooth flow condition in them. In addition, a pipe culvert will be additionally required where water is stagnant by closure due to construction of canals such as RS-4 and MR-3.

(2) Expanded Area

The Expanded Area consists of the Kaloleni ward and Mandaka Mnono village areas. Both areas are provided with a primitive irrigation system, but no drainage system. A drainage canal system is therefore planned considering the existing irrigation system. In the Kaloleni ward area, the Njoro river will function as a main drainage canal, considering its topographical condition. One secondary drain will be joined with it at the northern end of the Kaloleni ward area. Tertiary drains are planned to be directly connected with the Njoro river and the secondary drain.

The drainage canal system in the Mandaka Mnono village area is also planned following the existing irrigation system. No main drain will be required due to long and narrow area. Instead, a secondary drain will run around the centre of the Mandaka Mnono village area, from the south to the north, and will flow into the Rau river. The tertiary drains in the upstream area are planned to flow into the Rau river directly, but the remaining ones through the secondary drain.

An intercepting drain will be required along the left side of main canal and left secondary canal, in order to cut floods from hilly area and to protect the project facilities from such floods accordingly.

(3) New Extension Area

The New Extension Area extends around the Existing Lower Moshi Project Area. Two main drains are required for the New Extension Area. The first is the existing main drain (MD-3) flowing in the eastern part of the New Extension Area; the second is a new main drain to be located in the western part. Four new secondary drains will be connected with MD-3, to evacuate the excess water from the western part area. The second new main drain will be joined with four new secondary drains and two sub-secondary drains. The two main drains will finally pour themselves into the Nyumba Ya Mungu reservoir.

4.6 Required Drainage Facilities

Based on the proposed drainage system, the required drainage facilities for respective areas are determined as follows:

(1) Existing Lower Moshi Project Area

The inventory survey results showed that although no major repairs and/or rehabilitation are needed for the constructed drainage canal system, removal of grasses and sediments from drains will be required. In addition, a pipe culvert will be additionally required where water is stagnant by closure due to construction of canals such as RS-4 and MR-3. The details of required drainage works are given in Table K.3.9.

(2) Expanded Area

The required drainage facilities for the Expanded Area are as follows:

(a) Kaloleni area

1) Northern Kaloleni area

- No need of drainage works except on-farm works mentioned later.

2) Eastern Kaloleni area

- Tertiary drains
- Cross drains

3) Southern Kaloleni area

- Secondary drains
- Tertiary drains
- Cross drains
- Junction structures for tertiary drain with secondary drain

(b) Mandaka Mnono area

- Secondary drains

- Tertiary drains
- Cross drains
- Junction structures for tertiary drain with secondary drain

The details of required drainage works are given in Table K.3.10.

(3) New Extension Area

From the proposed drainage system for the New Extension Area, the required drainagefacilities are planned as follows:

- Main drains	:	10.5 km
- Secondary drains	:	27.6 km
- Tertiary drains	:	60.5 km
- Cross drains	:	3 nos.
- Junction structures	:	81 nos.

Table K.3.11 presents the details of the required drainage construction works.

4.7 Design of Drainage Facilities

Based on the proposed drainage system, the required drainage facilities for respective areas are designed based on the following conditions:

(1) Design Criteria

The design of drainage facilities are also made based on the design criteria applied for the Existing Lower Moshi Project.

(2) Drainage Canals

(a) Canal type

All drainage canals are proposed to be of unlined type, and any lining will not be provided.

(b) Flow formula

The Manning formula is employed for hydraulic calculation of irrigation canals. In the formula, the roughness coefficients to be proposed is 0.035.

(c) Allowable flow velocity

The allowable flow velocity used for design of drainage canals are between 0.3 m/sec and 1.2 m/sec.

(d) Free board

The free board employed for the drainage canal design is more than 0.3 m.

(e) Side slope

The side slope of 1 to 1.5 is applied for all drainage canals since there has not found any severe sliding at the side slope of the existing drainage canals.

(f) Bank width and berm width

The used width of bank and berm for the drainage canals are as follows:

Design discharge (m3/sec)	Bank width (m)	Berm width (m)
Less than 2.0	0.5	0.5
Over 2.0	1.0	0.5

(3) Structures

The proposed drainage system will also need a lot of structures consisting of cross drain and junction structure. The cross drain is made of reinforced concrete and pipes or box conduit at the point where the drainage canal will cross with road and/or irrigation canal. The junction structure is proposed to be of wet stone masonry, which will be provided to protect the drainage canal from scouring due to water inflow from one drainage canal to another.

5. FLOOD PROTECTION WORKS

5.1 Need of Flood Protection Dike

The Mandaka Mnono area extends over the left riparian area of the Rau river. According to the site inspection and interview with farmers in the Mandaka Mnono area, some parts of the area are suffered from floods by the Rau river and also some small streams from hilly side every year. In order to protect the irrigation and drainage facilities to be constructed under the Project, it is essential to provide a flood protection dike.

5.2 Design Criteria for Flood Protection Dike

In the Existing Lower Moshi Project Area, a flood protection dike of 15.4 km was provided along the Njoro and Rau rivers, to protect the project facilities from floods. Except damage of a part of the dike by flood occurred in April 1995, the present flood dike has not had any problem so far. Accordingly, in principle the same design criteria with the Existing Lower Moshi Project Area, was applied for the flood dike for the Mandaka Mnono area.

5.3 Design of Flood Protection Dike

(1) Design Floods

In the canal layout plan for the Mandaka Mnono area, the main canal and the secondary canal No.2 will run at the eastern side, and the secondary canal No.1 at the western side. The flood protection dike was therefore designed using the canal embankment of them, so as to save construction cost.

In the design of flood protection dike for the Existing Lower Moshi Project Area, design floods of 271m^3/s before and 307 m3/s after the confluence with the Njoro river for the Rau river, which were equivalent to a recurrence interval of 20 years, were employed. In this study, the same magnitude flood was planned to be used although a flood discharge itself should be confirmed using the updated data. The results of the flood analysis presented that the updated 20 years floods for the Rau river were 288 m3/s before and 326 m3/s after the confluence with the Njoro river which were slightly larger than the previous ones mentioned above. In this study, the updated floods be applied for design of flood protection dike against the Rau river.

On the other hand, the floods from the small streams are difficult for estimation of flood discharge. An interview with village people showed that the maximum flood water depth from the small streams were about 30 cm above the ground surface where water stagnant occurred. From these flood marks, the left embankment of main canal and secondary canal No.2 was proposed to be 1.0 m higher than the ground surface. Also, an intercepting drain was proposed to be constructed along this dike. Dimensions of intercepting drain were so determined as to balance the earth volume with left canal embankment volume.

(2) Check of Existing Flood Dikes

As stated above, the flood protection dike of 15.4 km was already constructed on the right bank along the Njoro and Rau rivers. In this study, a flood protection dike is proposed to be constructed at the left riparian area of the Rau river, to protect the Mandaka Mnono area from floods by its river. The location of proposed dikes was provisionally determined considering the extent of existing paddy fields. And then, a study was executed whether the proposed location of flood protection dike would lead to severe influence to the existing dikes or not, through a non-uniform calculation using the survey results and roughness coefficient of 0.04 which had been employed for the design of the existing dikes. The results are given in Figure K.5.1. From this calculation results, it was confirmed that the flood protection dike at the left riparian area of the Rau river, would not bring about substantial additional work to the existing dikes if the flood protection dike is constructed with the distance of more than 400 m from the existing one.

(3) Section and Length of Dike

The employed section of the dike is 2.5 m of crest width, inner side slope of 1: 2.0 and outer side slope of 1:1.5, which are the same with the existing one because the existing dike is functioning satisfactorily. The proposed length and height of the dike are as follows:

Flood Protection Dike	Length (m)	Height (m)
Left Flood Protection Dike	7.7	1.0
Right Flood Protection Dike	8.4	0.3 - 2.3

5.4 Drainage Sluice

A drainage sluice will be provided for the flood protection dike where drains crosses the flood protection dike. A drainage sluice consists of closed conduit and control gate, inlet and outlet wings, and transition. A control gate will be of flap gate type the same as the Existing Lower Moshi Project since it is presently functioning. The required number of drainage sluice would be two in total.

6. FARM ROAD WORKS

6.1 Design Criteria

The Existing Lower Moshi Project was provided with trunk road, main farm road, secondary farm road, and tertiary farm road. Except trunk road, other farm roads were constructed along canals. This road system has not offered any technical problem so far, so that the same design criteria was applied for the other areas. In principle, the farm roads to be provided are as follows:

- Main farm road : along main irrigation canal with 7 m wide and laterite pavement
- Secondary farm road : along main irrigation canal with 6 m wide and no pavement
- Tertiary farm road : along main irrigation canal with 4 m wide and no pavement

6.2 Farm Road Network

Based on the design criteria mentioned above and the feasibility level canal layout on the 1/5,000 topo-maps, a farm road network will be newly established for the Expanded Area and the New Extension Area, and that for the Existing Lower Moshi Project Area will be rehabilitated. The newly established farm road network for the Expanded Area and the New Extension Area are as follows:

(1) Expanded Area

(a) Kaloleni area

- Secondary farm road : 0.3 km
- Tertiary farm road : 5.9 km

(b) Mandaka Mnono area

- Main farm road : 1.2 km
- Secondary farm road : 8.1 km
- Tertiary farm road : 12.1 km

(2) New Extension Area

- Main farm road : 10.0 km
- Secondary farm road : 29.7 km
- Tertiary farm road : 70.2 km

6.3 Road Structures

To cross the irrigation and drainage canals, it is necessary to construct a culverts and cross drains at crossing point with farm road, respectively. These structures are discussed in Sub-sections 3.8 and 4.6.

7. ON-FARM WORKS

7.1 General

The on-farm works consist of construction of watercourses, field drains, field roads and their related structures. The land leveling works for paddy fields and construction of farm ridges are also included in the on-farm works. The on-farm works for the Existing Lower Moshi Project Area had been executed satisfactorily and any problem has not been found so far, so that the same design criteria has been applied for the upland crop area in the Existing Lower Moshi Project Area, the Expanded Area and the New Extension Area. However, the land leveling work is planned under the specification of tolerance of ± 10cm instead of ± 7.5cm, because further leveling is expected by farmers themselves through land puddling activities under farmers' participation philosophy.

7.2 Farm Layout

One irrigation block is less than 50 ha, and is divided into a lot of farm plots, whose size is 30 m x 100m. The irrigation block shall be designed in the following criteria for easier water management:

(a) Canal function of irrigation and drainage shall be completely separated.

(b) Existing canal and streams shall be incorporated into new system as much as possible.

(c) The area of one irrigation block shall not exceed 50ha in net The maximum length of tertiary canal will not exceed 2.0 km for easier water management, except exceptional case.

(d) The watercourses and field drains will be provided branching off from the tertiary canals and drains, respectively, at a standard interval of 200m.

(e) The standard length of a watercourse will be 400m, but be allowed to be extended up to 600m according to topographic conditions.

(f) Field road shall be provided at one side of watercourse for operation and maintenance of canal and for carrying agricultural inputs and outputs.

(g) All watercourses and drains in the irrigation block shall be of unlined earth type with trapezoidal sections. Related structures such as division boxes, pipe culverts, etc. shall be designed considering maximum use of locally available construction materials.

7.3 Irrigation Block Facilities

(1) Watercourse

The design discharge of watercourse was determined so that rotational irrigation could be smoothly executed. The design discharge thus determined are as follows:

Irrigation Block Area	Design Discharge
up to 25 ha	60 l/s
25 to 50ha	120 l/s
50 to 75ha	180 l/s

(2) Field Drain

The field drain was designed using the unit drainage water requirement of 5 l/s/ha . All field drains are unlined trapezoidal channel.

(3) Field road

The field road was provided at one side of watercourse. Road width and minimum height of road embankment will be 4.0 m and 0.3 m, respectively. No pavement was provided.

(4) Related structures

The structures related watercourse, field drain and field road are division box, drop, farm access structures and drain inlet.

7.4 Land Leveling

The land leveling will be executed for not only the upland crop area of the existing Lower Moshi Project Area, but also the New Extension Area and the Expanded Area. The executed area will therefore come to 3,600ha in total. The land leveling operation consists of earthmoving and fine leveling. The earthmoving is executed by cutting high grounds and filing depression in each field plot, within which earthfilling and excavation shall be generally balanced. During earthmoving operation, filling materials for nearby watercourse, field road and farm ridge will also be extracted. Subsequent to earthmoving, the field surface will be scarified and planned by routing bulldozers or land planners so that the finished surface of field is within the deviation of 10 cm above or below the prescribed surface. Further fine leveling work is planned to be executed by farmers themselves through land preparation activities under farmers' participation program.

Tables

Table K.2.1 Field Water Requirement Measured by KADC

(Unit:mm)

Period		ETc + P	ETc	P
1 Measurement in 1982				
September	8 - 10	30.9	12.0	18.9
	11 - 20	101.0	64.9	36.1
	21 - 30	122.0	46.0	76.0
	Average	11.0	5.3	5.7
October	1 - 10	137.7	69.6	68.1
	11 - 20	134.9	63.1	71.8
	21 - 31	285.0	143.6	141.4
	Average	18.0	8.9	9.1
November	1 - 10	179.0	136.0	43.0
	11 - 20	218.0	122.8	95.2
	21 - 30	140.3	83.8	56.5
	Average	18.0	11.4	6.6
Average for Total		16.3	8.9	7.4
		(100%)	(55%)	(45%)
2 Measurement in 1984				
October	1	8.4	1.5	6.9
	7	7.7	2.4	5.3
	14	6.9	3.7	3.2
	21	9.6	4.5	5.1
	28	11.4	6.2	5.2
	Average	8.8	3.7	5.1
November	5	9.6	6.5	3.1
	12	12.1	7.1	5.0
	19	12.1	8.3	3.8
	26	13.5	9.5	4.0
	Average	11.8	7.8	4.0
December	2	10.0	8.1	1.9
	9	10.2	8.6	1.6
	16	10.5	8.9	1.6
	Average	10.2	8.5	1.7
Average for Total		10.2	6.3	3.9
		(100%)	(60%)	(40%)

Note:

ETc: Crop Evapotranspiration (Consumptive use water)

P: Percolation

Table K.2.2 Field Water Requirements for Each Area

(Unit:mm/day)

Area/Year	Rainy Season Paddy						Early Dry Season Paddy								Late Dry Season Paddy							Ave-rage
	Feb	Mar	Apr	May	Jun	Ave.	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave.	Oct	Nov	Dec	Jan	Feb	Mar	Ave.	
(1) Upper Mabogini																						
1986									22.5	12.6	13.5	13.4		15.5								15.5
1987	11.0	14.6	11.8			12.5			21.2	13.5	13.4	13.4		15.4								14.1
1988	14.6	14.5	12.5	14.2	14.8	14.1	8.2	16.3	19.8	18.8	25.3			17.7		16.0	22.6	17.9	13.4		17.5	16.4
1989	19.3	15.1	11.7	9.6	5.9	12.3		14.5	15.9	19.5	21.9	20.7		18.5		23.0	10.4	8.1	4.7		11.6	16.5
1990		6.4	4.4			5.4																5.4
1991								16.3	21.1	19.4	19.1			19.0								19.0
1992		5.4	4.0			4.7		13.0	4.2	2.6	3.3			5.8								5.4
Average	**15.0**	**11.2**	**8.9**	**11.9**	**10.4**	**11.2**	**8.2**	**15.0**	**17.5**	**14.4**	**16.1**	**15.8**		**15.5**		**19.5**	**16.5**	**13.0**	**9.1**		**11.6**	**13.9**
(2) Lower Mabogini																						
1986									34.5	32.8	24.9	29.9		30.5								30.5
1987	19.4	24.9	34.7	31.9		27.7		19.3	25.7	27.6	23.0	17.2		22.6								24.9
1988	22.0	21.3	19.3	17.9	11.7	18.4		39.0	29.5	32.9	27.6			32.3	24.4	20.6	21.4	22.1	22.0		22.1	23.7
1989		21.1	19.5	21.5	21.4	20.9		20.3	25.7	32.3	27.8	20.7		25.4	26.8	24.0	28.6	25.2	24.6		25.8	24.3
1990	21.8	23.9	24.7			23.5																23.5
1991								23.6	27.1	27.7	29.4	29.6		27.5								27.5
1992			24.2			24.2																24.2
Average	**21.1**	**22.8**	**24.5**	**23.8**	**16.6**	**22.4**		**25.6**	**28.5**	**30.7**	**26.5**	**24.4**		**27.3**	**25.6**	**22.3**	**25.0**	**23.7**	**23.3**		**25.8**	**25.0**
(3) Rau Ya Kati																						
1986																						
1987	11.0	9.1	9.2	7.3		9.2		13.9	6.1	7.3	18.9	32.8		15.8								12.8
1988	20.3	21.9	20.7	14.5	17.4	19.0	11.3	13.2	13.8	18.1	18.9			15.1	16.2	22.0	21.7	14.8	19.3		18.8	17.6
1989	18.3	12.4	11.9	11.9	14.1	13.7	17.7	12.9	12.6	15.1	16.3	11.4		14.3	14.5	13.0	13.1	12.9	15.0	11.2	13.3	13.8
1990		11.9	12.0	12.6	14.4	12.7		17.0	14.3	12.4	13.5	13.2	13.4	14.0								13.5
1991																	17.6	30.9	29.8		26.1	26.1
1992	41.3	49.5	42.4			44.4	19.9	18.7	22.1	22.2	19.8			20.5								29.5
Average	**22.7**	**21.0**	**19.2**	**11.6**	**15.3**	**18.3**	**16.3**	**15.1**	**13.8**	**15.0**	**17.5**	**19.1**	**13.4**	**15.8**	**15.4**	**17.5**	**17.5**	**19.5**	**21.4**	**11.2**	**17.6**	**17.1**
(4) Chekereni																						
1986									12.6	11.2	9.4	9.5		10.7								10.7
1987								19.9	14.4	12.6	17.5	19.4		16.8								16.8
1988	24.5	23.3	21.7	26.5	27.8	24.8	17.8	22.1	18.9	19.5	16.0	16.5		18.5	20.3	18.3	16.3	16.5	17.7		17.8	20.2
1989	18.7	18.6	17.6	18.8		18.4				13.0	12.7	12.2	13.1	12.8								15.6
1990																						
1991																	13.9	18.0	19.4	19.7	17.8	17.8
1992	19.4	19.6	19.3	19.4		19.4	16.7	17.6	19.8	19.2	18.0			18.3								18.8
Average	**20.9**	**20.5**	**19.5**	**21.6**	**27.8**	**21.2**	**17.3**	**19.9**	**16.4**	**15.1**	**14.7**	**14.4**	**13.1**	**15.8**	**20.3**	**18.3**	**15.1**	**17.3**	**18.6**	**19.7**	**17.8**	**17.7**
(5) Oria																						
1986																						
1987									20.1	20.7	19.7	30.8		22.8								22.8
1988							11.4	13.8	16.8	24.0	11.8			15.6								15.6
1989	18.0	12.0	14.7	14.5		14.8	13.7	13.8	12.9	15.5	14.6	13.8		14.1	15.2	22.3	22.0	15.4			18.7	15.6
1990				15.6	13.9	14.8	14.2	15.3	14.0	13.4	12.8	13.2	14.1	13.9		10.5	16.3	14.9	15.4	15.5	14.5	14.2
1991																		29.7	24.7		27.2	27.2
1992								21.0	22.0	23.9	18.3			21.3								21.3
Average	**18.0**	**12.0**	**14.7**	**15.1**	**13.9**	**14.8**	**13.1**	**16.0**	**17.2**	**19.5**	**15.4**	**19.3**	**14.1**	**16.8**	**15.2**	**16.4**	**19.2**	**20.0**	**20.1**	**15.5**	**18.4**	**16.9**

Source : KADP

Table K.2.3 Cultivation Record of Paddy (1985 to 1997) (1/3)

Name of Block	Area (Ha.)	Nos. of Plot	1985	1986		1987		1988			1989		
			Dry	Rainy	Dry	Rainy	Dry	I	II	III	I	II	III
MABOGINI													
MS 1-1	21.24	73	*		*	*			*			*	
1-2	20.21	64			*	*		*			*		*
1-3	21.52	71			*	*		*		*		*	
2-1	20.80	74	*		*	*			*			*	
2-2	27.31	92	*		*	*			*			*	
2-3	24.17	87	*		*		*			*		*	
3-1	17.64	68			*	*		*			*		*
3-2	26.65	87			*		*			*		*	
4-1	20.85	72			*	*			*		*		*
4-2	31.82	112			*		*		*			*	
5-1	39.67	138		*	*		*			*			
5-2	27.59	92			*	*		*			*		*
5-3	28.89	96			*	*		*			*		*
6-1	32.07	116			*	*		*			*		
6-2	21.29	76			*	*		*		*		*	
6-3	11.80	44			*	*			*		*		*
7-1	39.63	140		*	*			*			*		*
7-2	39.82	137		*	*			*		*		*	
MS Total	472.97	1,639	94	119	473	271	122	249	134	173	199	235	177
Yearly Total			94		592		393			556			611
Rau													
RS 1-1	15.18	50				*		*			*		*
1-2	28.82	98				*		*		*			*
1-3	28.45	98				*			*			*	
1-4	25.56	90				*			*		*		
1-5	22.35	76				*			*		*		*
1-6	21.87	77				*			*		*		
1-7	21.78	77					*				*		*
1-8	10.88	39					*		*			*	
1-9	10.81	39					*		*			*	
3-1	20.28	68						*		*			*
3-2	23.81	82						*		*		*	
3-3	28.63	97						*		*		*	
3-4	25.41	88						*			*		*
4-1	34.78	122					*		*		*		
4-2	13.54	45					*		*		*		*
4-3	41.11	137					*		*		*		*
4-4	29.80	102					*		*			*	
4-5	22.27	77					*			*		*	
4-6	18.80	63					*		*		*		*
4-7	22.06	77						*			*		*
4-8	18.75	63						*		*		*	
4A-1A	21.17	70					*			*		*	
4A-1B	21.17	70					*			*		*	
8-2A	25.20	81					*		*		*		
8-2B	12.05	39					*		*		*		*
8-3	33.41	117					*			*		*	
8-4	32.66	106					*		*			*	
RS Total	630.60	2,148	0	0	0	142	349	183	328	218	300	282	241
Yearly Total			0	0	0		491			729			823
Total	1,103.57	3,787	94		592		884			1285			1434

Souce : KADP

Table K.2.3 Cultivation Record of Paddy (1985 to 1997) (2/3)

Name of Block	Area (Ha.)	Nos. of Plot	1990			1991			1992			1993		
			I	II	III	I	II	III	I	II	III	I	II	III
MABOGINI														
MS 1-1	21.24	73	*		*			*				*		
1-2	20.21	64		*			*			*		*		
1-3	21.52	71		*			*				*			*
2-1	20.80	74	*		*			*				*		
2-2	27.31	92	*				*				*			*
2-3	24.17	87		*			*			*			*	
3-1	17.64	68		*			*					*		
3-2	26.65	87	*		*		*			*		*		
4-1	20.85	72		*			*			*			*	
4-2	31.82	112	*		*		*				*			
5-1	39.67	138		*			*				*			*
5-2	27.59	92		*			*			*			*	
5-3	28.89	96	*		*			*				*		
6-1	32.07	116	*		*		*				*			
6-2	21.29	76		*			*			*			*	
6-3	11.80	44			*		*				*			*
7-1	39.63	140		*			*			*			*	
7-2	39.82	137	*				*				*			*
MS Total	472.97	1,639	229	233	173	0	402	71	0	180	204	135	134	140
Yearly Total					635			473			384			409
Rau														
RS 1-1	15.18	50		*		*					*			*
1-2	28.82	98		*				*				*		
1-3	28.45	98		*		*				*			*	
1-4	25.56	90	*			*				*			*	
1-5	22.35	76			*			*			*			
1-6	21.87	77	*		*			*				*		
1-7	21.78	77		*		*				*			*	
1-8	10.88	39	*		*			*			*			*
1-9	10.81	39	*		*			*			*			*
3-1	20.28	68		*		*				*			*	
3-2	23.81	82	*		*			*			*			*
3-3	28.63	97		*		*					*		*	
3-4	25.41	88	*	*		*				*		*		
4-1	34.78	122	*			*		*			*			*
4-2	13.54	45		*		*				*			*	
4-3	41.11	137		*		*				*			*	
4-4	29.80	102	*		*			*				*		
4-5	22.27	77		*		*		*				*		
4-6	18.80	63		*				*			*			*
4-7	22.06	77		*		*				*			*	
4-8	18.75	63	*		*			*			*			
4A-1A	21.17	70	*		*			*				*		
4A-1B	21.17	70	*		*			*			*			*
8-2A	25.20	81	*		*					*			*	
8-2B	12.05	39			*			*			*			*
8-3	33.41	117		*		*				*		*		
8-4	32.66	106	*		*			*			*		*	
RS Total	630.60	2,148	302	320	251	332	0	330	0	257	250	183	259	127
Yearly Total					873			662			507			569
Total	1,103.57	3,787			1,508			1135			891			978

Source : KADP

Table K.2.3 Cultivation Record of Paddy (1985 to 1997) (3/3)

Name of Block	Area (Ha.)	Nos. of Plot	1994			1995			1996			1997		
			I	II	III	I	II	III	I	II	III	I	II	III
MABOGINI														
MS 1-1	21.24	73		*		*			*					
1-2	20.21	64		*		*			*					
1-3	21.52	71			*	*			*				*	
2-1	20.80	74		*				*				*		
2-2	27.31	92			*						*			
2-3	24.17	87			*				*				*	
3-1	17.64	68		*		*		*			*			
3-2	26.65	87			*						*			
4-1	20.85	72					*					*		
4-2	31.82	112		*						*				
5-1	39.67	138						*					*	
5-2	27.59	92					*				*			
5-3	28.89	96		*						*				
6-1	32.07	116		*						*				
6-2	21.29	76					*				*			
6-3	11.80	44						*				*		
7-1	39.63	140					*						*	
7-2	39.82	137							*					
MS Total	472.97	1,639	0	173	100	80	109	90	127	93	120	53	166	
Yearly Total					273			279			340			
Rau														
RS 1-1	15.18	50						*				*		
1-2	28.82	98		*					*				*	
1-3	28.45	98			*					*				
1-4	25.56	90					*				*			
1-5	22.35	76		*						*				
1-6	21.87	77		*						*				
1-7	21.78	77					*				*			
1-8	10.88	39							*				*	
1-9	10.81	39							*				*	
3-1	20.28	68			*						*			
3-2	23.81	82						*					*	
3-3	28.63	97					*					*		
3-4	25.41	88		*						*				
4-1	34.78	122		*				*					*	
4-2	13.54	45					*				*			
4-3	41.11	137					*						*	
4-4	29.80	102		*						*				
4-5	22.27	77		*						*				
4-6	18.80	63		*					*					
4-7	22.06	77			*						*			
4-8	18.75	63		*						*				
4A-1A	21.17	70			*						*			
4A-1B	21.17	70		*					*			*		
8-2A	25.20	81		*					*				*	
8-2B	12.05	39						*				*		
8-3	33.41	117		*			*				*			
8-4	32.66	106			*					*			*	
RS Total	630.60	2,148	0	249	125	0	164	86	116	202	158	77	208	
Yearly Total					374			250			476			
Total	1,103.57	3,787			647			529			816			

Source : KADP

Table K.2.4 Field Water Requirement for Paddy by Automatic Instrument

Location : Plot No.202 of RS 4-1

(Unit:mm/day)

Jun.	FWR	Jul.	FWR	Aug.	FWR	Sept.	FWR	Oct.	FWR
1		1	6.9	1	11.5	1	*22.0	1	
2		2	*29.0	2	9.0	2	14.5	2	*29.0
3		3	11.7	3	8.5	3	15.0	3	*29.0
4		4	4.0	4	*44.0	4	13.0	4	18.9
5		5	*38.9	5	19.0	5	12.5	5	14.0
6		6	*30.0	6	13.0	6	12.5	6	13.7
7		7	9.0	7	10.5	7	12.0	7	17.1
8		8	12.0	8	11.0	8	11.0	8	*35.5
9		9	9.5	9	9.5	9	16.6	9	
10		10	6.0	10	10.5	10	17.0	10	
11		11	16.0	11	10.5	11	19.0	11	
12		12	17.5	12	13.5	12	13.5	12	
13		13	6.5	13	11.5	13	16.0	13	
14		14	7.5	14	16.5	14	15.0	14	
15		15	6.8	15	12.5	15	17.0	15	
16		16	8.5	16	12.0	16	12.0	16	
17		17	15.5	17	10.0	17	13.0	17	
18		18	10.5	18	10.0	18	12.8	18	
19		19	9.0	19	10.5	19	13.5	19	
20		20	8.0	20	10.0	20	14.0	20	
21		21	7.5	21	16.5	21	*38.0	21	
22		22	*26.5	22	13.0	22	10.5	22	
23		23	18.0	23	*22.0	23	17.0	23	
24		24	13.0	24	14.0	24	12.5	24	
25	11.0	25	11.0	25	15.0	25	13.0	25	
26	8.0	26	*36.0	26	18.0	26	13.0	26	
27	8.0	27	19.5	27	*29.0	27	16.0	27	
28	8.0	28	12.0	28	*40.0	28	*38.0	28	
29	8.0	29	12.0	29	*39.5	29		29	
30	7.0	30	17.5	30	*36.5	30		30	
31		31		31	*23.0	31		31	
Total	50.0	Total	275.4	Total	296.0	Total	351.9	Total	63.7
Average	8.3	Average	11.0	Average	12.3	Average	14.1	Average	15.9

*: excluded in analysis due to high value.

Table-K.2.5 Field Water Requirement of Paddy measured in 1997

(Unit:mm)

Period		Plot No.317 of MS 5-1 at Lower Mabogini Area				Plot No.215 of RS 1-2 at Rau Ya Kati Area				Plot No.214 of RS 8-4 at Oria Area			
		ETc+ P	ETc	P	Observation days	ETc+ P	ETc	P	Observation days	ETc+ P	ETc	P	Observation days
June	1 - 10	-	-	-	-	-	-	-	-	-	-	-	-
	11 - 20	22.0	14.0	8.0	2days	-	-	-	-	21.0	14.0	7.0	2days
	21 - 30	43.0	31.0	12.0	5days	-	-	-	-	59.0	42.0	17.0	4days
	Average	**9.3**	**6.4**	**2.9**		-	-	-	-	**13.3**	**9.3**	**4.0**	
July	1 - 10	58.0	44.0	14.0	7days	20.0	9.0	11.0	3days	42.0	29.0	13.0	4days
	11 - 20	23.0	16.0	7.0	3days	55.0	40.0	15.0	8days	73.0	62.0	11.0	8days
	21 - 31	35.0	30.0	5.0	5days	10.0	7.0	3.0	2days	144.0	86.0	58.0	8days
	Average	**7.7**	**6.0**	**1.7**		**6.5**	**4.3**	**2.2**		**13.0**	**8.9**	**4.1**	
August	1 - 10	15.0	12.0	3.0	3days	40.0	27.0	13.0	4days	83.0	56.0	27.0	8days
	11 - 20	20.0	16.0	4.0	4days	20.0	14.0	6.0	2days	78.0	50.0	28.0	8days
	21 - 31	27.0	21.0	6.0	5days	22.0	16.0	6.0	3days	75.0	55.0	20.0	9days
	Average	**5.2**	**4.1**	**1.1**		**9.1**	**6.3**	**2.8**		**9.4**	**6.4**	**3.0**	
September	1 - 10	10.0	8.0	2.0	2days	80.0	63.0	17.0	7days	49.0	33.0	16.0	4days
	11 - 20	60.0	50.0	10.0	10days	70.0	56.0	14.0	6days	105.0	70.0	35.0	9days
	21 - 30	59.0	49.0	10.0	10days	75.0	55.0	20.0	6days	76.0	50.0	26.0	6days
	Average	**5.9**	**4.9**	**1.0**		**11.8**	**9.1**	**2.7**		**12.1**	**8.0**	**4.1**	
October	1 - 10	45.0	37.0	8.0	8days	50.0	37.0	13.0	4days	115.0	76.0	39.0	10days
	11 - 20	54.0	45.0	9.0	9days	-	-	-	-	26.0	18.0	8.0	3days
	21 - 31	20.0	16.0	4.0	3days	-	-	-	-	-	-	-	-
	Average	**6.0**	**4.9**	**1.1**		**12.5**	**9.2**	**3.3**		**10.8**	**7.2**	**3.6**	
Average		**6.5**	**5.1**	**1.3**		**9.8**	**7.2**	**2.6**		**11.4**	**7.7**	**3.7**	

Note ETc : Crop Evapotranspiration (Consumtive use water)
P : Percolation

Table K.2.6 Present Conditions of Project Facilities: Mabogini Canal System (1/2)

Structure	Unit	Q'ty	Conditions A	Conditions B	Conditions C	Remarks
I. Mabogini Intake						
1.1 Civil Works						
Foundation	-		o			
Weir body	-		o			
Retaining wall	-		o			
Scouring sluice	-		o			
Upstream Protection	-		o			
Downstream protection	-		o			
Settling basin	-		o			
Pershall flume	-		o			
1.2 Metal Works						
Intake gate	Set	2	o			
Scouring sluice gate	Set	1		o		spindle is damaged
Sand flush gate	Set	1	o			
Trashrack	Set	2	o			
1.3 Miscellaneous						
Staff gauge	-		o			
Water level recorder	Set				o	instrument is missed
Handrail	-		o			
II. Irrigation Canal						
2.1 Main Canal						
(a) Canal	Km	4.8				
Lining condition				o		about 45m is damaged
Bank condition			o			
Canal leakage			o			
Sedimentation			o			
(b) Structure	Nos.					
Turnout		7	o			
Check/drop		6	o			
Drop		6	o			
Culvert/aqueduct		8	o	*		* one no. is exposed
Spillway		2	o			
Siphon		1	o			
2.2 Secondary Canal						
(a) Canal	Km	6.5				
Lining condition				o		about 200m is damaged
Bank condition			o			
Canal leakage			o			
Sedimentation			o			
(b) Structure	Nos.					
Turnout		17		o		10 nos. of spindles are missed
Check/drop		10		o		3 nos. of spindles are missed
Drop		3	o			
Culvert		7		o		3 nos. are exposed
Spillway		0				
Siphon		0				
2.3 Tertiary Canal						
(a) Canal	Km	27.8				
Lining condition			o			
Bank condition			o			
Canal leakage			o			
Sedimentation			o			
(b) Structure	Nos.					
Culvert		130	o			
Division box		132		o		about 30 % are damaged

(to be continued)

Conditions: A; Good, B; To be repaired, C; To be replaced

Table K.2.6 Present Conditions of Project Facilities: Mabogini Canal System (2/2)

Structure	Unit	Q'ty	Conditions A	Conditions B	Conditions C	Remarks
III. Drainage Canal						
3.1 Main Drain						
(a) Canal	Km	12.2				
Bank condition				o		reshaping is needed
Inside condition				o		reshaping is needed
(b) Structure	Nos.					
Culvert(circular)		2		o		2 nos. are exposed
Culvert(rectangular)		7		o		2 nos. are exposed
3.2 Secondary Drain						
(a) Canal	Km	14.7				
Bank condition				o		reshaping is needed
Inside condition				o		reshaping is needed
(b) Structure	Nos.					
Culvert(circular)		7	o			2 nos. are exposed
Culvert(rectangular)		17	o			4 nos. are exposed
3.3 Tertiary Drain						
(a) Canal	Km	17.1				
Bank condition				o		reshaping is needed
Inside condition				o		reshaping is needed
(b) Structure	Nos.					
Culvert(circular)		110		o		about 40 % are broken
Culvert(rectangular)		0				
IV. Farm Road						
4.1 Trunk Road	Km	16.1				
Road surface condition				o		Repairig is necessary
Metalling condition				o		Repairig is necessary
4.2 Main Road	Km	7.4				
Road surface condition				o		Repairig is necessary
4.3 Secondary Road	Km	16.2				
Road surface condition				o		Repairig is necessary
4.4 Tertiary Road	Km	20.6				
Road surface condition				o		Repairig is necessary
V. On Farm Works						
5.1 Water Course	Km	32.2	o			Reshaping is necessary
5.2 Field Drain	Km	28.6		o		Reshapng is necessary
5.3 Field Road	Km	36.2		o		Repairig is necessary

Conditions: A; Good, B; To be repaired, C; To be replaced

Table K.2.7 Present Conditions of Project Facilities: Rau Canal System (1/2)

Structure	Unit	Q'ty	Conditions A	B	C	Remarks
I. Rau Ya Kati Intake						
1.1 Civil Works						
Foundation	-		o			
Weir body	-		o			
Retaining wall	-		o			
Scouring sluice	-		o			
Upstream Protection	-		o			
Downstream protection	-		o			
Settling basin	-		o			
Pershall flume	-		o			
1.2 Metal Works						
Intake gate	Set	2	o			
Scouring sluice gate	Set	1	o			
Wasteway gate	Set	2		o		spindle is damaged
Flap gate	Set	1	o			
1.3 Miscellaneous						
Staff gauge	-		o			
Water level recorder	-				o	instrumentis missed
Handrail	-		o			
II. Irrigation Canal						
2.1 Main Canal						
(a) Canal	Km	5.3				
Lining condition			o	*		* about 60m is damaged
Bank condition			o			
Canal leakage			o			
Sedimentation			o			
(b) Structure	Nos.					
Turnout		5	o			
Check/drop		5	o			
Drop		8	o			
Culvert/aqueduct		8		o		one no. is exposed
Spillway		1	o			
Siphon		0				
2.2 Secondary Canal						
(a) Canal	Km	18.1				
Lining condition			o	*		about 200 m is damaged
Bank condition			o			
Canal leakage			o			
Sedimentation			o			
(b) Structure	Nos.					
Turnout		35		o		15 nos. of spindles are missed
Check/drop		27		o		10 nos. of spindles are missed
Drop		2	o			
Culvert		28		o		16 nos. are exposed
Spillway		0				
Siphon		2	o			
2.3 Tertiary Canal						
(a) Canal	Km	37.8				
Lining condition			o			
Bank condition			o			
Canal leakage			o			
Sedimentation			o			
(b) Structure	Nos.					
Culvert		165		o		about 10 % are damaged
Division box		157		o		about 30 % are damaged

(to be continued)

Conditions: A; Good, B; To be repaired, C; To be replaced

Table K.2.7 Present Conditions of Project Facilities: Rau Canal System (2/2)

Structure	Unit	Q'ty	Conditions A	B	C	Remarks
III. Drainage Canal						
3.1 Main Drain						
(a) Canal	Km	4.4				
Bank condition				o		Reshaping is needed
Inside condition				o		Reshaping is needed
(b) Structure	Nos.					
Culvert(circular)		0				
Culvert(rectangular)		0				
3.2 Secondary Drain						
(a) Canal	Km	17.3				
Bank condition				o		Reshaping is needed
Inside condition				o		Reshaping is needed
(b) Structure	Nos.					
Culvert(circular)		15		o		9 nos. are exposed
Culvert(rectangular)		28		o		11 nos. are exposed
3.3 Tertiary Drain						
(a) Canal	Km	23.8				
Bank condition				o		Reshaping is needed
Inside condition				o		Reshaping is needed
(b) Structure	Nos.					
Culvert(circular)		161		o		about 40 % are damaged
Culvert(rectangular)		1	o			
IV. Farm Road						
4.1 Main Road	Km	10.3				
Road surface condition				o		Repairing is necessary
4.2 Secondary Road	Km	22.5				
Road surface condition				o		Repairing is necessary
4.3 Tertiary Road	Km	35				
Road surface condition				o		Repairing is necessary
V. On Farm Works						
5.1 Water Course	Km	38.7		o		Repairing is necessary
5.2 Field Drain	Km	35.8		o		Repairing is necessary
5.3 Field Road	Km	41.6		o		Repairing is necessary
VI. Flood Dike	Km	11.4				
Condition of dike				o		

Conditions: A; Good, B; To be repaired, C; To be replaced

Table K.2.8 Number of Canal Structures in Existing Lower Moshi Project Area

(Unit:no./nos.)

Canal	Turnout*	Check drop	Drop	Culvert	Spillway	Syphon	Division Box	Total
I Mabogini Canal System								
(1) Main Canal	7	6	6	8 **	2	1	-	30
(2) Secondary Canal								
MS-1	2	1	-	-	-	-	-	3
MS-2	2	1	-	-	-	-	-	3
MS-3	1	-	-	-	-	-	-	1
MS-5	2	1	3	-	-	-	-	6
MS-6	6	5	-	4	-	-	-	15
MS-8	2	1	-	1	-	-	-	4
MS-9	2	1	-	2	-	-	-	5
(3) Tertiary Canal	-	-	-	130	-	-	132	262
Sub-Total	24	16	9	145	2	1	132	329
II Rau Ya Kati Canal System								
(1) Main Canal	5	5	8	8	1	-	-	27
(2) Secondary Canal								
RS-1	7	6	-	7	-	-	-	20
RS-2	3	2	-	-	-	-	-	5
RS-3	4	3	-	3	-	-	-	10
RS-4	7	6	1	5	-	1	-	20
RS-4A	2	1	-	2	-	-	-	5
RS-5	2	1	-	2	-	-	-	5
RS-6	5	4	-	5	-	-	-	14
RS-7	-	-	-	-	-	1	-	1
RS-8	5	3	-	4	-	-	-	12
(3) Tertiary Canal	-	-	-	165	-	-	157	322
Sub-Total	40	31	9	201	1	2	157	441
Total	64	47	18	346	3	3	289	770

Source : Project Completion Report, March 1988

** : Nos. of turnou site. ** : Including aqueduct.*

Table K.2.9 Measurement of Canal Seepage Loss for Secondary Canal (1/2)

(1) General information

Measurement date	: May 30, 1997	Design water depth	: 0.274 m - 0.603
Canal length	: 5,266.68 m	Side slope	: 1: 0.00 - 1.25
Design discharge	: 782 lit./sec.	Bottom width	: 0.3 m - 1.0 m
Canal gradient	: 1/450 - 1/1800	Lining	: Concrete block lining

(2) Measurement on Decrease in Water Level

Length : 474 m

Time (mm)	Reading of dial gauge (mm)	Decrease in water level (mm)
0	13.76	
10	10.50	3.26
20	8.88	1.62
30	6.71	2.17
40	4.94	1.77
50	3.36 (24.15)	1.58
60	22.35	1.80
70	20.40	1.95
80	18.75	1.65
90	16.80	1.95
100	15.05	1.75
110	13.35	1.70
120	11.18	2.17

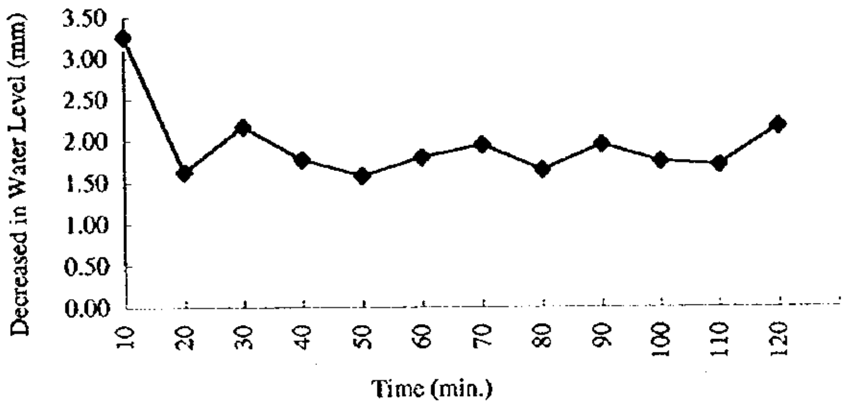


Table K.2.9 Measurement of Canal Seepage Loss for Secondary Canal (2/2)

(3) Water Surface Width and Water Depth just after Finish of Measurement

Section	Width of Water Surface	Water Depth	Wetted Perimeter	Area of Wetted Perimeter
No.0 (00.0m)	0.75 m	0.110 m	0.752 m	
No.1 (30.0m)	0.78 m	0.160 m	0.912 m	24.96 m2
No.2 (60.0m)	0.90 m	0.185 m	0.992 m	28.56 m2
No.3 (90.0m)	0.92 m	0.220 m	1.104 m	31.44 m2
No.4 (120.0m)	1.01 m	0.240 m	1.168 m	34.08 m2
No.5 (150.0m)	1.12 m	0.290 m	1.328 m	37.44 m2
No.6 (180.0m)	1.20 m	0.290 m	1.328 m	39.84 m2
No.7 (210.0m)	1.21 m	0.320 m	1.424 m	41.28 m2
No.8 (240.0m)	1.31 m	0.350 m	1.520 m	44.16 m2
No.9 (270.0m)	1.35 m	0.400 m	1.680 m	48.00 m2
No.10 (300.0m)	1.43 m	0.430 m	1.776 m	40.95 m2
No.11 (330.0m)	1.49 m	0.450 m	1.840 m	42.85 m2
No.12 (360.0m)	1.62 m	0.470 m	1.904 m	44.37 m2
No.13 (390.0m)	1.67 m	0.490 m	1.968 m	45.88 m2
No.14 (420.0m)	1.79 m	0.520 m	2.064 m	47.78 m2
No.15 (450.0m)	1.97 m	0.590 m	2.288 m	51.57 m2
No.16 (474.0m)	2.22 m	0.720 m	2.704 m	59.90 m2

Average width of water surface	:	1.31 m
Total area of wetted perimeter	:	717.18 m2

(4) Calculation of Canal Seepage Rate

Decreasing rate in water level (Dr) approaches to a constant value of 1.70 mm/10 min., that is 0.0028 mm/sec. Canal seepage rate (Cs) is as follows:

Cs = 0.0028 x 474 x 1.31 x (1,000/717.18) = 2.4 lit./sec/1,000m2

(5) Calculation of Total Canal Seepage Loss at Design Discharge

Total wetted perimeter area = 10,947.6 m2

Total canal seepage loss = 10,947.6 x 2.4/1,000 = 26.3 lit/sec.

Conveyance efficiency = (782-26.3)/ 782 x 100 = 97 %

Table K.2.10 Measurement of Canal Seepage Loss for Tertiary Canal (1/2)

(1) General information

Measurement date	: May 26, 1997	Design water depth	: 0.26 m
Canal length	: 827 m	Side slope	: 1: 1.00
Design discharge	: 46 lit./s.	Bottom width	: 0.4 m
Canal gradient	: 1/850	Lining	: Concrete block lining

(2) Measurement on Decrease in Water Level

Length : 91.3 m

Time (mm)	Reading of dial gauge (mm)	Decrease in water level (mm)
0	24.72	
10	22.87	1.85
20	22.41	0.46
30	21.76	0.65
40	20.42	1.34
50	18.40	2.02
60	17.92	0.48
70	16.75	1.17
80	15.55	1.20
90	14.30	1.25
100	13.13	1.17
110	11.98	1.15
120	10.97	1.01

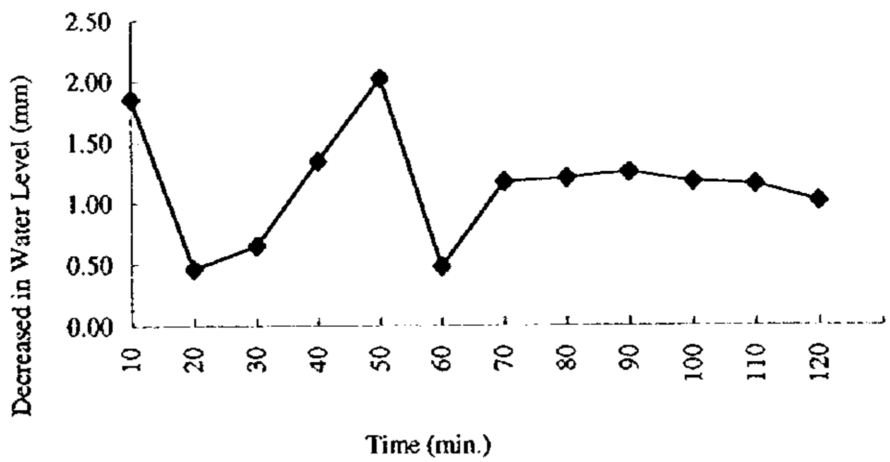


Table K.2.10 Measurement of Canal Seepage Loss for Tertiary Canal (2/2)

(3) Water Surface Width and Water Depth just after Finish of Measurement

Section	Width of Water Surface	Water Depth	Wetted Perimeter	Area of Wetted Perimeter
No.0 (00.0m)	0.74 m	0.305 m	1.346 m	
No.1 (20.0m)	0.75 m	0.270 m	1.247 m	25.94 m2
No.2 (40.0m)	0.74 m	0.380 m	1.558 m	28.06 m2
No.3 (60.0m)	0.93 m	0.400 m	1.615 m	31.73 m2
No.4 (80.0m)	0.96 m	0.405 m	1.629 m	32.44 m2
No.5 (91.3m)	0.99 m	0.460 m	1.785 m	19.29 m2

Average width of water surface : 0.84 m

Total area of wetted perimeter : 137.46 m2

(4) Calculation of Canal Seepage Rate

Decreasing rate in water level (Dr) approaches to a constant value of 1.1 mm/10 m., that is 0.002 mm/s. Canal seepage rate (Cs) is as follows:

Cs = 0.002 x 91.3 x 0.84 x (1,000/137.46) = 1.12 lit./s/1,000m2

(5) Calculation of Total Canal Seepage Loss at Design Discharge

Total wetted perimeter area = (0.55 + 0.08 x 2 + 0.18 x 1.414 x 2) x 827 = 1,008 m2

Total canal seepage loss = 1,008 x 1.12/1,000 = 1.1 lit/sec.

Conveyance efficiency = (46-1.1)/ 46 x 100 = 98 %

Table K.2.11 Measurement of Canal Seepage Loss for Watercourse (I) (1/2)

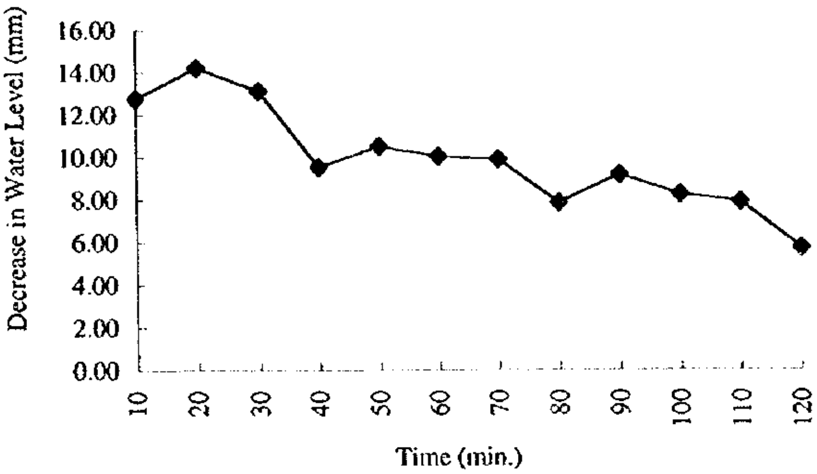
(1) General information

Measurement date	: May 28, 1997	Design water depth	: 0.22 m
Canal length	: 411.1 m	Side slope	: 1:1.0
Design discharge	: 46 lit./sec.	Bottom width	: 0.3 m
Canal gradient	: 1/440	Lining	: Unlined

(2) Measurement on Decrease in Water Level

Length : 81 m

Time (mm)	Reading of dial gauge (mm)	Decrease in water level (mm)
0	14.93	
10	2.18 (16.28)	12.75
20	2.10 (25.18)	14.18
30	12.10	13.08
40	2.60 (29.28)	9.50
50	18.80	10.48
60	8.80 (31.45)	10.00
70	21.61	9.84
80	13.80	7.81
90	4.68 (29.65)	9.12
100	21.44	8.21
110	13.60	7.84
120	7.92	5.68



TableK.2.11 Measurement of Canal Seepage Loss for Watercourse (1) (2/2)

(3) Water Surface Width and Water Depth just after Finish of Measurement

Section	Width of Water Surface	Water Depth	Wetted Perimeter	Area of Wetted Perimeter
No.0 (00.0m)	0.00 m	0.000 m	0.000 m	0.00 m2
No.0 + 5.0 m	0.50 m	0.015 m	0.534 m	1.34 m2
No.1 (15.0m)	0.90 m	0.041 m	0.992 m	7.63 m2
No.2 (36.0m)	1.65 m	0.210 m	2.112 m	32.59 m2

Average width of water surface : 0.97 m

Total area of wetted perimeter : 41.56 m2

(4) Calculation of Canal Seepage Rate

Dereasing rate in water level (Dr) approaches to a constant value of 5.6 mm/10 min., that is 0.009 mm/sec. Canal seepage rate (Cs) is as follows:

Cs = 0.009 x 36.0 x 0.97 x (1,000/41.56) = 7.6 l/s/1,000m2

(5) Calculation of Total Canal Seepage Loss at Design Discharge

Total wetted perimeter area = (1.10 + 0.12 x1.118 x 2) x 411.5 = 563 m2

Total canal seepage loss = 563 x 7.6/1,000 = 4.3 l/s

Conveyance efficiency = (46 - 4.3)/ 46 x 100 = 90 %

Table K.2.12 Measurement of Canal Seepage Loss for Watercourse (2) (1/2)

(1) General information

Measurement date	: December 2, 1997	Design water depth	: 0.22 m
Canal length	: 411.1 m	Side slope	: 1:1.0
Design discharge	: 46 lit./sec.	Bottom width	: 0.3 m
Canal gradient	: 1/440	Lining	: Unlined

(2) Measurement on Decrease in Water Level

Length : 57 m

Time (mm)	Reading of dial gauge (mm)	Decrease in water level (mm)
0	18.73	
10	2.20 (26.00)	16.53
20	15.66	10.34
30	4.58 (26.98)	11.08
40	20.50	6.48
50	11.52	8.98
60	3.75 (27.48)	7.77
70	24.57	4.98
80	20.57	4.00
90	17.82	2.75
100	15.23	2.59

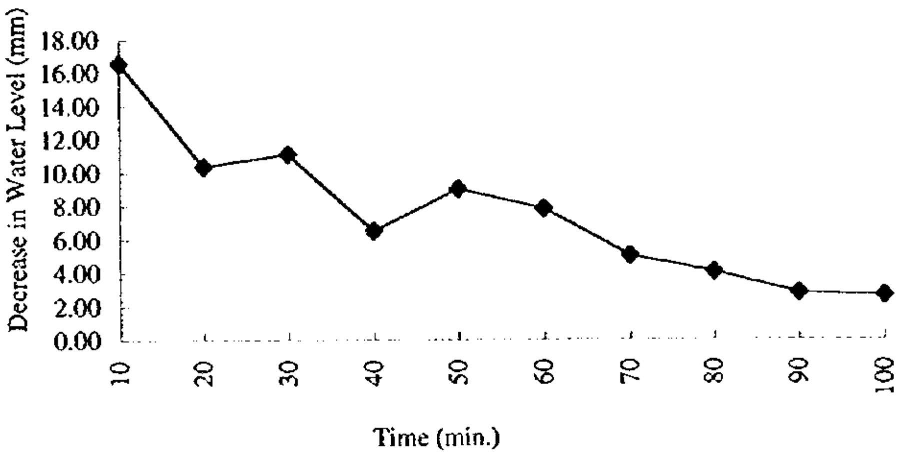


Table K.2.12 Measurement of Canal Seepage Loss for Watercourse(2) (2/2)

(3) Water Surface Width and Water Depth just after Finish of Measurement

Section	Width of Water Surface	Water Depth	Wetted Perimeter	Area of Wetted Perimeter
No.0 (00.0m)	0.82 m	0.01 m	1.04 m	
No.1 (20.0m)	0.82 m	0.03 m	0.89 m	19.00 m2
No.2 (40.0m)	0.83 m	0.02 m	0.87 m	17.60 m2
No.3 (57.0m)	0.57 m	0.04 m	0.76 m	13.77 m2

Average width of water surface : 0.80 m
Total area of wetted perimeter : 50.37 m2

(4) Calculation of Canal Seepage Rate

Dereasing rate in water level (Dr) approaches to a constant value of 2.6 mm/10 min., that is 0.004 mm/sec. Canal seepage rate (Cs) is as follows:

Cs = 0.004 x 57.0 x 0.80 x (1,000/50.37) = 3.62 l/s/1,000m2

(5) Calculation of Total Canal Seepage Loss at Design Discharge

Total wetted perimeter area = (1.10 + 0.12 x1.118 x 2) x 411.5 = 563 m2

Total canal seepage loss = 563 x 3.6/1,000 = 2.0 l/s

Conveyance efficiency = (46 - 2.0)/ 46 x 100 = 96 %

Table K.2.13 Measured Return Flow Amount at Tertiay Block RS 4-3

Location: RS 4-3 at Chekereni area   Area: 41ha

(Unit:m3)

Date	June 1997			July 1997			August1997			September1997			October1997		
	Qin	Qr	Qout	Qin	Qr	Qout	Qin	Qr	Qout	Qin	Qr	Qout	Qin	Qr	Qout
1				9,763	41	291	8,035		182	10,973		0	6,998		0
2				10,368	1,644	590	8,035		48	9,763	206	508	4,493		0
3				7,517	411	868	4,493		92	8,640		0	5,443		0
4							7,517		128	9,763		0	5,443	1,603	0
5							6,998		519	9,763		329	6,998		0
6				8,640		868	8,640		374	9,763		0	5,443	740	0
7				5,443		1,032	8,035		792	9,158		3	8,640	164	0
8				4,493		214	8,035		346	9,763		0	9,763		0
9				4,493		329	8,035		304	9,158	164	34	6,998		0
10				6,998		201	4,493		654	4,493		0	11,578	206	0
11				8,640		105	8,035		394	10,368		0	8,035		868
12				9,763		291	8,035		80	10,368		0	4,493	123	0
13				9,763		475	8,035		77	4,493		0	4,493		0
14				5,962	103	590	9,763		176	6,998		3	4,493		0
15				9,155		214	12,874		680	8,035		0	864		0
16				6,998	493	374	8,640		497	6,998		0	4,493		0
17	8,640		948	8,640		291	8,640		92	3,629		0	5,962		0
18	6,998		1,212	5,962		2,687	9,158		680	7,517	288	0	2,506		0
19	6,998	144	1,032	8,036		165	10,368		0	6,998		0	2,506	4,111	0
20	4,493		868	6,998		84	10,368		554	5,443		0	2,506	2,056	0
21	4,493		1,410	9,158		67	9,158		443	9,763		0	2,506	6,249	0
22	8,035	41	1,032	9,158		508	9,158		12	7,517		0			
23	9,763	1,069	1,212	9,763		931	8,640		165	5,011		0			
24	10,973	617	1,032	8,640		948	9,158		7	1,728		0			
25	12,874		868	8,035		868	8,035		0	5,443		0			
26	12,874		884	8,035		374	8,035		0	1,728		0			
27	11,578		554	6,998		159	9,763		31	864		0			
28	11,578	164	2,449	5,962		250	9,763		0	9,763		0			
29	8,640		899	6,998		356	9,763		0	5,962		0			
30	10,368		1,120	9,764		1,212	9,763		0	5,443		0			
31				8,035		423	9,763		0						
Total	128,305	2,035	15,520	228,178	2,692	15,765	267,231		7,327	215,306	658	877	114,654	15,252	868
Average Supply discharge	2.6 l/s/ha			2.2 l/s/ha			2.4 l/s/ha			2.0 l/s/ha			1.5 l/s/ha		
Qout/(Qin+Qr) x 100 (%)=	12 %			7 %			3 %			0 %			1 %		
Return flow rate for one cropping season	4 %														
Average irrigation supply discharge	2.2 l/s/ha														

Note

Oin : Water supply discharge

Qr : Rainfall

Table K.3.1 Estimate on Consumptive Use of Paddy

(1) Potential Evapotranspiration (ETo)

(a) Climatic data

Station: TPC Langasani (Altitude:701m)

Description	Unit	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Temperature	o C												
Maximum		32.5	33.1	32.9	30.4	28.3	27.0	26.7	27.8	29.3	31.2	31.7	31.8
Minimum		19.5	19.5	20.0	20.1	18.8	16.5	15.7	15.9	16.7	18.2	19.3	19.4
Rel. humidity (mean)*	%	64	62	66	73	75	71	71	68	66	64	65	65
Wind speed	km/day	135	126	114	90	74	69	73	82	96	109	125	139
Sunshine hours	hrs.	8.5	8.6	7.9	6.8	5.7	5.3	5.4	6.0	7.6	8.1	8.1	8.1

(b) Potential Evapotranspiration by Modified Penman Method

Description	Unit	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Potential ETo	mm/day	5.9	6.0	5.6	4.6	3.8	3.4	3.5	4.0	4.9	5.5	5.6	5.6

* estimated using data measured as 9:00 am and 3:00 pm.

(2) Crop Coefficient of Paddy (Kc)

(a) Rainy season paddy

Description	Feb.		Mar.		Apr.		May		Jun.		Jul.	
1st half	1.06	1.10	1.14	1.19	1.25	1.27	1.26	1.19				
2nd half		1.06	1.10	1.14	1.19	1.25	1.27	1.26	1.19			
3rd half			1.06	1.10	1.14	1.19	1.25	1.27	1.26	1.19		
4th half				1.06	1.10	1.14	1.19	1.25	1.27	1.26	1.19	
Average	1.06	1.13	1.10	1.12	1.17	1.21	1.24	1.24	1.24	1.23	1.19	

(b) Dry season paddy

Description	Aug.		Sept.		Oct.		Nov.		Dec.		Jan.	
1st half	1.06	1.10	1.14	1.19	1.25	1.27	1.26	1.19				
2nd half		1.06	1.10	1.14	1.19	1.25	1.27	1.26	1.19			
3rd half			1.06	1.10	1.14	1.19	1.25	1.27	1.26	1.19		
4th half				1.06	1.10	1.14	1.19	1.25	1.27	1.26	1.19	
Average	1.06	1.13	1.10	1.12	1.17	1.21	1.24	1.24	1.24	1.23	1.19	

(3) Estimate on Crop Evapotranspiration (Consumptive use water) of Paddy

(a) Rainy season paddy

Description	Feb.		Mar.		Apr.		May		Jun.		Jul.	
Potential ETo (mm/day)	6.0	6.0	5.6	5.6	4.6	4.6	3.8	3.8	3.4	3.4	3.5	
Kc	1.06	1.13	1.10	1.12	1.17	1.21	1.24	1.24	1.24	1.23	1.19	
ETc (mm/day)	6.4	6.8	6.2	6.3	5.4	5.6	4.7	4.7	4.2	4.2	4.2	
ETc (mm/month)		185		194		165		146		126		130

(b) Dry season paddy

Description	Aug.		Sept.		Oct.		Nov.		Dec.		Jan.	
Potential ETo (mm/day)	4.0	4.0	4.9	4.9	5.5	5.5	5.6	5.6	5.6	5.6	5.9	
Kc	1.06	1.13	1.10	1.12	1.17	1.21	1.24	1.24	1.24	1.23	1.19	
ETc (mm/day)	4.2	4.5	5.4	5.5	6.4	6.7	7.0	7.0	6.9	6.9	7.0	
ETc (mm/month)		135		164		203		210		214		217

Table K.3.2 Calculated Percolation Rates for Each Area

1.Rainy Season Paddy (Unit:mm/day)

Area/Year	Feb		Mar		Apr		May		Jun		Average
(1) Estimated ETo	6.6		6.3		5.5		4.7		4.2		
	ETo+P	P	ETo+P	P	ETo+P	P	ETo+P	P	ETo+P	P	P
(2) Upper Mabogini											
1987	11.0	4.4	14.6	8.3	11.8	6.3					**6.3**
1988	14.6	8.0	14.5	8.2	12.5	7.0	14.2	9.5	14.8	10.6	**8.7**
1989	19.3	12.7	15.1	8.8	11.7	6.2	9.6	4.9	5.9	1.7	**6.9**
Average	**15.0**	**8.4**	**14.7**	**8.4**	**12.0**	**6.5**	**11.9**	**7.2**	**10.4**	**6.2**	**7.3**
(3) Lower Mabogini											
1987	19.4	12.8	24.9	18.6	34.7	29.2	31.9	27.2			**22.0**
1988	22.0	15.4	21.3	15.0	19.3	13.8	17.9	13.2	11.7	7.5	**13.0**
1989			21.1	14.8	19.5	14.0	21.5	16.8	21.4	17.2	**12.6**
1990	21.8	15.2	23.9	17.6	24.7	19.2					**17.3**
Average	**21.1**	**14.5**	**22.8**	**16.5**	**24.6**	**19.1**	**23.8**	**19.1**	**16.6**	**12.4**	**16.3**
(4) Rau Ya Kati											
1987	11.0	4.4	9.1	2.8	9.2	3.7	7.3	2.6			**3.4**
1988	20.3	13.7	21.9	15.6	20.7	15.2	14.5	9.8	17.4	13.2	**13.5**
1989	18.3	11.7	12.4	6.1	11.9	6.4	11.9	7.2	14.1	9.9	**8.3**
1990			11.9	5.6	12.0	6.5	12.6	7.9	14.4	10.2	**6.0**
Average	**16.5**	**9.9**	**13.8**	**7.5**	**13.5**	**8.0**	**11.6**	**6.9**	**15.3**	**11.1**	**8.7**
(5) Chekereni											
1987											
1988	24.5	17.9	23.3	17.0	21.7	16.2	26.5	21.8	27.8	23.6	**19.3**
1989	18.7	12.1	18.6	12.3	17.6	12.1	18.8	14.1			**12.7**
1990											
Average	**21.6**	**15.0**	**21.0**	**14.7**	**19.7**	**14.2**	**22.7**	**18.0**	**27.8**	**23.6**	**17.1**
(6) Oria											
1987											
1988											
1989	18.0	11.4	12.0	5.7	14.7	9.2	14.5	9.8			**11.9**
1990							15.6	10.9	13.9	9.7	**13.5**
Average	**18.0**	**11.4**	**12.0**	**5.7**	**14.7**	**9.2**	**15.1**	**10.4**	**13.9**	**9.7**	**12.7**
(7) Average		**11.6**		**11.2**		**11.8**		**12.0**		**11.5**	

2.Dry Season Paddy (Unit:mm/day)

Area/Year	Aug		Sep		Oct		Nov		Dec		Average
(1) Estimated ETo	4.4		5.5		6.6		7		7		
	ETo+P	P	ETo+P	P	ETo+P	P	ETo+P	P	ETo+P	P	P
(2) Upper Mabogini											
1987	21.2	16.8	13.5	8.0	13.4	6.8	13.4	6.4			9.5
1988	19.8	15.4	18.8	13.3	25.3	18.7					15.8
1989	15.9	11.5	19.5	14.0	21.9	15.3	20.7	13.7			13.6
Average	**19.0**	**14.6**	**17.3**	**11.8**	**20.2**	**13.6**	**17.1**	**10.1**			**12.5**
(3) Lower Mabogini											
1987	25.7	21.3	27.6	22.1	23.0	16.4	17.2	10.2			17.5
1988	29.5	25.1	32.9	27.4	27.6	21.0					24.5
1989	25.7	21.3	32.3	26.8	27.8	21.2	20.7	13.7			20.8
1990											
Average	**27.0**	**22.6**	**30.9**	**25.4**	**26.1**	**19.5**	**19.0**	**12.0**			**19.9**
(4) Rau Ya Kati											
1987	6.1	1.7	7.3	1.8	18.9	12.3	32.8	25.8			10.4
1988	13.8	9.4	18.1	12.6	18.9	12.3					11.4
1989	12.6	8.2	15.1	9.6	16.3	9.7	11.4	4.4			8.0
1990	14.3	9.9	12.4	6.9	13.5	6.9	13.2	6.2	13.4	6.4	7.3
Average	**11.7**	**7.3**	**13.2**	**7.7**	**16.9**	**10.3**	**19.1**	**12.1**	**13.4**	**6.4**	**8.8**
(5) Chekereni											
1987	14.4	10.0	12.6	7.1	17.5	10.9	19.4	12.4			10.1
1988	18.9	14.5	19.5	14.0	16.0	9.4	16.5	9.5			11.9
1989			13.0	7.5	12.7	6.1	12.2	5.2	13.1	6.1	5.0
1990											
Average	**16.7**	**12.3**	**15.0**	**9.5**	**15.4**	**8.8**	**16.0**	**9.0**	**13.1**	**6.1**	**9.1**
(6) Oria											
1987	20.1	15.7	20.7	15.2	19.7	13.1	30.8	23.8			17.0
1988	16.8	12.4	24.0	18.5	11.8	5.2					12.0
1989	12.9	8.5	15.5	10.0	14.6	8.0	13.8	6.8			8.3
1990	14.0	9.6	13.4	7.9	12.8	6.2	13.2	6.2	14.1	7.1	7.4
Average	**16.0**	**11.6**	**18.4**	**12.9**	**14.7**	**8.1**	**19.3**	**12.3**	**14.1**	**7.1**	**10.4**

Table K.3.3 Unit Irrigation Water Requirement of Paddy

(1) Area to be Irrigated from Njoro and Rau Rivers

Rainy Season Paddy

Description	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Cultivation		←		Rainy Season Paddy			→					
(1) ETc (mm/m)		185	194	165	146	126	130					
(2) P (mm/m)		224	248	240	248	240	248					
(3) ER80 (mm/m)	1	0	11	56	33	0	0					
(4) NWD (mm)	-1	409	431	349	361	366	378					
(5) CI		1/4	3/4	1	15/16	1/2	1/16					
(6) NW (mm)	7	18	11									
(7) PW (mm)	18	108	94									
(8) NR (mm/m)	17	210	417	349	338	183	24					
(9) GR (mm/m)	24	292	580	485	470	254	33					
(10) GR (l/s/ha)	0.1	1.2	2.2	1.9	1.8	1.0	0.1					

Dry Season Paddy

Description	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Cultivation	→							←	Dry Season Paddy			→
(1) ETc (mm/m)	217							135	164	203	210	214
(2) P (mm/m)	248							248	240	248	240	248
(3) ER80 (mm/m)	1						0	0	0	0	2	20
(4) NWD (mm)	464						0	383	404	451	448	442
(5) CI	1/16							1/2	3/4	1	15/16	1/2
(6) NW (mm)							7	18	11			
(7) PW (mm)							18	108	94			
(8) NR (mm/m)	29						18	300	397	451	420	221
(9) GR (mm/m)	40						25	416	551	626	583	307
(10) GR (l/s/ha)	0.2						0.1	1.6	2.1	2.3	2.2	1.2

(2) Area to be Irrigated from Kikuletwa River

Rainy Season Paddy

Description	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Cultivation		←		Rainy Season Paddy			→					
(1) ETc (mm/m)		185	194	165	146	126	130					
(2) P (mm/m)		224	248	240	248	240	248					
(3) ER80 (mm/m)	1	0	11	56	33	0	0					
(4) NWD (mm)		409	431	349	361	366	378					
(5) CI		1/4	3/4	1	15/16	1/2	1/16					
(6) NW (mm)	7	18	11									
(7) PW (mm)	18	108	94									
(8) NR (mm/m)	18	228	428	349	338	183	24					
(9) GR (mm/m)	26	331	621	506	490	265	34					
(10) GR (l/s/ha)	0.1	1.4	2.3	2.0	1.8	1.0	0.1					

Dry Season Paddy

Description	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Cultivation	→							←	Dry Season Paddy			→
(1) ETc (mm/m)	217							135	164	203	210	214
(2) P (mm/m)	248							248	240	248	240	248
(3) ER80 (mm/m)	1						0	0	0	0	2	20
(4) NWD (mm)	464						0	383	404	451	448	442
(5) CI	1/16							1/4	3/4	1	15/16	1/2
(6) NW (mm)							7	18	11			
(7) PW (mm)							18	108	94			
(8) NR (mm/m)	29						18	222	408	451	420	221
(9) GR (mm/m)	42						26	321	591	654	609	320
(10) GR (l/s/ha)	0.2						0.1	1.2	2.3	2.4	2.3	1.2

Note
- ETc : Crop Evapotranspiration (Consumptive use water)
- P : Percolation
- ER80 : Effective rainfall with 80% dependability estimated using data for 15 years from 1982 to 1996 observed at the Chekereni Station.
- NWD : Net water deficit (FWR - ER80)
- CI : Crop index
- NW : Nursery water
- PW : Puddling water
- NR : Net requirement
- GR : Gross requirement using overall irrigation efficiency of 0.72 for area to be irrigated from Njoro and Rau rivers and 0.69 for area to be irrigated from Kikuletwa river.

Table K.3.4 Unit Irrigation Water Requirement of Upland Crop

(1) Crop Coefficient of Alfalfa (Kc)

Description	Oct.		Nov.		Dec.		Jan.		Feb.	
1st half	0.40	0.50	0.70	0.89	1.10	1.15	1.08	0.88	0.60	
2nd half		0.40	0.50	0.70	0.89	1.10	1.15	1.08	0.88	0.60
Average	0.40	0.45	0.60	0.80	1.00	1.13	1.12	0.98	0.74	0.60

(2) Estimate on Crop Evapotranspiration of Alfalfa

Description	Oct.		Nov.		Dec.		Jan.		Feb.	
ETo (mm/day)	5.5	5.5	5.6	5.6	5.6	5.6	5.9	5.9	6.0	6.0
Kc	0.40	0.45	0.60	0.80	1.00	1.13	1.12	0.98	0.74	0.60
ETc (mm/day)	2.2	2.5	3.4	4.5	5.6	6.3	6.6	5.8	4.4	3.6

(3) Estimate on Irrigation Requiremet of Alfalfa

Area to be Irrigated from Njoro and Rau River

Description	Oct.	Nov.	Dec.	Jan.	Feb.
ETc (mm/m)	72	118	185	192	113
ER80 (mm/m)	0	2	21	7	0
NWD (mm/m)	72	116	164	185	113
CI	1/8	7/8	1	1	1/2
PI (mm)	30	30			
NR(mm/m)	39	131	164	185	56
GR (mm/m)	74	247	309	349	106
GR (l/s/ha)	0.3	1.0	1.2	1.3	0.4

Area to be Irrigated from Kikuletwa River

Description	Oct.	Nov.	Dec.	Jan.	Feb.
ETc (mm/m)	72	118	185	192	113
ER80 (mm/m)	0	2	21	7	0
NWD (mm/m)	72	116	164	185	113
CI	1/8	7/8	1	1	1/2
PI (mm)	30	30			
NR(mm/m)	39	131	164	185	56
GR (mm/m)	77	257	321	363	110
GR (l/s/ha)	0.3	1.0	1.2	1.4	0.5

Note

ETc : Crop Evapotranspiration (Consumptive use water)
ER80 : Effective rainfall with 80% dependability estimated using data for 15 years from 1982 to 1996
NWD : Net water deficit (ETc - ER80)
CI : Crop index
PI : Preirrigation requirement
NR : Net requirement
GR : Gross requirement using overall irrigation efficiency of 0.53 for are to be irrigated from Njoro and Rau rivers , and 0.51 for area to be irrigated from Kikuletwa river.

TableK.3.5 Effective Rainfall of Upland Crop

(1) Monthly rainfall

Locati : Chekereni (Unit:mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct.	Nov	Dec	Total
1981										58.5	17.9	58.7	135.1
1982	12.8	8.4	4.1	74.8	267.3	56.7	35.9	7.8	23.8	137.6	119.3	43.9	792.4
1983	11.4	27.7	12.4	130.0	116.0	16.7	4.8	0.0	1.7	4.3	2.7	89.6	417.3
1984	11.0	5.8	14.8	228.5	45.5	29.8	49.4	4.0	4.0	5.5	54.6	57.0	509.9
1985	43.0	138.9	86.0	58.0	100.5	6.0	12.0	1.0	0.5	20.1	46.0	55.5	567.5
1986	86.5	58.5	11.0	98.2	159.8	1.2	0.0	7.8	0.0	11.5	7.8	154.2	596.5
1987	48.0	6.6	57.7	72.1	79.0	10.7	33.1	40.6	3.5	1.0	48.8	0.0	401.1
1988	18.7	0.0	165.8	200.1	41.1	2.0	3.4	23.0	18.1	0.0	19.6	53.7	545.5
1989	67.4	22.2	53.0	336.6	35.1	2.1	0.0	5.5	15.6	23.5	8.7	87.2	656.9
1990	36.5	34.5	268.3	456.3	19.9	1.9	0.0	0.0	3.0	30.6	40.9	40.4	932.3
1991	148.3	0.0	34.5	91.9	138.4	1.6	12.1	18.4	12.1	0.0	22.4	89.0	568.7
1992	0.0	0.0	34.0	235.5	95.7	7.0	1.9	0.0	0.0	1.4	0.0	43.4	418.9
1993	90.5	100.5	56.8	36.4	117.1	0.0	0.0	0.0	0.0	11.1	35.6	42.4	490.4
1994	0.0	0.0	104.9	114.7	143.3	14.6	0.0	0.0	4.4	0.0	31.9	111.5	525.3
1995	7.5	46.8	20.9	166.6	134.6	0.0	0.0	35.9	0.0	22.0	17.5	38.2	490.0
1996	28.0	116.2	93.6	119.0	0.0	112.4	0.0	0.0	0.0	4.5	0.0	0.0	473.7
Average	40.6	37.7	67.9	161.2	99.6	17.5	10.2	9.6	5.8	20.7	29.6	60.3	559.1

(2) Crop Evapotranspiration (Consumptive Use Water) of Crops

Crop : Alfalfa

	Oct		Nov		Dec		Jan		Feb	
ETo (mm/day)	5.5	5.5	5.6	5.6	5.6	5.6	5.9	5.9	6.0	6.0
Kc	0.40	0.45	0.60	0.80	1.00	1.13	1.12	0.98	0.74	0.60
ETc (mm/day)	2.2	2.475	3.36	4.48	5.6	6.328	6.608	5.782	4.44	3.6
Ave. (mm/month)	72		118		185		192		113	

(3) Effective Rainfall for Upland Crops

ER = 0.2 x R**0.95 x ETc**0.31

Where, ER : Average Monthly effective rainfall in mm

R : Monthly rainfall in mm

ETc : Monthly crop water requirement in mm

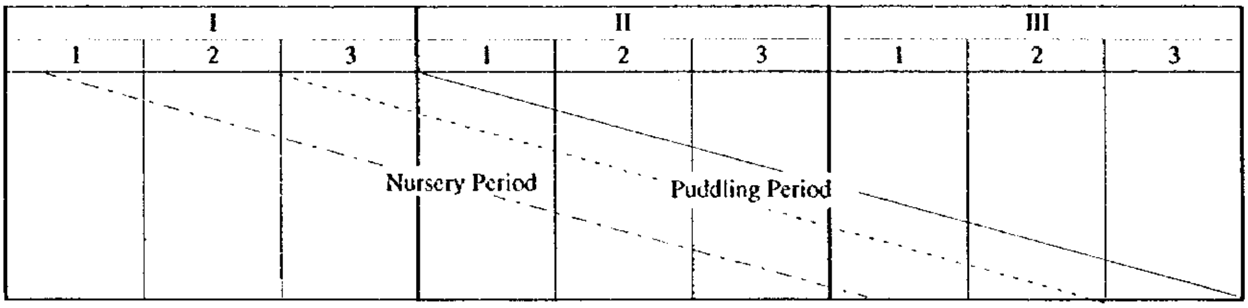
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct.	Nov	Dec	Total
1981	-	-	-	-	-	-	-	-	-	35.9	13.6	48.3	135.1
1982	11.5	6.5	-	-	-	-	-	-	-	81.0	82.4	36.7	218.1
1983	10.3	20.3	-	-	-	-	-	-	-	3.0	2.3	72.2	108.1
1984	10.0	4.6	-	-	-	-	-	-	-	3.8	39.2	47.0	104.6
1985	36.4	94.0	-	-	-	-	-	-	-	13.0	33.3	45.8	222.5
1986	70.6	41.3	-	-	-	-	-	-	-	7.7	6.2	120.9	246.7
1987	40.4	5.2	-	-	-	-	-	-	-	0.8	35.3	0.0	81.6
1988	16.5	0.0	-	-	-	-	-	-	-	0.0	14.8	44.4	75.7
1989	55.7	16.5	-	-	-	-	-	-	-	15.1	6.9	70.4	164.5
1990	31.1	25.0	-	-	-	-	-	-	-	19.4	29.8	33.9	139.3
1991	117.9	0.0	-	-	-	-	-	-	-	0.0	16.8	71.7	206.4
1992	0.0	0.0	-	-	-	-	-	-	-	1.0	0.0	36.3	37.3
1993	73.7	69.1	-	-	-	-	-	-	-	7.4	26.1	35.5	211.9
1994	0.0	0.0	-	-	-	-	-	-	-	0.0	23.5	88.9	112.4
1995	6.9	33.4	-	-	-	-	-	-	-	14.2	13.3	32.1	100.0
1996	24.2	79.3	-	-	-	-	-	-	-	3.1	0.0	0.0	106.7
Ave.	33.7	26.4	-	-	-	-	-	-	-	12.8	21.5	49.0	142.4
1/5	6.6	0.2	-	-	-	-	-	-	-	0.0	2.1	20.5	29.4

Table K.3.6 Soil Physical Properties of Cultivable Layers

Area & Land Use	Depth (cm)	Bulk Density	Real Density	Water (%)	Air Space (%)	Porosity (%)	Solid (%)	Field Capacity (%)	Wilting Point (%)	Available Moisture (%)
1. Lowr Mabogini:	0 - 18	1.48	2.73	5.4	39.8	45.2	54.8	31.2	20.1	11.1
Paddy Field	18 - 50	1.48	2.22	6.3	27.0	33.3	66.7	35.1	20.6	14.5
	50 - 90	1.38	2.83	7.7	43.8	51.5	48.6	35.9	26.0	9.9
	Average	1.45	2.59	6.5	36.9	43.3	56.7	34.1	22.2	11.8
2. Lowr Mabogini:	0 - 15	1.38	2.12	5.4	29.4	34.8	65.2	28.9	20.1	8.8
Upland Crop Field	15 - 45	1.43	2.66	6.8	39.4	46.2	53.8	32.1	20.7	11.4
	45 - 65	1.43	2.44	7.6	33.8	41.4	58.6	34.2	24.3	9.9
	Average	1.41	2.41	6.6	34.2	40.8	59.2	31.7	21.7	10.0
3. Oria:	0 - 15	1.35	2.30	9.6	31.7	41.3	58.7	36.5	23.7	12.8
Paddy Field	15 - 40	1.42	2.19	10.2	25.0	35.2	64.8	37.4	26.6	10.8
	40 - 70	1.33	2.01	11.2	22.5	33.7	66.3	33.5	25.4	8.1
	70 - 95	1.30	2.11	11.2	27.1	38.3	61.8	34.2	24.2	10.0
	Average	1.35	2.15	10.6	26.6	37.1	62.9	35.4	25.0	10.4
4. Rau:	0 - 25	1.10	2.01	9.1	36.3	45.4	54.6	36.2	20.1	16.1
Upland Crop Field	25 - 60	1.25	2.74	8.8	45.6	54.4	45.6	39.0	28.8	10.2
	60 - 80	1.35	2.64	10.4	38.6	49.0	51.1	38.2	28.4	9.8
	Average	1.23	2.46	9.4	40.2	49.6	50.4	37.8	25.8	12.0
5. Rau:	0 - 15	1.28	2.51	9.7	39.3	49.0	51.0	36.6	23.0	13.6
Paddy Field	15 - 30	1.41	1.93	8.3	18.7	49.0	73.0	38.2	25.4	12.8
	30 - 60	1.38	2.72	8.6	40.7	27.0	50.7	33.5	25.3	8.2
	60 - 100	1.51	2.74	8.7	36.4	49.3	55.0	38.1	27.0	11.1
	Average	1.40	2.48	8.8	33.8	43.6	57.4	36.6	25.2	11.4
6. Chekereni:	0 - 20	1.54	2.90	6.1	40.8	46.9	53.1	33.9	21.4	12.5
Paddy Field	20 - 50	1.49	2.07	8.8	19.1	27.9	72.1	33.3	18.5	14.8
	50 - 90	1.36	2.48	10.7	34.5	45.2	54.8	27.8	18.5	9.3
	Average	1.46	2.48	8.5	31.5	40.0	60.0	31.7	19.5	12.2
7. Mabogini:	0 - 18	1.36	2.33	5.9	35.6	41.5	58.5	32.1	15.8	16.3
Upland Crop Field	18 - 30	1.46	2.21	6.2	28.5	34.6	65.4	34.4	20.1	14.3
	30 - 50	1.39	2.17	7.0	29.0	36.0	64.0	32.7	20.2	12.5
	50 - 70	1.43	2.11	8.2	24.0	32.2	67.8	33.2	20.9	12.3
	Average	1.41	2.21	6.8	29.3	36.1	63.9	33.1	19.3	13.9
8. Mtakuja:	0 - 15	1.37	2.75	5.4	44.9	50.3	49.7	27.6	17.3	10.3
Upland Crop Field	15 - 35	1.35	2.19	5.7	33.1	38.8	61.3	34.8	16.2	18.6
	35 - 70	1.38	2.47	6.0	38.1	44.1	55.9	29.3	17.4	11.9
	70 - 95	1.35	2.62	6.9	41.7	48.6	51.5	26.8	14.6	12.2
	Average	1.36	2.51	6.0	39.5	45.5	54.6	29.6	16.4	13.3
9. Mtakuja:	0 - 15	1.36	2.70	6.6	42.8	49.4	50.6	29.9	16.4	13.5
Upland Crop Field	15 - 35	1.41	2.16	6.8	27.8	34.6	65.4	29.0	16.0	13.0
	35 - 65	1.35	2.13	7.3	29.6	36.9	63.2	34.8	17.0	17.8
	65 - 105	1.23	2.21	8.5	36.0	44.5	55.6	35.6	16.0	19.6
	Average	1.34	2.30	7.3	34.1	41.4	58.7	32.3	16.4	16.0
10. Upper Mabogini:	0 - 18	1.33	2.12	11.1	26.2	37.3	62.7	35.4	20.6	14.8
Upland Crop Field	18 - 40	1.36	2.67	9.6	39.4	49.0	51.0	29.2	18.4	10.8
	40 - 65	1.38	2.25	9.4	29.4	38.8	61.3	31.7	21.7	10.0
	65 - 100	1.35	2.77	10.9	40.5	51.4	48.7	30.6	21.6	9.0
	Average	1.36	2.45	10.3	33.9	44.1	55.9	31.7	20.6	11.2

Table K.3.7 Puddling and Nursery Water Requirements

(1) Puddling and Nursery Schedules



(2) Puddling Water Requirement

Phase	Period	Puddling Area	Puddling Water	Monthly Puddling W.	Planted Area
	(days)		(mm)	(mm)	
I - 1					
I - 2					
I - 3	10	1/12	18	18	
II - 1	10	2/12	36		1/12
II - 2	10	2/12	36		3/12
II - 3	10	2/12	36	108	5/12
III - 1	10	2/12	38		7/12
III - 2	10	2/12	38		9/12
III - 3	10	1/12	18	94	11/12
					12/12
Total			220		

(3) Nursery Water Requirement

Phase	Period	Puddling Water	Water Demand			Total		
			Crop Index	Consumptive Use	Percolation	Total	Weighted Average (5%)	Mothly Total
	(day)	(mm)		(mm)	(mm)	(mm)	(mm)	(mm)
I - 1	5	9	-					
I - 2	10	9	1/10	4	1	14	1	
	15	18	3/10	11	2	31	2	
I - 3	20	18	5/10	18	4	40	2	
	25	18	7/10	25	6	49	2	7
II - 1	30	18	9/10	32	7	57	3	
	35	18	10/10	35	8	61	3	
II - 2	40	18	10/10	35	8	61	3	
	45	19	10/10	35	8	62	3	
II - 3	50	19	10/10	35	8	62	3	
	55	19	10/10	35	8	62	3	18
III - 1	60	19	10/10	35	8	62	3	
	65	9	10/10	35	8	52	3	
III - 2	70	9	9/10	32	7	48	2	
	75		7/10	25	6	31	2	
III - 3	80		5/10	18	4	22	1	
	85		3/10	11	2	13	1	11
IV - 1	90		1/10	4	1	5	0	
		220		410				36

Table K.3.8 Check of Flow Capacity of Existing Major Canals in Lower Moshi Area (1/3)

Canal System	Section	Design Conditions: Design Discharge (m3/sec)	Bottom Width (m)	Wate Depth (m)	Side Slope (1:Z)	Roughness Coefficient	Canal Gradient	Canal Height (m)	New Design Condition: Design Discharge (m3/sec)	Wate Depth (m3/sec)	Increased Depth (m)	Velocity (m)	Afford-ability (m)	Required Freeboar (m)	Required Heightening (m)
I. Mabogini Canal System															
(1) Main Canal	1	1.280	0.60	0.878	1.25	0.015	0.000500	1.20	0.902	0.747	-0.131	0.786	0.453	0.219	0
	2	1.178	0.60	0.846	1.25	0.015	0.000500	1.20	0.727	0.676	-0.170	0.745	0.524	0.212	0
	3-1	1.072	0.50	0.789	1.25	0.015	0.000667	1.00	0.545	0.578	-0.211	0.773	0.422	0.209	0
	3-2	1.072	1.50	0.790	0.00	0.015	0.000658	1.00	0.545	0.482	-0.308	0.755	0.518	0.213	0
	3-3	1.072	0.50	0.789	1.25	0.015	0.000667	1.00	0.545	0.578	-0.211	0.773	0.422	0.209	0
	4	0.918	0.50	0.699	1.25	0.015	0.000833	1.00	0.281	0.398	-0.301	0.708	0.602	0.195	0
	5-1	0.839	0.50	0.682	1.25	0.015	0.000773	1.00	0.150	0.290	-0.392	0.602	0.710	0.183	0
	5-2	0.839	0.50	0.670	1.25	0.015	0.000833	1.00	1.444	0.857	0.187	1.071	0.143	0.251	0.108
	6	0.453	0.30	0.558	1.00	0.015	0.001250	0.75	0.777	0.711	0.153	1.082	0.039	0.245	0.206
	7	0.340	0.30	0.457	1.00	0.015	0.001667	0.75	0.584	0.586	0.129	1.125	0.164	0.244	0.080
(2) Secondary Canal															
MS-1	1	0.184	0.30	0.326	1.00	0.015	0.002000	0.50	0.182	0.324	-0.002	0.901	0.176	0.208	0.032
	2	0.092	0.30	0.303	1.00	0.015	0.000667	0.50	0.118	0.344	0.041	0.537	0.156	0.182	0.026
MS-2	1	0.184	0.30	0.308	1.00	0.015	0.002500	0.50	0.190	0.313	0.005	0.990	0.187	0.216	0.029
	2	0.092	0.30	0.211	1.00	0.015	0.002778	0.50	0.132	0.254	0.043	0.939	0.246	0.208	0
MS-3	1	0.162	0.30	0.289	1.00	0.015	0.002500	0.50	0.276	0.376	0.087	1.088	0.124	0.229	0.105
MS-5	1	0.184	0.30	0.326	1.00	0.015	0.002000	0.50	0.238	0.369	0.043	0.864	0.131	0.207	0.076
	2	0.138	0.30	0.282	1.00	0.015	0.002000	0.50	0.139	0.284	0.002	0.843	0.216	0.200	0
MS-6	1	0.368	0.30	0.534	1.00	0.015	0.001000	0.85	0.458	0.590	0.056	0.874	0.260	0.218	0
	2	0.322	0.30	0.445	1.00	0.015	0.001667	0.60	0.367	0.474	0.029	1.003	0.126	0.225	0.099
	3	0.276	0.30	0.443	1.00	0.015	0.001250	0.60	0.312	0.470	0.027	0.864	0.130	0.212	0.082
	4	0.230	0.30	0.377	1.00	0.015	0.001720	0.60	0.283	0.416	0.039	0.951	0.184	0.217	0.033
	5	0.184	0.30	0.329	1.00	0.015	0.001890	0.50	0.202	0.346	0.017	0.906	0.154	0.209	0.055
	6	0.092	0.30	0.260	1.00	0.015	0.001374	0.50	0.101	0.266	0.006	0.676	0.234	0.187	0

Table K.3.8 Check of Flow Capacity of Existing Major Canals in Lower Moshi Area (2/3)

		Design Conditions							New Design Condition						
Canal System	Section	Design Discharge (m3/sec)	Bottom Width (m)	Water Depth (m)	Side Slope (1:Z)	Roughness Coefficient	Canal Gradient	Canal Height (m)	Design Discharge (m3/sec)	Water Depth (m3/sec)	Increased Depth (m)	Velocity (m)	Afford-ability (m)	Required Freeboar (m)	Required Heightening (m)
MS-8	1	0.276	0.30	0.396	1.00	0.015	0.002000	0.60	0.302	0.414	0.018	1.023	0.186	0.224	0.038
	2	0.184	0.30	0.326	1.00	0.015	0.002000	0.50	0.202	0.341	0.015	0.925	0.159	0.211	0.052
MS-9	1	0.276	0.30	0.396	1.00	0.015	0.002000	0.60	0.307	0.417	0.021	1.027	0.183	0.225	0.042
	2	0.184	0.30	0.326	1.00	0.015	0.002062	0.50	0.223	0.358	0.032	0.949	0.142	0.214	0.072
Tertiary	1	0.046	0.30	0.215	1.00	0.015	0.000667	0.45	0.060	0.246	0.031	0.453	0.204	0.173	0
	2	0.092	0.30	0.299	1.00	0.015	0.000714	0.55	0.120	0.341	0.042	0.553	0.209	0.183	0
II. Rau Ya Kati Main Canal															
(1) Main Canal	1-1	1.802	0.60	1.000	1.25	0.015	0.000564	1.20	0.341	0.456	-0.544	0.640	0.744	0.194	0
	1-2	1.802	0.60	1.000	1.25	0.015	0.000564	1.20	3.094	1.269	0.269	1.115	-0.069	0.277	0.346
	2	1.510	0.60	0.893	1.25	0.015	0.000645	1.20	2.592	1.138	0.245	1.126	0.062	0.272	0.210
	3	1.360	0.60	0.852	1.25	0.015	0.000645	1.20	2.335	1.086	0.234	1.097	0.114	0.266	0.152
	4	1.146	0.50	0.785	1.25	0.015	0.000780	1.00	1.967	0.997	0.212	1.128	0.003	0.265	0.262
	5-1	0.596	0.50	0.582	1.25	0.015	0.000769	1.00	0.980	0.733	0.151	0.944	0.267	0.232	0
	5-2	0.596	0.40	0.613	1.25	0.015	0.000769	0.85	0.980	0.765	0.152	0.943	0.085	0.234	0.149
	6	0.508	0.30	0.559	1.00	0.015	0.001667	0.75	0.589	0.597	0.038	1.098	0.153	0.241	0.088
(2) Secondary Canal															
RS-1	1	0.368	0.30	0.499	1.00	0.015	0.001333	0.75	0.475	0.562	0.063	0.982	0.188	0.227	0.039
	2	0.322	0.30	0.443	1.00	0.015	0.001714	0.75	0.403	0.491	0.048	1.036	0.259	0.229	0
	3	0.276	0.30	0.475	1.00	0.015	0.000929	0.75	0.331	0.517	0.042	0.784	0.233	0.207	0
	4	0.230	0.30	0.443	1.00	0.015	0.000872	0.60	0.269	0.477	0.034	0.728	0.123	0.201	0.078
	5	0.184	0.30	0.384	1.00	0.015	0.001008	0.60	0.214	0.414	0.030	0.726	0.186	0.198	0.012
	6	0.138	0.30	0.281	1.00	0.015	0.002043	0.50	0.158	0.301	0.020	0.887	0.199	0.205	0.006
	7	0.092	0.30	0.266	1.00	0.015	0.001119	0.50	0.103	0.283	0.017	0.629	0.217	0.184	0
RS-2	1	0.230	0.30	0.380	1.00	0.015	0.001667	0.60	0.269	0.409	0.029	0.928	0.191	0.214	0.023
	2	0.138	0.30	0.268	1.00	0.015	0.002438	0.50	0.175	0.303	0.035	0.962	0.197	0.212	0.015
	3	0.138	0.30	0.266	1.00	0.015	0.002538	0.50	0.149	0.277	0.011	0.938	0.223	0.209	0

Table K.3.8 Check of Flow Capacity of Existing Major Canals in Lower Moshi Area (3/3)

Canal System	Section	Design Conditions: Design Discharge (m3/sec)	Bottom Width (m)	Water Depth (m)	Side Slope (1:Z)	Roughness Coefficient	Canal Gradient	Canal Height (m)	New Design Condition: Design Discharge (m3/sec)	Water Depth (m3/sec)	Increased Depth (m)	Velocity (m)	Afford-ability (m)	Required Freeboar (m)	Required Heightening (m)
RS-3	1	0.322	0.30	0.462	1.00	0.015	0.001429	0.60	0.384	0.501	0.039	0.956	0.099	0.222	0.123
	2	0.276	0.30	0.411	1.00	0.015	0.001724	0.60	0.307	0.432	0.021	0.971	0.168	0.220	0.052
	3	0.184	0.30	0.317	1.00	0.015	0.002222	0.50	0.230	0.354	0.037	0.994	0.146	0.218	0.072
	4	0.138	0.30	0.251	1.00	0.015	0.003125	0.50	0.151	0.264	0.013	1.016	0.236	0.216	0
RS-4	1	0.782	1.00	0.594	0.00	0.015	0.002222	1.30	1.030	0.735	0.141	1.401	0.565	0.287	0
	2	0.644	0.40	0.603	1.25	0.015	0.000962	0.85	0.816	0.672	0.069	0.980	0.178	0.233	0.055
	3	0.598	0.40	0.573	1.25	0.015	0.001042	0.85	0.730	0.627	0.054	0.982	0.223	0.231	0.008
	4	0.552	0.40	0.600	1.25	0.015	0.000714	0.85	0.674	0.659	0.059	0.836	0.191	0.219	0.028
	5	0.460	0.30	0.545	1.00	0.015	0.001430	0.75	0.576	0.603	0.058	1.057	0.147	0.237	0.090
	6	0.184	0.30	0.444	1.00	0.015	0.000556	0.50	0.202	0.464	0.020	0.572	0.036	0.190	0.154
	7	0.092	0.30	0.274	1.00	0.015	0.001000	0.50	0.120	0.314	0.040	0.627	0.186	0.186	0
RS-4A	1	0.230	0.30	0.380	1.00	0.015	0.001667	0.60	0.302	0.432	0.052	0.955	0.168	0.218	0.050
	2	0.184	0.30	0.370	1.00	0.015	0.001250	0.60	0.202	0.382	0.012	0.775	0.218	0.200	0
RS-5	1	0.184	0.30	0.326	1.00	0.015	0.002000	0.50	0.192	0.333	0.007	0.914	0.167	0.209	0.042
	2	0.092	0.30	0.282	1.00	0.015	0.002000	0.50	0.137	0.282	0.000	0.840	0.218	0.200	0
RS-6	1	0.322	0.30	0.502	1.00	0.015	0.001000	0.75	0.408	0.560	0.058	0.849	0.190	0.215	0.025
	2	0.276	0.30	0.460	1.00	0.015	0.001111	0.75	0.336	0.500	0.040	0.842	0.250	0.211	0
	3	0.230	0.30	0.460	1.00	0.015	0.000714	0.75	0.259	0.491	0.031	0.669	0.259	0.197	0
	4	0.184	0.30	0.330	1.00	0.015	0.002000	0.50	0.202	0.341	0.011	0.925	0.159	0.211	0.052
	5	0.138	0.30	0.260	1.00	0.015	0.002857	0.50	0.132	0.253	-0.007	0.951	0.247	0.209	0
RS-7	1	0.130	0.30	0.361	1.00	0.015	0.000667	0.60	0.100	0.318	-0.043	0.517	0.282	0.180	0
RS-8	1	0.506	0.30	0.550	1.00	0.015	0.001587	0.75	0.589	0.595	0.045	1.106	0.155	0.242	0.087
	2	0.406	0.30	0.530	1.00	0.015	0.002041	0.75	0.521	0.607	0.077	1.179	0.143	0.251	0.108
	3	0.276	0.30	0.490	1.00	0.015	0.000833	0.75	0.350	0.544	0.054	0.771	0.206	0.208	0.002
	4	0.230	0.30	0.390	1.00	0.015	0.001429	0.60	0.269	0.424	0.034	0.876	0.176	0.210	0.034
	5	0.184	0.30	0.330	1.00	0.015	0.002000	0.50	0.187	0.330	0.000	0.908	0.170	0.209	0.039
Tertiary	1	0.046	0.30	0.215	1.00	0.015	0.000667	0.45	0.060	0.246	0.031	0.453	0.204	0.173	0
	2	0.092	0.30	0.288	1.00	0.015	0.000714	0.55	0.120	0.328	0.040	0.586	0.222	0.184	0

Table K.3.9 Project Facilities for Existing Lower Moshi Project Area (1/2)

Facilities		Mabogini Canal System	Rau ya Kati Canal System
(1) Haedworks		1 nos.	1 nos.
- Weir	:	No repairment	No repairment
- Inlet	:	- do -	- do -
- Gate	:	- do -	Sluice Gate 1 nos.
- Spillway & Parshall Flume	:	- do -	No repairment
- Protection Wosk & Retaining Wall	:	- do -	- do -
- Others	:	- do -	- do -
(2) Main canal			
- Total Length	:	4.9 km	5.3 km
- Repairment Length (m)	:	0.1 km	0.1 km
- Heightening	:	0.10 m to 0.25 m	0.10 m to 0.35 m
- Heightening Length	:	1.4 km	4.2 km
- Total Major Structure	:	29 nos.	26 nos.
- Replace of Major Structure	:	2 nos.	5 nos.
- Repair of Structure	:	9 nos.	10 nos.
(3) Secondary canal			
- Total Length	:	6.8 km	18.2 km
- Repairment Length (m)	:	0.1 km	-
- Heightening	:	0.05 m to 0.15 m	0.05 m to 0.20 m
- Heightening Length	:	4.2 km	12.4 km
- Total Major Structure	:	37 nos.	96 nos
- Replace of Major Structure	:	-	3 nos.
- Repair of Structure	:	12 nos.	26 nos
(4) Tertiary canal			
- Total Length	:	27.8 km	37.8 km
- Repairment Length (m)	:	1.7 km	1.9 km
- Heightening	:	-	-
- Heightening Length	:	-	-
- Total Major Structure	:	246 nos.	317 nos.
- Replace of Major Structure	:	-	-
- Repair of Structure	:	71 nos	127 nos
(5) Main drain			
- Total Length	:	12.2 km	4.4 km
- Repairment Length (m)	:	12.2 km	4.4 km
- Total Major Structure	:	15 nos.	6 nos.
- Replace of Major Structure	:	12 nos.	-
- Repair of Structure	:	-	-
(6) Secondary drain			
- Total Length	:	14.7 km	17.3 km
- Repairment Length (m)	:	14.7 km	17.3 km
- Total Major Structure	:	47 nos.	61 nos.
- Replace of Major Structure	:	-	-
- Repair of Structure	:	5 nos.	5 nos.
(7) Tertiary drain			
- Total Length	:	17.1 km	23.8 km
- Repairment Length (m)	:	11.1 km	15.3 km
- Total Major Structure	:	87 nos	110 nos.
- Replace of Major Structure	:	-	-
- Repair of Structure	:	26 nos.	36 nos.
(8) Farm road			
- Repair of Main farm road	:	7.4 km (100%)*	10.3 km (100%)*
- Repair of Secondary farm road	:	16.2 km (100%)*	22.5 km (100%)*
- Repair of Tertiary farm road	:	20.6 km (100%)*	35.0 km (100%)*
(9) Major structures			
	:	Refer to Table K.3.9 (2/2)	
(10) On-farm works (completed totally)	:	885 ha	1,265 ha

* : Percentage shows the ratio between existing length and repair length.

Table K.3.9 Project Facilities for Existing Lower Moshi Project Area (2/2)

Facilities		Mabogini Canal System			Rau ya Kati Canal System		
		Existing (nos.)	Replace (nos.)	Repair (nos.)	Existing (nos.)	Replace (nos.)	Repair (nos.)
(1) Main canal							
- Bifurcation structure	:	0	0	0	1	0	1
- Turnout	:	7	0	5	5	0	3
- Check drop	:	11	0	2	13	0	4
- Drop	:	0	0	0	0	0	0
- Culvert	:	7	2	0	6	5	1
- Spillway	:	2	0	2	1	0	1
- Syphon	:	1	0	0	0	0	0
- Bridge & Aqueduct	:	1	0	0	0	0	0
- Division Box	:	0	0	0	0	0	0
Total		29	2	9	26	5	10
(2) Secondary canal							
- Bifurcation structure	:	0	0	0	0	0	0
- Turnout	:	18	0	7	38	0	7
- Check drop	:	16	0	5	34	0	9
- Drop	:	0	0	0	0	0	0
- Culvert	:	3	0	0	22	3	10
- Spillway	:	0	0	0	0	0	0
- Syphon	:	0	0	0	2	0	0
- Bridge & Aqueduct	:	0	0	0	0	0	0
- Division Box	:	0	0	0	0	0	0
Total		37	0	12	96	3	26
(3) Tertiary canal							
- Bifurcation structure	:	0	0	0	0	0	0
- Turnout	:	0	0	0	0	0	0
- Check drop	:	0	0	0	0	0	0
- Drop	:	0	0	0	0	0	0
- Culvert	:	130	0	35	160	0	64
- Spillway	:	0	0	0	0	0	0
- Syphon	:	0	0	0	0	0	0
- Bridge & Aqueduct	:	0	0	0	0	0	0
- Division Box	:	116	0	36	157	0	63
Total		246	0	71	317	0	127
(4) Main drain							
- Culvert	:	7	5	0	0	0	0
- Junction	:	8	7	0	4	0	0
- Cross Drain	:	0	0	0	2	0	0
- Drainage Sluice	:	0	0	0	0	0	0
- Drainage Inlet	:	0	0	0	0	0	0
Total	:	15	12	0	6	0	0
(5) Secondary drain							
- Culvert	:	25	0	5	29	0	5
- Junction	:	21	0	0	31	0	0
- Cross Drain	:	1	0	0	0	0	0
- Drainage Sluice	:	0	0	0	0	0	0
- Drainage Inlet	:	0	0	0	1	0	0
- Total	:	47	0	5	61	0	5
(6) Tertiary drain							
- Culvert	:	87	26	0	110	36	0
- Junction	:	0	0	0	0	0	0
- Cross Drain	:	0	0	0	0	0	0
- Total	:	87	26	0	110	36	0

Table K.3.10 Project Facilities for Expanded Area

Facilities		Kaloleni Area: Notrthern Area	Kaloleni Area: Eastern Area	Kaloleni Area: Sourthern Area	Mandaka Mnono Area
(1) Irrigable area	:	4 ha	27 ha	69 ha	360 ha
(2) Intake Facilitis					
- Water source	:	Springs	Springs	Spring/Njoro river	Spring/Mamba river
- Type	:	Concrete weir	Concrete weir	Concrete weir	Concrete weir
- Number	:	3 nos.	1 no.	2 nos.	2 nos.
(3) Supply canal					
- Design discharge	:	60 l/s	60 l/s to 70 l/s	60 l/s to 90 l/s	300 l/s to 490 l/s
- Type	:	Concrete block lining	Concrete block lining	Concrete block lining	Concrete block lining
- Total length	:	0.1 km	0.1 km	0.1 km	1.6 km
- Bottom width	:	0.3 m	0.3 m	0.3 m	0.3 m to 0.4 m
- Height	:	0.45 m to 0.55 m	0.45 m to 0.55 m	0.45 m to 0.55 m	0.6 m to 0.85 m
- Side slope	:	1:1.0	1:1.0	1:1.0	1: 1.0 to1:1.25
(4) Main canal					
- Design discharge	:	-	-	-	640 l/s to 780 l/s
- Type	:	-	-	-	Concrete block lining
- Total length	:	-	-	-	1.2 km
- Bottom width	:	-	-	-	0.4 m to 0.5 m
- Height	:	-	-	-	0.85 m to 1.0 m
- Side slope	:	-	-	-	1:1.25
(5) Secondary canal					
- Design discharge	:	-	-	-	60 l/s to 380 l/s
- Type	:	-	-	-	Concrete block lining
- Total length	:	-	-	-	10.3 km
- Bottom width	:	-	-	-	0.3 m to 0.5 m
- Height	:	-	-	-	0.5 m to 1.0 m
- Side slope	:	-	-	-	1: 1.0 to1:1.25
(3) Tertiary canal					
- Design discharge	:	60 l/s	60 l/s	60 l/s	60 l/s to 120 l/s
- Type	:	Concrete block lining	Concrete block lining	Concrete block lining	Concrete block lining
- Total length	:	0.8 km	1.9 km	3.2 km	12.1 km
- Bottom width	:	0.3 m	0.3 m	0.3 m	0.3 m
- Height	:	0.45 m	0.45 m	0.45 m	0.45 m
- Side slope	:	1:1.0	1:1.0	1:1.0	1:1.0
(5) Secondary drain					
- Design discharge	:	-	-	70 l/s to 270 l/s	170 l/s to 1,650 l/s
- Type	:	-	-	Unlined	Unlined
- Total length	:	-	-	1.3 km	6.1 km
- Bottom width	:	-	-	0.6 m	0.6 m to 1.0 m
- Height	:	-	-	0.6 m	0.6 m to 1.0 m
- Side slope	:	-	-	1:1.5	1:1.5
(6) Tertiary drain					
- Design discharge	:	-	50 l/s to 100 l/s	40 l/s to 100 l/s	20 l/s to 170 l/s
- Type	:	-	Unlined	Unlined	Unlined
- Total length	:	-	0.8 km	2.1 km	10.5 km
- Bottom width	:	-	0.4 m	0.4 m	0.4 m
- Height	:	-	0.6 m	0.6 m	0.6 m
- Side slope	:	-	1:1.5	1:1.5	1:1.5
(7) Farm road					
- Main farm road	:	-	-	-	1.2 km
- Secondary farm road	:	0.1 km	0.1 km	0.1 km	10.3 km
- Tertiary farm road	:	0.8 km	1.9 km	3.2 km	12.1 km
(8) Major structures					
- Turnout	:	1	2	2	28
- Check drop	:	0	0	0	20
- Drop	:	0	0	0	0
- Culvert	:	2	2	8	74
- Spillway	:	0	0	0	1
- Syphon	:	0	0	0	-
- Dividsion box	:	2	4	9	49
- Flood dike (km)	:	-	-	-	16
- Cross drain	:	-	0	0	20
- Junction structure	:	-	2	5	13
(9) On-farm works		4 ha	27 ha	69 ha	360 ha

Table K.3.11 Project Facilities for New Extension Area

Facilities		System-A	System-B	System-C
(1) Irrigable area	:	181 ha	1,569 ha	340 ha
(2) Main canal				
- Design discharge	:	0.4 m3/s	0.6 m3/s to 3.6 m3/s	0.8 m3/s
- Type	:	Concrete block lining	Concrete block lining	Concrete block lining
- Length	:	0.1 km	7.4 km	2.1 km
- Bottom width	:	0.3 m	0.4 m to 0.8 m	0.4 m
- Height	:	0.75 m	0.85 m to 1.60 m	0.85 m
- Side slope	:	1:1.00	1:1.25	1:1.25
(3) Secondary canal				
- Design discharge	:	60 l/s to 270 l/s	60 l/s to1,200 l/s	140 l/s to 430 l/s
- Type	:	Concrete block lining	Concrete block lining	Concrete block lining
- Total length	:	3.1 km	18.9 km	3.0 km
- Bottom width	:	0.3 m	0.3 m to 0.6 m	0.3 m
- Height	:	0.50m	0.50m to 1.20m	0.60m to 0.75m
- Side slope	:	1:1.00	1:1.00	1:1.00
(4) Tertiary canal				
- Design discharge	:	60 l/s to 180 l/s	60 l/s to 120 l/s	60 l/s to 120 l/s
- Type	:	Concrete block lining	Concrete block lining	Concrete block lining
- Total length	:	7.2 km	52.2 km	10.9 km
- Bottom width	:	0.3m	0.3m	0.3m
- Height	:	0.45 m	0.45 m	0.45 m
- Side slope	:	1:1.0	1:1.0	1:1.0
(5) Main drain				
- Design discharge	:	-	4.6 m3/s to 6.3 m3/s	-
- Type	:	-	Unlined	-
- Total length	:	-	10.5 km	-
- Bottom width	:	-	2.0 m	-
- Height	:	-	1.0 m	-
- Side slope	:	-	1:1.5	-
(6) Secondary drain				
- Design discharge	:	0.1 m3/s to 0.7 m3/s	0.3 m3/s to 2.6 m3/s	0.4 m3/s to 1.0 m3/s
- Type	:	Unlined	Unlined	Unlined
- Total length	:	5.0 km	19.0 km	3.6 km
- Bottom width	:	0.6 m	0.6 m to 1.0 m	0.6 m to 0.8 m
- Height	:	0.6 m	0.6 m to 1.0 m	0.6 m to 0.8 m
- Side slope	:	1:1.5	1:1.5	1:1.5
(7) Tertiary drain				
- Design discharge	:	40 l/s to 145 l/s	20 l/s to 260 l/s	120 l/s to250 l/s
- Type	:	Unlined	Unlined	Unlined
- Total length	:	6.8 km	43.6 km	10.1 km
- Bottom width	:	0.4 m	0.4 m	0.4 m
- Height	:	0.6 m	0.6 m	0.6 m
- Side slope	:	1:1.5	1:1.5	1:1.5
(8) Farm road				
- Main farm road (7 m wide)	:	0.1 km	13.2 km	1.7 km
- Secondary farm road (6m wide)	:	4.4 km	34.5 km	1.5 km
- Tertiary farm road (4m wide)	:	6.1 km	52.7 km	11.4 km
(9) Major structures				
- Diversion structure	:	1	1	1
- Turnout	:	9	52	9
- Check drop	:	6	45	7
- Drop	:	1	9	1
- Culvert	:	60	413	95
- Spillway	:	0	2	1
- Syphon	:	0	0	0
- Division box	:	22	191	41
- Cross drain	:	0	3	0
- Junction structure	:	12	63	6
(10) On-farm works		181 ha	1,569 ha	340 ha