1.2.2 Miwaleni Pump Lift Scheme

(1) Selection of Pump System

The Miwaleni upland area has gradually dipping slopes towards the general direction of the Miwaleni springs. To irrigate the area, the following is taken into account in determination of the general layout of the scheme.

(i) A pump station site has to be selected such that the Miwaleni springs flow can easily be introduced to the pump station. The site inbetween the Kahe NAFCO weir site and the junction of two major springs streams satisfies the above requirement.

(ii) A pump station site has to be selected to provide the alignment of the shortest pipeline for commanding the irrigable area of 2,000 ha.

Consequently, the general layout of the scheme is such that the pump station is situated just downstream of the junction of the spring streams. The pipeline extends toward north, ending nearby the Miwaleni experimental sub-station. At the end of the pipeline, the irrigation canals bifurcate in east and west directions.

With this conception of the pump lift scheme, the following pumping systems are conceivable.

(i) The pumps lift up the whole amount of water needed in the scheme area directly to an outlet. Each pump is provided with the same capacity. This system will reduce the number of pump contributing to reducing the pump equipment cost, but will have high electric energy cost since the whole amount of water is pumped up once to the outlet.

(ii) The pumps with different capacities and heads are provided and separate pipelines with the different outlets are constructed. This system will save electric energy cost; however, the pump equipment cost will increase, and additional canals running toward the east and west directions will be needed.

In order to determine the most economical pumping system to irrigate the Miwaleni pump lift scheme area of 2,000 ha, the following three alternative pumping systems are compared:

<u>Plan - 1: One outlet system</u>: The outlet of the discharge pipeline is set at one site with elevation of 730 m. The pumps to be used are of the same capacity. The pumps lift up the water to the outlet through one lane of discharge pipeline.

Plan - 2: Two outlets system: The outlet of discharge pipelines is separately set at two sites with the elevations of 730 m and 725 m. Two pipelines are provided to supply the water to respective outlets. Two canals starting from the outlets toward the east and west directions are arranged.

Plan - 3: Three outlets system: The outlet is further separated into three parts at elevations of 730 m, 725 m and 720 m. Three pipelines are provided and three canals extending toward east and west directions are arranged.

An economic comparison was made in terms of the annual cost of the initial investment of pump equipment and canal system, and the power electric energy cost. The results are as shown in Table VII-9. According to the results, the Plan-1 is the most economic plan due mainly to economical canal system construction. Therefore the Miwaleni pump lift scheme is contemplated with the plan that the Water is lifted by pumps with the same capacities through one lane of discharge pipeline, and two main canals branch to the east and west from the outlet of the pipe line.

(2) Irrigation System

The Miwaleni pump lift scheme area is divided into two areas with respect to canalization system; east area and west area. The irrigation water to those areas is lifted with the pumps through the discharge pipeline to the outlet. From the outlet structure to be provided with Parshall flume, two main canals start toward the east and the west. The east main canal commands an area of 1,170 ha and the west main canal covers an area of 830 ha.

The land use plan as discussed in ANNEX V shows that paddy rice cultivation is proposed in a major part of the west area and uplant crops are recommended in the east area. Irrigation water supply for paddy fields will be made on 24-hour basis, but for the upland field 18-hour basis at the peak demand period is taken. Therefore, regulating farm ponds are provided on the canals for upland fields; five on the secondary canals in the east area.

The low-lying area located in the west area along the Rau river is sometimes inundated by the Rau river floods. To protect the scheme area from the flood flow, the flood protection dike is proposed to be constructed parallel with the proposed irrigation canal on the left bank of the Rau river. Many seasonal rivers originating in the Kilimanjaro slopes gather in the Lower-Moshi area, causing the flooding in the scheme area. To control the flood flow, floodways are proposed to be introduced into the Rau river and the Miwaleni springs stream. Out of the floodways, Miwaleni floodway is planned for protection of the scheme. Although, the Mue and Uchira rivers disappear, their river courses lie in the scheme, thus the flooding occurs sometimes in such area. The restoration of the rivercourses is proposed. These flood protection works are discussed in detail in the succeeding section. The above mentioned flood protection works are prerequisite to the implementation of the Miwaleni pump lift scheme.

The layout of the scheme is shown in attached drawings. The irrigation diagram and drainage diagram are as shown in Fig. VII-10 and VII-11. The general features of the scheme are as shown in Table VII-8.

(3) Pump Station

(a) Station Layout

The pump station consists of a pump house, inlet channel, suction pond, switchyard, discharge pipeline and outlet structure. The site of a pump house is selected at a point approximately 650 m upstream from the NAFCO intake weir, 100 m upstream from which, major two streams of Miwaleni springs join. The following station layout is arranged, based on the results of the study on the pumping system in preceding section.

The pump house is located at the end of the inlet channel with the suction pond. A gradually varied transition connects with suction pits. A discharge pipeline extends from the pump house toward the north. The switchyard is constructed contiguously to the pump house.

(b) Design Discharge and Pumping Head

The irrigation water requirement of the scheme is calculated in ANNEX IV. The maximum water requirement of 2.0 m^3/sec occurs in June.

The water level at the suction pond is determined from the existing NAFCO intake weir crest level which is located 650 m downstream from the site. A water level at the outlet structure is to be the water level enough for commanding the irrigable area of 2,000 ha. The following water levels at the suction pond and outlet structure are set for the pump design.

Suction Pond	
High water level (m):	714.00
Low water level (m):	713.70
Outlet Structure	
Water level (m):	731.00
Design Static head (m):	17.30

The loss heads to determine the rated pump head are influenced by the characteristics of discharge pipeline. Thus, the economical diameters of the discharge pipeline is determined as shown in the succeeding section. According to the results, the rated total head for the design of pumps are as shown below.

Rated discharge per unit:	40 m^3/min.
Length of discharge pipeline:	1,850 m
Diameter of discharge pipeline:	1,100 mm
Total loss head:	6.7 m
Static head:	17.3 m
Total rated head:	24.0 m

(c) Standby and Spare Set

The pumping equipment is designed on the basis of continuous 24 hour operation at the period of the peak water demand to utilize the continuous spring flow effectively. Spare sets or spare capacity of pumps has to be considered in case of pump breakdown in the peak demand period, since the heavy breakdown or replacement accompanies long time interruption of pump operation and commonly the purchase and installation take so long that serious crop damage results. In design of the pump equipment, therefore, it is proposed to provide one standby pump equipment set.

(d) Type of Pump

Two types of pumps are considered applicable taking into account the total head and the discharge of pump unit; (1) horizontal shaft double suction volute pump, and (2) vertical shaft mixed flow pump as shown in Fig. VII-12. The economic comparison was made between two types in terms of construction costs of the pumping equipment and the pump house. The result is as shown in Table VII-10. The result indicates that the horizontal shaft double suction volute type is more economical in terms of construction cost. Further this type has the following advantages in view of operation and maintenance:

(1) High pumping efficiency to be maintained even under the wide range of lifted discharge.

(2) Suitability for discharge control by valves.

(3) Simple and easy maintenance and replacement because of horizontal installation of pump shaft.

In consideration of the above, the horizontal shaft volute pump is proposed in the pump station of the Miwaleni Pump Lift Scheme.

(e) Speed

A high speed of pump is more economical to save the pump equipment cost with the limit that no cavitation will occur under all ranges of expected operating condition with such speed. By estimating the suction head to prevent occurrence of cavitation, the speed of pump is set to be 730 rpm.

(f) Valves

Two kinds of valves are provided in the pump station. At the delivery side of each pump, a check valve is installed to prevent backflow of the water in the discharge pipe into the pump. The other is a discharge control valve of butterfly type to be installed at the delivery side of the check valve.

(g) Electric Motor

A horizontal shaft three phase induction motor is proposed for the pump. The motor is directly connected to the pump. The motor is started by use of the starting reactor to control occurrence of large starting current. The general features of the motor are as follows:

Output	(KW):	230
Voltage	(kV):	11
Frequency	(Hz):	50
Synchronous speed	(rpm):	750
Enclosure	:	Open type

(h) Control System

The control system proposed is that the pumps are manually started and stopped by control pannel in the pump station, and in emergency low water level at the suction pond,they are automatically stopped. The pumps are, in principle, continuously operated and the discharge control in the low demand period is made by the valve. On starting of pumps, it is necessary to prime the water in suction pipes by use of the vacuum pump.

(i) Auxiliary Facilities

The following auxiliary facilities are installed in the pump station; an overhead travelling hoist of 5 ton capacity, two sets of vacuum pumps and sealing pumps, and trash racks.

(4) Discharge Pipeline

(a) Diameter of pipeline

The discharge pipeline to connect the pump station to the outlet structure is comparatively long. The diameter of the pipeline greatly influences the pump equipment capacity and the initial investment of pumps and pipeline. Thus an economic comparison was made for determination of economical diameter of pipeline. The economical diameter of the pipeline is studied on the basis of the following conditions:

(i) Comparative cost consists of construction cost of pipeline, pipeline civil works and pump equipment and of power energy cost. The cost for civil works of a pump house is excluded, because of no significant difference in cost between the alternative diameters of pipes.

(ii) The type of pump is of horizontal shaft double suction volute pump. The number of pump is to be 4 sets including one standby set.

(iii) Pipeline material is to be steel.

The result is as shown in Table VII-11. It indicates that the diameter of 1,100 mm is the most economical one for the discharge pipeline.

(b) Water hammer

The water hammer in the pipeline is analysed to confirm pipe safety against extraordinary hydraulic pressure. Based on the characteristics of pumps and motors and pipeline as determined above, the maximum and minimum water head to occur in the pipe are examined under the following conditions:

Total head:	:	24.0 m
Static head:	:	17.3 m
Maximum discharge:	:	2.0 m^3/sec
Pump design efficiency:	:	0.82
Pump speed	:	730 rpm
Fly wheel effect of pump and motor	:	100 kg-m^2
Pipe diameter	:	1,100 mm
Length of pipeline	:	1,850 m

The analysis results of water hammer are as shown in Fig. VII-13. The maximum and minimum water head at the center of the pump are 34.1 m and 4.3 m, respectively. No negative pressure occurs in the pipeline.

(c) Pipeline

Four pumps are connected to the pipeline with manifold provided under the ground. A major part of the pipeline is exposed and it is supported by ring girders. The mechanical joints are proposed for connecting each pipe unit.

(5) Electric Power Supply System

(a) Power Supply System

Electric power required for the Miwaleni pump station is contemplated to be supplied from the existing 33 kV transmission line running along the Moshi-Himo road, after stepping-down the voltage from 33 kV to 11 kV. The transformer substation is constructed nearby the existing 33 kV transmission line. To connect the substation to the pump station, an 11 kV distribution line is constructed. The line is of overhead, single circuit on concrete poles. The schematic layout of a distribution line is as shown in Fig. VII-14.

(b) Sub-Station Facilities

A capacity of the sub-station is determined to enable supply of power including the requirements of the groundwater tube well pumps. Thus, the power to be supplied for the Project is estimated as follows:

Miwaleni Pump Station	800 kW (1,000 kVA)
Groundwater tube well pumps	640 kW (800 kVA)
Total	1,440 kW (1,800 kVA)

To meet the above requirement, one bank of 2,000 kVA transformer is provided in the sub-station. Secondary voltage of the transformer is taken to be 11 kV so that direct connection to the pump motors can be made. Auxiliary pump station equipment is fed with low voltage of 400 - 230 V supplied from the secondary circuit of the station service transformer. Sub-station equipment is to be of outdoor type installed in cubicles.

1.2.3 Himo River System

The irrigation plan of the Himo river system located in the eastern edge of the Lower-Moshi Project area comprises two irrigation schemes using the Himo river water. As mentioned in ANNEX III, soils in this area limit the crops to be introduced. The main crops are upland crops, and some paddy rice is introduced on the alluvial deposits of the lower reaches of the Himo. With the assessment of the available irrigation water of the Himo river as detailed in ANNEX IV, the irrigation area of 1,000 ha is determined in the Himo river system. Two irrigation systems are formulated mainly focusing on improvement of the existing irrigation systems. The general description of the proposed schemes are presented hereunder.

(1) Makuyuni Irrigation Scheme

The Makuyuni irrigation system is located on the left bank of the Himo river. In this system area in the Lower-Moshi area, presently there are two irrigation systems. One is the Makuyuni system located 2 km southeast from Himo town. This system has granted water rights of 5 cusec (0.142 m^3/sec), and the water is taken from two intakes and transported through their distant head reaches. The system was constructed about a century ago, and thus it is superannuated. The other is the Marangu/Siding system which is located on the north of the Moshi-Mombasa railway. The intake structure of the system is located just downstream of the Himo river bridge in the Himo town. In both systems, no adequate irrigation facilities are provided.

Due to the heavy water losses during long conveyance from the intake to the irrigation area, the water granted by the water rights cannot even reach to the area.

The Makuyuni scheme is formulated to command the two existing irrigation systems to produce efficient water intake and distribution. The water balance study made in ANNEX IV indicates that the Himo river can provide a dependable water supply to the area of 500 ha. In consideration of the soil, topography, present land use and water use, the Makuyuni irrigation system area is delineated to command an area of 500 ha. The existing Marangu/Siding intake is used for the scheme.

The Project works consists of improvement of the existing Marangu/Siding intake structure and head reach, construction of irrigation, drainage and road systems, and on-farm works. Irrigation water of maximum 0.44 m^3 / sec is diverted from the Himo river through the improved intake structure and the canal system.

The existing intake structure needs to be provided with the scouring sluice and stilling basin. The existing weir crest level of

EL. 726.0 m is enough for commanding the scheme area and diverting the required water. The head reach of 1.7 km in length is constructed with concrete flumes, to prevent seepage loss and flushing out of canal by the surface runoff on its slopes.

The head reach bifurcates into Makuyuni area and Marangu/Siding area. The main and secondary irrigation canal of 8.9 km in total is lined with thin plain concrete.

The general layout of the scheme is as shown in the attached drawing. The irrigation diagram showing the canal capacities, command areas and canal lengths is as presented in Fig. VII-15. The drainage diagram also showing the drainage areas, canal capacities and length is presented in Fig. VII-16. The general features of the scheme are as shown in Table VII-12.

(2) Ghona and Kileo Irrigation Scheme

The Ghona and Kileo irrigation scheme is situated in narrow strips along the lower reaches of the Himo river. Some of the right bank strips is presently served with the traditional irrigation system of Ghona. The intake for the scheme with concrete weir is located 5 km downstream of the Moshi-Himo road crossing. Due to the low weir crest level, however, enough water cannot be taken when the riverwater is low. Further, the diverted water is lost from the head reach running along the steep slopes of the Himo river bank for approximately 3 km. Adjacent to the existing Ghona system area, irrigable land extends on the both banks.

According to the water balance study, the Himo river after giving irrigation water to the Makuyuni scheme can supply the water for the area of 500 ha in the rainy season and of 260 ha in the dry season. Based on the available irrigation water as mentioned above, and land capability, the scheme area is delineated so as to command the existing Ghona system area and additional extended area on its lower edge. The small patch of irrigable area in the Kileo village is included by supplying water through crossing structure on the Himo river.

The Project works consist of improvement of the existing Ghona intake and head reach, construction of irrigation, drainage and farm road system and on-farm works. Irrigation water of maximum 0.48 m^3/sec is diverted from the Himo river through the improved intake structure and the canal system.

The existing intake weir crest is heightened by 0.5 m, and the scouring sluice is provided on the left side of the weir. The stilling basin is re-constructed with concrete. The head reach of 2.4 km in length is constructed with concrete flumes. The Himo river crossing structure to supply water to the Kileo area is of syphon type. The main and secondary irrigation canals of 7.3 km in total are lined with thin plain concrete.

The general layout of the scheme is as shown in the attached drawing. The irrigation diagram and drainage diagram are as presented in Fig. VII-15 and Fig. VII-16, respectively. The general features of the scheme are as shown in Table VII-13.

1.3 Irrigation System - Groundwater Development

1.3.1 General

Groundwater development potential in the Lower-Moshi area is studied with respect to the available amount of groundwater source, aquifer capacity, and water quality as detailed in ANNEX II. The promising groundwater development area is selected in two areas. The Miwaleni upland area located on the northern part of the Project area (north groundwater area) has high potential. Kiomu area situated on the eastern edge of the Project area (east groundwater area) is evaluated as also promising.

Potential development amounts of groundwater source is estimated in the ANNEX II. However, the whole amount of groundwarer potential cannot be made available because the groundwater flow will fluctuate seasonally depending on the rainfall pattern and also the existing springs outflow has to be maintained.

In order to determine the optimum scale of the groundwater development scheme, the following assessment is made:

	Item		North groundwater area	East groundwater area
1.	Potential available water ($10^6 m^3$/year)		41	9
2.	Extraction efficiency	(%)	30	30
3.	Available groundwater ($10^6 m^3$/year)		12.3	2.7
4.	Production rate per well	(ℓ/s)	60	30
5.	Irrigation Water requirement(m/year)		1.4	1.4
6.	Irrigable area	(ha)	880	190
			60 ha x 14	30 ha x 6

Consequently, 14 wells in the north groundwater scheme and 6 wells in the east groundwater scheme are proposed in the Lower-Moshi area.

1.3.2 Pump and Electrical Facilities

(1) Pump and motor

Two kinds of pumps are installed depending on productivity and the require head of tube wells drilled in the north and east groundwater schemes. Pumps and motors are selected to meet the following hydraulic requirements of tube wells as mentioned in ANNEX 11.

Scheme	Productivity of water	Required head	Total number of well
	(ℓ/sec/well)	(m)	(Nos)
North groundwater	60	35	14
East groundwater	30	25	6

Pumps to be installed are of submersible type which has such advantages as simple installation and easy maintenance. The pump is directly coupled with submersible motor under the water. Thus, no sealing water and lubricating oil are needed. The motor is set at the lower side of pump. Cab type cable is wired along the discharge pipe in the tube well. The electric power for the pump is contemplated to be supplied from the proposed 11 kV distribution line as mentioned later.

The principal features of pumps are as follows:

Item		For tube well in the north groundwater scheme	For tube well in the east groundwater scheme
Type		Submersible	Submersible
Discharge	(ℓ/sec)	60 (3.6 m^3/min)	30 (1.8 m^3/min)
Total head	(m)	35	25
Diameter of pump	(mm)	200	125
Number of impellers	(units)	2	2
Motor output	(kW)	37	15
Synchronous speed	(rpm)	3,000	3,000

The pump is manually started and stopped from the pump house, further it can be automatically stopped when the water level in the well exceeds the allowable low level during operation. In order to maintain the proper and efficient operation, check valve, sluice valve, air valve, compound gauge, etc., are provided.

(2) Electric Power Supply System

Electric power for the groundwater tube well pumps is supplied from 11 kV distribution to be constructed from the existing 33 kV transmission line to the Miwaleni pump station. An 11 kV distribution line is provided, of overhead, single circuit on concrete poles. The schematic layout of distribution lines to each groundwater scheme is as shown in Fig. VII-14.

The transformers are installed on the pole near each groundwater pump house for stepping down the voltage from 11 kV of distribution line voltage to 400-230 V for a tube well pump motor.

1.3.3 Irrigation system

The groundwater scheme areas are situated at an interval of well of at least 1 Km in both north and east groundwater areas. The irrigation system consists of a tube well pump station, a regulating pond, lead canal to connect the regulation pond to secondary canals, secondary and tertiary canals. The regulating pond is lined with thin plain concrete. The irrigation canals are concrete-lined upto the tertiary canal.

The general layout of the groundwater schemes is as shown in the attached drawing. The general features of the schemes are as shown in Table VII-14 and VII-15.

The hydraulic properties of the main canals to be provided in the proposed irrigation schemes are shown in Table VII-16. The numbers of related canal structures to be constructed in the schemes are as shown in Table VII-17.

2. Flood Protection Facilities

2.1 Present Conditions of Rivers

2.1.1 General features of rivers

There are various small rivers developed in the Lower-Moshi area as a natural drain. Three major tributaries of the Pangani river, (i.e. the Rau, Mue and Himo rivers) run south-eastward or southward across the Lower-Moshi area. Between the Rau and the Mue rivers, twelve seasonal rivers run south-westward across the Moshi-Himo road and their watercourses disappear in the field. There also exist four major springs in the area, (i.e. the Njoro, Miwaleni, Soko and Kileo), which are connected with the above rivers and feed them with perennial flow throughout the year.

The principal features of rivers are summarized as follows. Location of rivers are shown on Figure I-19 in Annex I.

Item	Rau	Mue	Himo
Catchment area (km^2)			
- at the Moshi-Himo road	122	85	247
- at the confluence (BP)	311	306	295
Length of river from BP to the road (km)	49	23	21
Slope of riverbed from BP to the road	1/50-1/1000	1/60-1/860	1/50-1/460
Discharge (Q) at the Moshi-Himo road			
Annual runoff (MCM)	50	15	50
Recorded min. Q (m^3/sec)	0	2.3	0
" max. Q (m^3/sec)	6.6	13.3	41.6
Estimated flood Q (m^3/sec) 5 % Probability	193	130	312

2.1.2 Flow capacity of rivers

During field investigations from December 1979 to March 1980, cross section surveys were carried out at 28 sites (i.e. 16 sites on the Rau river, 6 sites on the Mue river and 6 sites on the Himo river) in order to clarify the present flow condition of each river. Survey results are shown in Figures VII-17 to VII-20.

Based on the survey results, present flow capacity for each river is estimated. Flow capacity for each river section is estimated by using non-uniform flow equation which is solved by Ida's method using electronic computer. Results are shown in Table VII-18 and summarized below.

River	Distance (km)	Slope	Flow Area (m^2)	Flow Capacity (m^3/sec)
Rau	0 - 30	1/1040 - 1/340	4 - 33	1 - 6
	30 - 46	1/900 - 1/120	8 - 34	6 - 41
	46 - 50	1/140 - 1/50	19 - 47	41 - 161
Mue	0 - 15	1/860 - 1/590	23 - 35	16 - 35
	15 - 21	1/590 - 1/280	0 - 20	0 - 30
	21 - 23	1/280 - 1/60	18 - 40	65 - 140
Himo	0 - 10	1/460 - 1/390	7 - 43	4 - 105
	10 - 14	1/450 - 1/390	43 - 90	105 - 210
	14 - 24	1/450 - 1/50	90 - 780	210 - 980

The Rau river has a flow capacity of about 100 m^3/sec near the Moshi-Himo road. However, flow capacity of the lower reaches of the Rau river decrease rapidly from about 100 m^3/sec to 10 m^3/sec or less as shown in the table. In the middle reaches of the Rau river, it averages about 20 m^3/sec. According to the interview with farmers, flood runoff overflows the river bank and causes annual inundation on the field along the Rau river.

The Mue river course disappears in its middle reaches (i.e. just upstream of the junction with the Miwaleni flow and the Mue river) for about 3 km distance because of accumulation of soils. Hence, seasonal floods the Mue river flow over as sheet flows on the ground surface downstream of this portion. Watercourses upstream and downstream of this portion have a flow capacity ranging from 18 to 40 m^3/sec.

The Himo river has enough flow capacity in its upper reaches against flood runoff. On the other hand, lower reaches of the Himo river, or downstream of the Ghona and Kileo scheme, have smaller flow capacity from 210 to 4 m^3/sec. Especially, the flow capacity downstream of the bridge on the Himo-Same road is quite small and hence, flood runoff overflows in this portion annually.

2.1.3 Flooded area

Present flow capacity of rivers, especially that of the Rau river, is so small that regular inundation occurs extensively. In order to clarify the flooding conditions, field investigation was made by means of interview with farmers and flood mark survey during January to March 1980. Based on results of survey, flooded areas are delineated on the topographic map (scale 1/50,000) as shown in Figure VII-21.

Flood damages in the Lower-Moshi area are caused by two kinds of floods: submergence and washouts. The former is seen annually along the Rau river. The latter generally occurs at the end of watercourses of the Mue and other seasonal rivers.

As extraordinarily big flood occurred on the Rau river in April 1979. The magnitude of the 1979 flood is equivalent to 2% probability of occurrence as mentioned in Annex I.

Accordingly, flooded areas are estimated by three categories, i.e. regular flood (submergence), the 1979 flood (submergence) and washouts. Flooded areas are estimated in detail in Annex VI. They are summarized below.

Flooded Area

(Unit: ha)

Name of Village	Total Flooded Area			Flooded Area Cropped		
	Regular Flood	1979 Flood	Washout	Regular Flood	1979 Flood	Washout
1. Msaranga/ Mandaka	100	430	980	90	390	880
2. Yam Makaa	60	120	940	55	110	850
3. Uchira	-	50	400	-	45	360
4. Kisange-Sangeni	1,100	1,700	-	250	340	-
5. Kitereni2	-	250	1,040	-	180	380
6. Ghona	-	-	60	-	-	-
7. Mabogini	10	100	-	10	90	-
8. Rau Ya Kati	330	870	-	240	730	-
9. Oria	600	2,310	-	65	780	-
10. Mangaria	1,770	2,370	380	1,090	3,045	70
Total	3,970	8,700	3,800	1,090	3,045	2,540

2.2 Flood Protection Method

2.2.1 General

Flood protection is indispensable for implementation of any irrigation scheme in the Mandaka, Miwaleni and Uchira areas and in areas along the Rau river as shown in Figure VII-21.

In the Mandaka, Miwaleni and Uchira areas, seasonal flooding rivers regularly cause flood damages by washout due to disappearance of their watercourses. In order to implement the North groundwater scheme and the Miwaleni pump lift scheme, construction of floodway is quite necessary.

In areas along the Rau river, regular or occasional inundation occur extensively. Depth of inundation in most areas is about 1 m or less at its maximum during the 1979 flood. Hence, low flood protection dike seem to be recommendable in these areas.

2.2.2 Design flood discharge

Possible flood discharge for each river is calculated in detail in Annex I. For design of flood protection facilities, flood discharge with a recurrence interval of 20 years is employed. Design flood discharge is as follows.

Name of River	Catchment Area 1/ (km^2)	Design Flood Discharge (m^3/sec)
Rau river	122	193
Mue river	85	130
Seasonal flooding rivers		
1. Kisiringo	14	32
2. Msáranga	17	39
3. Msangaji	10	22
4. Mola	7	17
5. Mlalo	9	22
6. Nanga	21	46
7. -	8	17
8. Cholo	9	23
9. Mokraii	5	11
10. Uchira	24	47
11. Kandalu	4	9
12. Urenga	15	30

1/: Catchment area measured at the Moshi-Himo road.

2.2.3 Floodway

(1) Planning

Part of areas to be commanded by the North groundwater scheme and the Miwaleni pump lift scheme is regularly damaged by seasonal washouts originating both from the Mue and seasonal rivers as shown in Figure VII-21. At present, watercourses of the Mue and seasonal rivers disappear on the field at 3 to 7 km downstream from the Moshi-Himo road. In order to prevent this flood damage, a floodway is proposed. It is planned so as to lead flood discharge to the Rau or the Mue river as schematically shown in Figure VII-22.

The watercourse of each floodway is determined taking into account natural ground conditions and locations of seasonal rivers. Basic figures of each floodway are as follows.

Name of Floodway	Relevant Rivers	Design Discharge (m^3/sec)	Total Length (km)	Junction
(1) Mandaka FW	Kishiringo, Msaranga, Msangaji, Mola, and Mlalo.	17 - 132	11.55	Rau river
(2) Nanga FW	Nanga.	46	4.55	Rau river
(3) Miwaleni FW	Cholo and its tributary.	40	6.30	Mue river
(4) Mue FW	Urenga, and Mue.	160	3.00	Mue river
(5) Uchira FW	Uchira and Kandalu	56	2.75	Mue river

For the purpose to introduce excess water from outside area floodway and to give access across the floodway by vehicle, open dikes of about 2 km interval are proposed as shown in drawings attached. Canal base at the open dike is paved by wet rubble and gabion in order to protect canal base against erosion and to assure accessibility. Detailes are shown in Drawing No. 3-03.

(2) Design concept

Gradient

Gradient of existing watercourse of seasonal rivers in the Lower-Moshi area ranges from 1/20 to 1/100. The expected flow velocity of design flood on these rivers is calculated ranging between 4 m/sec and 2.5 m/sec, assuming that roughness coefficient of the Manning formula is 0.04. Existing riverbed of seasonal rivers in the Lower-Moshi area seems to be in equilibrium for a long time according to field investigation and interview with farmers. Accordingly, the floodway is proposed to be constructed along the natural ground slope ranging from 1/60 to 1/600 as shown in Table VII-19 and drawings attached.

Flow section

Bottom width of floodway is determined by using the following empirical equation.

$$B = 3 \cdot Q^{1/2}$$

where; B = bottom width in m,
Q = design flood discharge in m^3/sec.

Flow section of floodway is proposed to be trapezoidal type with side slope of 1:2 as shown in drawings attached.

Calculation of velocity

Hydraulic calculation is made by using the Manning formula as shown below.

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

where; V = velocity in m/sec,
R = hydraulic radius in m,
i = slope of the drain in m/m, and
n = coefficient of roughness.

Hydraulic properties for each floodway are calculated as shown in Table VII-19.

Freeboard

As shown in Table VII-19, water depth for each floodway ranges from 0.52 to 1.87 m. Freeboard is empirically determined at 0.6 m based on the following design standard.

Design Flood Discharge (m^3/sec)	Freeboard (m)
less than 200	0.6
200 to 500	0.8
more than 500	1.0

(3) Principal features of proposed floodway

Based on the above design concept, principal features of floodways are proposed as follows.

Name of Floodway	Design Discharge (m^3/sec)	Total Length (km)	Width (m)	Gradient	Exca. Depth (m)	Embank. Hight (m)
Mandaka	17-132	11.55	13-35	1/60-1/400	0.5-1.0	0.6-1.2
Nanga	46	4.55	20	1/130-1/600	0.8	0.6-1.2
Miwaleni	40	6.30	20	1/60-1/400	0.6	0.6-1.1
Mue	160	3.00	40	1/190	0.7-1.1	0.6-1.4
Uchira	56	2.75	25	1/150	0.7	0.6-1.2

2.2.4 NAFCO canal crossing

(1) Necessity of Improvement

Flow capacities of the Rau river decrease sharply toward the lower reaches, causing inundation in the area lying along the river. At present, the flood water discharges downstream gradually through three aqueducts provided at the crossing point of the NAFCO lead canal. According to the field investigation, the flow capacity of these structures is so small as to be 25 m^3/sec.

Aqueduct	Flow Section				Length (m)	Capacity
	Width (m)	Height (m)	Numbers (nos.)	Area (m^2)		
No.1	3.68	1.00	1	3.68	25	4.5
No.2 (Rau river)	3.65	1.00	2	7.30	25	14.0
No.3	3.80	1.00	1	3.80	25	6.5
Total						25.0

With the proposed flood control plan, flood water originating in the Kilimanjaro slopes will be introduced so quickly to the Rau river. The design flood discharge for the Rau river flood protection facilities is estimated to be 371 m^3/sec at the lower reaches. In consideration of the design flood discharge of the Rau river and the present flow capacity of aqueducts, it is required to increase the flow capacity of the Rau river at the crossing point with the NAFCO canal. It is proposed to construct a syphon type structure on the NAFCO canal passing under the Rau river.

(2) Design of crossing facilities

In order to pass design flood discharge of the Rau river (371 m^3/sec), canalization of the Rau river at the existing NAFCO canal is indispensable. Thus a syphon structure is to be required as a crossing structure on the Rau river in order to convey irrigation water toward the NAFCO farm.

The syphon structure consists of inlet, culvert and outlet structures. The Culvert determined is to be a box type with inside area of 4 m^2 (2 m high, 2 m wide) in order to minimize hydraulic loss on the existing NAFCO canal.

The required width of river channel, or the length of culvert, at the NAFCO canal crossing is determined so as to minimize total construction cost of crossing facilities (= canalization plus syphon structure). Hydraulic calculations are as follows.

Design flood discharge:	371 m^3/sec
Permissible velocity:	3 m/sec
Roughness coefficient:	
River channel	0.03
Concrete culvert	0.017
Design discharge for the NAFCO canal:	2.9 m^3/sec
Permissible hydraulic loss on the NAFCO canal:	7 cm

Width of river channel, or length of syphon, is determined based on economic comparison between cost of syphon and cost of excavation downstream of the NAFCO canal crossing. Figure VII-23 is prepared in order to determine the proposed channel width by selecting a point of minimum total construction cost (syphon cost plus excavation cost). As a result, the proposed width of flow section at the NAFCO canal crossing is determined at 50 m. Hence, the length of culvert for syphon structure is 60 m as shown in Drawing No. 3-02.

In the river channel, a low-water channel is provided so as to have flow capacity of 14 m^3/sec, or present flow capacity at the existing aqueduct on the NAFCO canal. In addition, small culvert structures are provided on the low-water channel in order to maintain accessibility of operation road along the NAFCO canal.

(3) Principal features of crossing facilities

Principal features of the NAFCO canal crossing structure are summarized as follows. Details are shown in Drawing No. 3-02.

1. River channel

High-water channel:	Bed width:	50 m
	Depth:	3 m
Low-water channel:	Bed width:	5 m
	Depth:	1.2 m

Pavement: Wet rubble masonry

2. Syphon structure

Conduit:	Section:	2 m x 2 m Box culvert
	Length:	60 m
Transition (Inlet and Outlet)		10 m

2.2.5 Flood protection dike

(1) Necessity of flood protection dike

Extensive areas along the Rau river are flooded regularly or occasionally as shown in Figure VII-21. Especially, the 1979 flood caused extensive inundation over an area of about 12,000 ha with a water depth from 0.5 to 1.0 m on average. This big flood is equivalent to 2% probability of occurrence as mentioned in Annex I.

Irrigation schemes envisaged along the right bank of the Rau river are the Upper Mabogini, Mabogini, Rau ya Kati and Checkereni schemes. On the other hand, the Miwaleni pump lift scheme will be established in the left bank of the Rau river as shown in Figure VII-21. The inundation area caused by floods on the Rau river is estimated for each scheme as follows.

Name of Scheme	Scheme Area (ha)	Flooding Area: Regular Flood (ha)	Flooding Area: 1979 Flood (ha)
Upper Mabogini	150	10	60
Mabogini	850	20	190
Rau Ya Kati	450	200	450
Chekereni	850	200	380
Miwaleni Pump Lift	2,000	320	470

As shown on the above table, flood protection dikes are indespensable in order to ensure each irrigation scheme.

(2) Design of dike

i) Height of dike

During the 1979 flood, existing embankment (1 to 1.5m high) for railway connecting Moshi and Tanga functioned as a flood protection dike for Mabogini and Chekereni areas as shown in Figure VII-21. Height of dike is determined based on flood mark elevation traced by the 1979 flood. Elevation of the crest of dike is determined by adding the following freeboard height to the above water level.

Freeboard Height

Design Flood Discharge (m^3/sec)	Freeboard (m)
Less than 200	0.6
200 to 500	0.8

As shown in Drawing No. 3-01, height of dike is determined to be about 1.5 m above original ground surface on average.

ii) Location of dike

Location of proposed dike is carefully determined by selecting relatively higher place in order to save construction cost and to assure stability of dike. Location of the Miwaleni dike is determined so as to keep distance (at least 700 m) from the other dike on the right bank of the Rau river in order to minimize back water effect by design flood discharge of 371 m^3/sec.

Check calculation of flood water level for proposed dike span is conducted by using non-uniform flow equation which is solved by Ida's method using electronic computer. Results are summarized as follows.

Survey Section	Dike Span (m)	Velocity (m/s)	Calculated Water Level (El.m)	Surveyed 1979 Flood Water Level (El.m)	Difference (m)
5	1,200	0.33	715.4	715.4	±0
6	900	0.45	724.4	724.3	+0.1
7	700	0.57	728.5	728.6	-0.1

Note: Roughness coefficient = 0.1, location of survey section are shown in Table VII-18.

Result of calculation indicates that proposed dike causes negligible effect on water rise compared with water level by the 1979 flood.

iii) Length of dike

Required length of dike is estimated based on survey results on the water level by the 1979 flood as shown in Drawing No. 3-01. Length of dike for each scheme is summarized below.

Location	Name of Scheme	Length of Dike (km)
Right Bank	Upper Mabogini	2.7
"	Mabogini	1.3
"	Rau Ya Kati	5.2
"	Chekereni	4.4
	Sub-total	13.6
Left Bank	Miwaleni Pump Lift	5.7
	Total	19.3

iv) <u>Section of dike</u>

Section of dike is determined as follows. Details are shown in Drawings No. 3-01.

Crest width	:	3 m
Side slope	:	1:2

3. Farm Road

3.1 Trunk Farm Road

National roads and railways pass through the Lower-Moshi area. On the northern edge the national road connects Moshi to Taveta via Himo and its branch leads to Tanga. On the south, TPC road leads to Arusha Chini from Moshi. They are all weather tarmac roads and function as the trunk road in this area. A regional road starting from TPC road to Kahe village crosses longitudinally over the irrigation scheme areas of the Rau river system. This road is earthen over its length and is often impassable in the rainy season. Across the Miwaleni pump lift scheme and the north groundwater scheme areas, a road extends from Miwaleni to Moshi-Himo road. This road is also earthen and impassable in the rainy season.

In order to connect the scheme areas to the above trunk traffic lines, trunk farm roads are proposed. With improvement of Mabogini - Chekereni - Kahe road, the Chekereni trunk farm road of 19.0 km is arranged in the irrigation schemes in the Rau river system. Miwaleni trunk farm road of 5.8 km is to be improved as the Miwaleni - Uchira road. They are gravel-metalled with the total width of 7.0 m so as to be passable even in the rainy season.

With these trunk farm roads, the Kilimanjaro Agricultural Development Center (KADC) locating in Chekereni and the Miwaleni Experimental Sub-station are linked through the operation road of Kahe NAFCO lead canal.

3.2 Farm Road System

In addition to the trunk farm roads, the farm road system is arranged in each irrigation scheme. It consists of main farm road, secondary farm roads, tertiary farm roads and field roads. In principle, main, secondary and tertiary farm roads run alongside main, secondary and tertiary farm canals, respectively. Tertiary farm roads are looped so as to serve the irrigation blocks of 20 to 40 ha. They are all earthen roads with the following widths:

Main farm road	:	7.0 m
Secondary farm road	:	5.0 m
Tertiary farm road	:	4.0 m

Table VII-1 **IRRIGATION SYSTEM CAPACITY**

Scheme	Intake	Main Canal	Secondary Canal	Tertiary Canal
	(m^3/s)	(ℓ/s/ha)	(ℓ/s/ha)	(ℓ/s)
1. Rau River System				
(1) Upper Mabogini Scheme	0.20	1.34	1.34	37 /1
(2) Mabogini Scheme	1.08	1.27	1.34	37 /1
(3) Rau Ya Kati Scheme	0.58	1.29	1.34	37 /1
(4) Chekereni Scheme	1.11	1.31	1.40	37 /1
2. Himo River System				
(1) Makuyuni Scheme	0.44	0.88	0.88(1.17) /3	38 /2
(2) Ghona & Kileo Scheme	0.48	0.96	0.96(1.28) /3	38 /2
3. Miwaleni Scheme (Pump Station: 2.00 m^3/s)				
(1) East Area	1.07	0.91	0.91(1.21) /3	37
(2) West Area	1.06	1.34	1.34	37
4. Groundwater Scheme				
(1) North Groundwater Scheme	0.054	-	46 ℓ/s	23 /4
(2) East Groundwater Scheme	0.029	-	38 ℓ/s	19 /4

Note: /1: For an irrigation block of 20 ha at the peak requirement period of dry season paddy (1.85 ℓ/sec/ha) on 24-hour operation basis.

/2: For an irrigation block of 20 ha at the peak requirement period of dry season oilseeds (1.44 ℓ/sec/ha) on 18-hour operation basis.

/3: Average unit water requirement for canals in the downstream of farm pond (continuous supply $Qu \times \frac{24}{18}$)

/4: Using the peak requirement of dry season oilseeds (1.44 ℓ/sec/ha) for 12 ha for north groundwater scheme and 10 ha for east groundwater scheme on 18-hour operation basis.

Table VII-2 MEASUREMENT OF CANAL SEEPAGE LOSS

Scheme		Chekereni	Chekereni	NAFCO
Canal		Main head	Farm Canal	Lead Canal
Passing discharge				
Q_1	(m^3/s)	0.247	0.152	1.803
Q_2	"	0.219	0.150	1.478
dq	"	0.028	0.002	0.325
Average wetted perimeter	(m)	2.7	3.0	8.6
Length	(m)	750	100	5,650
Wetted area	(m^2)	2,025	300	48,590
Unit discharge loss	($m^3/s/10^6m^2$)	13.8	6.7	6.7

Scheme		Marang Siding	Himo Tannaries
Canal		Main Canal	Lead Canal
Passing discharge			
Q_1		0.315	0.067
Q_2		0.119	0.010
dq		0.196	0.057
Average wetted perimeter	(m)	1.90	2.10
Length	(m)	1.450	1,900
Wetted area		2,755	3,990
Unit loss discharge	($m^3/s/10^6m^2$)	71	14.3

Table VII-3 SLOPE STABILITY

Soil Properties /1	Sample Soil	
	Chekereni	Miwaleni
- Soil density in Saturated Condition (t/m^3)	2.0	1.9
- Soil density in Wet Condition (t/m^3)	1.8	1.7
- Cohesion in Saturated Condition (t/m^2)	1.7	2.4
- Internal friction angle in		
Wet Condition (^{o})	3.5	5.0
Dry Condition (^{o})	9.3	6.7

Critical height of embankment;

$$Hc = \frac{C}{r_s \cdot N_s \cdot SF}$$

Where,

- Hc : Critical height of embankment (m)
- C : Cohesion in saturated condition (t/m^2)
- r_s : Soil density in " (t/m^3)
- N_s : Coefficient of safety relating with internal friction angle and soil density
- SF : Safety factor, 1.5

Soil Sample	Side slope 1:1.5		Side slope 1:2.0	
	Ns	Hc (m)	Ns	Hc (m)
Chekereni	0.145	3.9	0.14	6.0
Miwaleni	0.14	4.0	0.13	6.5

/1 : Full data are presented in DATA BOOK

Table VII-4 GENERAL FEATURES OF UPPER MABOGINI IRRIGATION SCHEME

1. Name of Scheme	Upper Mabogini Irrigation Scheme
2. Source of Irrigation Water	Njoro river
3. Net Irrigation Area	150 ha
4. Maximum Diversion Water Requirement	0.20 m^3/sec
5. Irrigation Facilities	
(1) Upper Mabogini Intake structure	
Location	3.5 km upstream of confluence of the Rau and the Njoro rivers
Riverbed EL.	755.70 m
Weir type	Floating type concrete weir
Crest EL.	757.20 m
Weir height from river bed	1.5 m
Crest length	8.4 m
Scouring sluice	1.0 m width x 1 no.
Intake gate	Circular slide gate, ∅800 mm x 1 no.
(2) Main irrigation canal with related structures	
Canal type	Trapezoidal concrete lined canal
Length	0.60 km
Discharge	0.20 m^3/sec ~ 0.13 m^3/sec
(3) Secondary irrigation canal with related structures	
Canal type	Trapezoidal concrete lined canal
Length	0.45 km
Number	2
6. Drainage Facilities	
(1) Canal type	Trapezoidal earth canal
(2) Canal length	
Main drain	-
Secondary drain	0.65 km
7. Farm Road	
(1) Main farm road (W=7^m)	
Length	0.60 km
(2) Secondary farm road (W=5^m)	
Length	4.20 km
Number	3
8. On-farm Development Works	
(1) Tertiary irrigation canal	7.01 km
(2) Tertiary drainage canal	2.29 km
(3) Tertiary farm road	3.73 km
(4) Farm ditch, drain & road	for 150 ha
9. Land Levelling	150 ha
10. Flood Protection dike	
(1) Top width	3.0 m
(2) Length	2.7 km

Table VII-5 **GENERAL FEATURES OF MABOGINI IRRIGATION SCHEME**

1. Name of Scheme	Mabogini Irrigation Scheme
2. Source of Irrigation Water	Njoro river
3. Net Irrigation Area	850 ha
4. Maximum Diversion Water Requirement	1.08 m^3/sec
5. Irrigation Facilities	
(1) Mabogini Intake structure	
Location	2 km upstream of confluence of the Rau and the Njoro rivers
Riverbed EL.	751.30 m
Weir type	Floating type concrete weir
Crest EL.	752.80 m
Weir height from river bed	1.5 m
Crest length	8.4 m
Scouring sluice	1.0 m width x 1 no.
Intake gate	Slide gate 1,000mm x 1,500mm x 1 no.
(2) Main irrigation canal with related structures	
Canal type	Trapezoidal concrete lined canal
Length	3.53 km
Discharge	1.08 m^3/sec ~ 0.59 m^3/sec
(3) Secondary irrigation canal with related structures	
Canal type	Trapezoidal concrete lined canal
Length	7.98 km
Number	7
6. Drainage Facilities	
(1) Canal type	Trapezoidal earth canal
(2) Canal length	
Main drain	5.10 km
Secondary drain	11.89 km
7. Farm Road	
(1) Main farm road ($W=7^m$)	
Length	3.53 km
(2) Secondary farm road ($W=5^m$)	
Length	9.61 km
Number	3
8. On-farm Development Works	
(1) Tertiary irrigation canal	28.71 km
(2) Tertiary drainage canal	24.27 km
(3) Tertiary farm road	33.55 km
(4) Farm ditch, drain & road	for 780 ha
9. Land Levelling	780 ha
10. Flood Protection dike	
(1) Top width	3.0 m
(2) Length	1.3 km

Table VII-6 GENERAL FEATURES OF RAU YA KATI IRRIGATION SCHEME

1. Name of Scheme	Rau Ya Kati Irrigation Scheme
2. Source of Irrigation Water	Rau river
3. Net Irrigation Area	450 ha
4. Maximum Diversion Water Requirement	0.58 m^3/sec
5. Irrigation Facilities	
(1) Rau Ya Kati Intake structure	
Location	1.2 km downstream of confluence of the Rau and the Njoro rivers
Riverbed EL.	740.90 m
Weir type	Floating type concrete weir
Crest EL.	742.40 m
Weir height from river bed	1.5 m
Crest length	13.4 m
Scouring sluice	1.0 m width x 1 no.
Intake gate	Slide gate 1,000mm x 1,000mm x 1 no.
(2) Main irrigation canal with related structures	
Canal type	Trapezoidal concrete lined canal
Length	3.52 km
Discharge	0.58 m^3/sec ~ 0.28 m^3/sec
(3) Secondary irrigation canal with related structures	
Canal type	Trapezoidal concrete lined canal
Length	3.21 km
Number	3
6. Drainage Facilities	
(1) Canal type	Trapezoidal earth canal
(2) Canal length	
Main drain	0.25 km
Secondary drain	8.67 km
7. Farm Road	
(1) Main farm road ($W=7^m$)	
Length	6.15 km
(2) Secondary farm road ($W=5^m$)	
Length	2.55 km
Number	1
8. On-farm Development Works	
(1) Tertiary irrigation canal	14.35 km
(2) Tertiary drainage canal	13.69 km
(3) Tertiary farm road	24.25 km
(4) Farm ditch, drain & road	for 450 ha
9. Land Levelling	450 ha
10. Flood Protection dike	
(1) Top width	3.0 m
(2) Length	5.2 km

Table VII-7 **GENERAL FEATURES OF CHEKERENI IRRIGATION SCHEME**

1. Name of Scheme	Chekereni Irrigation Scheme
2. Source of Irrigation Water	Rau river
3. Net Irrigation Area	850 ha
4. Maximum Diversion Water Requirement	1.11 m^3/sec
5. Irrigation Facilities	
(1) Chekereni Intake structure	
Location	0.5 km upstream of the existing Chekereni intake
Riverbed EL.	724.00 m
Weir type	Floating type concrete weir
Crest EL.	725.50 m
Weir height from river bed	1.5 m
Crest length	13.4 m
Scouring sluice	1.0 m width x 1 no.
Intake gate	Slide gate 1,500mm x 1,500mm x 1 no.
(2) Main irrigation canal with related structures	
Canal type	Trapezoidal concrete lined canal
Length	3.35 km
Discharge	1.11 m^3/sec ~ 0.60 m^3/sec
(3) Secondary irrigation canal with related structures	
Canal type	Trapezoidal concrete lined canal
Length	7.45 km
Number	3
6. Drainage Facilities	
(1) Canal type	Trapezoidal earth canal
(2) Canal length	
Main drain	5.08 km
Secondary drain	12.15 km
7. Farm Road	
(1) Main farm road ($W=7^m$)	
Length	3.35 km
(2) Secondary farm road ($W=5^m$)	
Length	9.95 km
Number	3
8. On-farm Development Works	
(1) Tertiary irrigation canal	22.98 km
(2) Tertiary drainage canal	21.00 km
(3) Tertiary farm road	32.20 km
(4) Farm ditch, drain & road	for 780 ha
9. Land Levelling	780 ha
10. Flood Protection dike	
(1) Top width	3.0 m
(2) Length	4.4 km

Table VII-8 GENERAL FEATURES OF MIWALENI PUMP LIFT SCHEME

1. Name of Scheme	Miwaleni Pump Lift Scheme
2. Source of Irrigation Water	Miwaleni springs
3. Net Irrigation Area	2,000 ha
4. Maximum Diversion Water Requirement	2.00 m^3/sec
5. Irrigation Facilities	
(1) Pump station	
Pump	
Type	Horizontal shaft double suction volute type
Number of unit	4 sets including 1 spare
Pump capacity	40 m^3/min.
Static head	17.3 m
Rated head	24.0 m
Pump diameter	600 mm x 500 mm
Motor	
Type	Horizontal shaft three phase induction motor
Output of each motor	230 kW each
Discharge pipeline	
Nos. of pipeline	1 No.
Pipe material	Steel
Internal diameter	1,100 m
Length	1,850 m
Pumphouse	
Length	21.0 m
Width	16.0 m
Height	8.5 m
(2) Main irrigation canal with related structures	
Canal type	Trapezoidal concrete lined canal
Length and discharge	
East main canal	5.4 km, 1.07 m^3/sec - 0.41 m^3/sec
West main canal	6.5 km, 1.06 m^3/sec - 0.48 m^3/sec
(3) Secondary irrigation canal with related structures	
Canal type	Trapezoidal concrete lined canal
Length	19.2 km
Number	11
6. Drainage Facilities	
(1) Canal type	Trapezoidal earth canal
(2) Canal length	
Main drain	0.8 km
Secondary drain	17.4 km

7. Farm Road

(1) Main farm road (W = 7 m)

Length	11.9 km

(2) Secondary farm road (W = 5 m)

Length	15.8 km
Number	10

8. On-farm Development Works

(1) Tertiary irrigation canal	71.4 km
(2) Tertiary drainage canal	71.6 km
(3) Tertiary farm road	35.0 km
(4) Farm ditch, drain & road	for 2,000 ha

9. Land Levelling and grading 2,000 ha

10. Farm pond, 3 Nos.

No.1 on ES-1 Canal	Storage Capacity:	6,500 m^3
No.2 on ES-2 Canal	" :	1,900 m^3
No.3 on ES-3 Canal	" :	3,700 m^3
No.4 on ES-4 Canal	" :	4,100 m^3
No.5 on ES-5 Canal	" :	4,900 m^3

11. Flood Protection dike

(1) Top width	3.1 m
(2) Length	5.7 km

12. Power Distribution Line and Sub-station

(1) Voltage	11 kV
(2) Length	5.5 km
(3) Transformer	one bank of 2,000 kVA

Table VII-9 COMPARISON OF PUMPING SYSTEM

Item	Unit	Plan-1 High head pump	Plan-2 High head pump	Plan-2 Medium head pump	Plan-3 High head pump	Plan-3 Medium head pump	Plan-3 Low head pump
A. General Features							
1. Irrigation area	(ha)	2,000	700	1,300	700	800	500
2. Pump station							
(i) Pumping plant							
Type		Double suction horizontal shaft volute pump					
Number of unit	(Nos)	4	3	3	3	3	3
Rated discharge per unit	(m^3/min)	40	20	40	20	25	15
Pump diameter	(mm)	600 x 500	400 x 300	600 x 500	400 x 300	450 x 300	350 x 300
Static head	(m)	17.3	17.3	12.3	17.3	12.3	6.3
L.W.L	(m)	713.7	713.7	713.7	713.7	713.7	713.7
H.W.L	(m)	731.0	731.0	726.0	731.0	726.0	720.0
Rated total head	(m)	24	26	19	26	21	18
Motor output	(kW)	230	130	180	130	130	70
(ii) Discharge pipeline							
Diameter of pipe	(mm)	1,100	700	900	700	700	500
Length		1,850	1,850	1,500	1,850	1,500	900
(iii) Pump house	(m^2)	336	480		640		
(iv) Power consumption	(10^3kWh)	3,800	1,400	1,940	1,400	1,400	760
3. Canal & road							
(i) Main canal	(km)	11.5	16.0		18.0		
(ii) Main road	(km)	10.8	16.0		18.0		
B. Construction Cost (10^3 US$)							
1. Mechanical and electrical equipment							
(i) Pumping equipment		660	720		730		
(ii) Pipeline		1,570	1,597		1,562		
Sub-total		2,230	2,317		2,292		
2. Civilworks							
(i) Inlet channel & pump house		507	706		921		
(ii) Discharge pipeline & outlet		256	293		307		
(iii) Canal & road							
Main canal		1,000	1,280		1,350		
Main road		232	336		378		
Sub-total		1,995	2,615		2,956		
Total		4,225	4,932		5,248		
C. Annual Cost (10^3 US$)							
1. Annuity of Construction Cost		231	270		287		
2. Replacement cost		47	49		48		
3. Annual electric energy cost		152	134		142		
Total		430	453		477		

Note

/1: The cost of pumping equipment includes the costs for pumps, motors, valves, switchgears, control facilities and other auxiliary facilities.

/2: In canal and road systems, secondary and tertiary irrigation canals, drainage canals, secondary and tertiary farm roads are excluded because of no significant difference between alternatives.

/3: Annuity of construction cost is calculated by producting the construction cost with the capital recovery factor, on the basis of discount rate of 5% and economic useful life of 50 years, C.R.F. = 0.05478.

/4: Replacement cost is estimated for mechanical and electrical equipment by sinking fund deposit method on the basis of discount rate of 5% and economic life of 25 years, S.F.D.F = 0.02095.

/5: Electric energy cost is based on the unit rate of 0.04 US$/kWH.

Table VII-10 ECONOMIC COMPARISON OF PUMP TYPES

Item		Horizontal Shaft Double Suction Volute Type	Vertical Shaft Mixed Flow Type
I. Principal Features			
1. Maximum Water requirement	(m^3/sec)	2.0	2.0
2. Number of pump /1	(Nos)	4	4
3. Capacity per unit	(m^3/min)	40	40
4. Rated total head	(m)	24	24
5. Standard pump efficiency		0,82	0,78
6. Motor output	(KW)	230	240
7. Diameter of pump	(mm)	600 x 500	600
8. Pump house	(m^2)	352	280
(Length x Width)	(m)	16 x 22	14 x 20
II. Construction Cost (unit: US$)			
1. Pumping equipment /2		660,000	781,000
2. Civil works and building works			
(1) Pump house		71,000	57,000
(2) Inlet channel and sub-structure		1,148,000	1,090,000
Total		1,879,000	1,928,000

Note: /1: Including one standby set

/2: Direct construction cost for pump and motor equipment, the pipeline cost is not included.

Table VII-11 ECONOMIC DIAMETER OF DISCHARGE PIPELINE

Alternative diameter (mm)	900	1,000	1,100	1,200	1,350
1. Construction Cost (10^3US$)					
(1) Metal works for pipeline	1,073	1,291	1,570	1,846	2,235
(2) Civil works for pipeline	140	155	171	187	211
(3) Pump equipment	714	686	660	653	647
Total	1,927	2,132	2,401	2,686	3,093
2. Annual Cost (10^3US$)					
(1) Annuity of Construction Cost /1	106	117	132	147	169
(2) Replacement Cost of pump, motor & pipe /2	37	41	47	52	60
(3) Maintenance cost /3	39	43	48	54	62
Sub-total	182	201	227	253	291
(4) Electric energy cost /4	227	182	152	138	129
Total	409	383	379	391	420

Note: /1: Annuity of construction cost is calculated by producting the construction cost with the capital recovery factor, on the basis of discount rate of 5% and economic useful life of 50 years.

/2: Based on the sinking fund deposit method by use of discount rate of 5% and economic useful life of 25 years.

/3: Based on the annual rate of 2% to the capital cost.

/4: Electric energy cost is based on the unit rate of 0.44 US$/kWh.

Table VII-12 **GENERAL FEATURES OF MAKUYUNI IRRIGATION SCHEME**

1. Name of Scheme	Makuyuni Irrigation Scheme
2. Source of Irrigation Water	Himo river
3. Net Irrigation Area	500 ha
4. Maximum Diversion Water Requirement	0.44 m^3/sec
5. Irrigation Facilities	
(1) Makuyumi Intake structure	
Location	Just downstream of Moshi-Himo road crossing (existing Marangu/Siding intake)
Proposed crest EL.	826.0 m
Scouring sluice	1.0 m width x 1 no.
Intake gate	1.0 m width x 1 no.
(2) Main irrigation canal with related structures	
Canal type	Head reach; rectangular concrete flume Other; trapezoidal concrete lined canal
Length	5.17 km
Discharge	0.44 m^3/sec ~ 0.24 m^3/sec
(3) Secondary irrigation canal with related structures	
Canal type	Trapezoidal concrete lined canal
Length	5.42 km
Number	4
6. Drainage Facilities	
(1) Canal type	Trapezoidal earth canal
(2) Canal length	
Main drain	-
Secondary drain	4.64 km
7. Farm Road	
(1) Main farm road ($W=7^m$)	
Length	2.83 km
(2) Secondary farm road ($W=5^m$)	
Length	8.47 km
Number	4
8. On-farm Development Works	
(1) Tertiary irrigation canal	21.52 km
(2) Tertiary drainage canal	25.59 km
(3) Tertiary farm road	22.74 km
(4) Farm ditch, drain & road	for 500 ha
9. Land Levelling	500 ha
10. Farm pond	
No.1 on Main Canal	Storage Capacity: 7,300 m^3
No.2 on Secondary Canal-1	" : 2,300 m^3

Table VII-13 GENERAL FEATURES OF GHONA & KILEO IRRIGATION SCHEME

1. Name of Scheme	Ghona & Kileo Irrigation Scheme
2. Source of Irrigation Water	Himo river
3. Net Irrigation Area	500 ha
4. Maximum Diversion Water Requirement	0.48 m^3/sec
5. Irrigation Facilities	
(1) Ghona Intake structure	
Location	4 km downstream of Moshi-Himo road crossing (Existing Ghona intake)
Proposed crest EL.	740.0 m
Weir crest heightening	0.5 m
Scouring sluice	1.0 m width x 1 no.
Intake gate	1.0 m width x 1 no.
(2) Main irrigation canal with related structures	
Canal type	Head reach; rectangular concrete flume Other; trapezoidal concrete lined canal
Length	4.10 km
Discharge	0.48 m^3/sec
(3) Secondary irrigation canal with related structures	
Canal type	Trapezoidal concrete lined canal
Length	7.21 km
Number	3
6. Drainage Facilities	
(1) Canal type	Trapezoidal earth canal
(2) Canal length	
Main drain	-
Secondary drain	4.15 km
7. Farm Road	
(1) Main farm road ($W=7^m$)	
Length	4.10 km
(2) Secondary farm road ($W=5^m$)	
Length	4.61 km
Number	1
8. On-farm Development Works	
(1) Tertiary irrigation canal	18.41 km
(2) Tertiary drainage canal	17.14 km
(3) Tertiary farm road	13.15 km
(4) Farm ditch, drain & road	for 500 ha
9. Land Levelling	500 ha
10. Farm pond	1 Nos. Storage Capacity: 10,500 m^3

Table VII-14 GENERAL FEATURES OF NORTH GROUNDWATER SCHEME

(Typical Layout of One Tubewell Area)

1.	Net Irrigation Area	60 ha
2.	Maximum Diversion Water Requirement	54 ℓ/sec
3.	Irrigation Facilities	
	(1) Tubewell pump station	
	Pump	
	Type	Submersible type
	Pump capacity	60 ℓ/sec
	Rated head	35 m
	Pump diameter	200 mm
	Motor	
	Output of motor	37 kW
	Pumphouse (W x L x H)	4 m x 3 m x 2.5 m
	(2) Irrigation canal	
	Lead canal	50 m
	Secondary canal	1,100 m
	Tertiary canal	2,750 m
	Regulation pond	1 No. Storage Capacity, 1,300 m^3
	(3) Tubewell	
	Diameter	ø300 mm
	Depth	100 m
4.	Drainage Canal	4,500 m
5.	Farm Road	4,800 m
6.	Land Grading	60 ha
7.	Power Distribution Line	
	Transformer	11kV/400-230V
	Length of power line	18km/14 Nos. of wells
8.	Floodway	
	Mandaka Floodway	11.55 km, Q = 132 m^3/sec at maximum
	Nanga Floodway	4.55 km, Q = 46 m^3/sec at maximum

Table VII-15 GENERAL FEATURES OF EAST GROUNDWATER SCHEME

(Typical Layout of One Tubewell Area)

1.	Net Irrigation Area	30 ha
2.	Maximum Diversion Water Requirement	29 ℓ/sec
3.	Irrigation Facilities	
	(1) Tubewell pump station	
	Pump	
	Type	Submersible type
	Pump capacity	30 ℓ/sec
	Rated head	25 m
	Pump diameter	125 mm
	Motor	
	Output of motor	15 kW
	Pumphouse (W x L x H)	4 m x 3 m x 2.5 m
	(2) Irrigation canal	
	Lead canal	50 m
	Secondary canal	420 m
	Tertiary canal	1,350 m
	Regulation pond	1 No. storage capacity, 650 m^3
	(3) Tubewell	
	Diameter	ø300 mm
	Depth	100 m
4.	Drainage Canal	2,250 m
5.	Farm Road	2,300 m
6.	Land Grading	30 ha
7.	Power Distribution Line	
	Transformer	11kV/400-230V
	Length of power line	12km/6 Nos. of well

Table VII-16 HYDRAULIC PROPERTIES OF MAIN IRRIGATION CANALS

CANAL TYPE	DISTANCE (m)	DISCHARGE (m^3/sec)	HYDRAULIC GRADIENT	WATER DEPTH (m)	VELOCITY (m/sec)
Upper Mabogini Scheme					
C2	60	0.201	1/1,000	0.35	0.65
C2	140	0.126	1/1,000	0.29	0.61
Mabogini Scheme					
A2	530	1.080	1/1,000	0.65	1.04
A2	50	0.950	1/1,000	0.62	1.02
A2	400	0.919	1/1,000	0.61	1.01
A2	700	0.777	1/700	0.52	1.10
A2	300	0.683	1/700	0.48	1.06
B2	480	0.627	1/500	0.47	1.18
B2	1,070	0.594	1/500	0.46	1.17
Rau Ya Kati Scheme					
B2	400	0.581	1/500	0.46	1.16
B2	400	0.555	1/500	0.45	1.15
B2	450	0.529	1/500	0.44	1.14
C1	450	0.503	1/500	0.46	1.12
C1	450	0.477	1/500	0.45	1.11
C1	450	0.328	1/500	0.38	1.00
C2	450	0.302	1/300	0.32	1.19
C2	470	0.276	1/300	0.31	1.17
Chekereni Scheme					
A1	750	1.114	1/3,000	0.85	0.70
A2	1,630	0.603	1/1,200	0.52	0.84
A2	970	0.603	1/3,000	0.64	0.60
Miwaleni Scheme					
(West Main Canal)					
A1	300	1.060	1/3,000	0.83	0.69
A1	1,640	1.045	1/3,000	0.83	0.69
A1	1,010	0.988	1/3,000	0.81	0.68
A2	1,020	0.655	1/3,000	0.67	0.61
A2	1,520	0.578	1/3,000	0.63	0.69
B2	1,000	0.477	1/500	0.42	1.11
(East Main Canal)					
A1	50	1.070	1/3,000	0.84	0.69
A2	2,350	0.769	1/3,000	0.72	0.64
A2	1,100	0.746	1/3,000	0.71	0.63
A2	500	0.723	1/3,000	0.70	0.63
A2	200	0.573	1/3,000	0.63	0.59
B1	1,170	0.406	1/3,000	0.59	0.55

(continued)

CANAL TYPE	DISTANCE (m)	DISCHARGE (m^3/sec)	HYDRAULIC GRADIENT	WATER DEPTH (m)	VELOCITY (m/sec)
Makuyuni Scheme					
Flume Type/1	1,700	0.440	1/500	0.58	1.08
C_1	1,130	0.440	1/400	0.41	1.18
C_1	500	0.334	1/400	0.36	1.10
C_1	500	0.386	1/400	0.39	1.15
C_2	1,340	0.239	1/300	0.29	1.13
Ghona & Kileo Scheme					
Flume Type/2	2,400	0.480	1/500	0.48	1.30
-	600	0.480	1/500	0.45	1.11
-	1,000	0.480	1/500	0.45	1.11
-	100	0.602	1/500	0.47	1.18

/1 Base Width = 0.70 m   Flume Height = 0.80 m

/2 Base Width = 0.90 m   Flume Height = 0.80 m

Table VII-17(1) LIST OF RELATED STRUCTURES

Unit: Nos.

	Rau River System			
	Upper Mabogini Scheme	Mabogini Scheme	Ran Ya Kati Scheme	Chekereni Scheme
1. Irrigation Canal				
(1) Main Canal				
- Turnout	3	9	13	5
- Check gate	1	5	7	2
- Culvert	-	1	1	2
- Syphon	-	1	-	1
- Drop	-	1	1	-
- Cross drain	-	-	-	-
- Spillway	-	2	2	2
Total	4	19	24	12
(2) Secondary Canal				
- Turnout	4	25	11	28
- Check gate	1	8	6	11
- Culvert	1	10	3	7
- Syphon (aqueduct)	-	-	-	-
- Drop	1	10	6	-
- Cross drain	-	2	-	1
- Spillway	1	7	3	4
Total	8	62	29	51
(3) Tertiary Canal				
- Division box	27	173	90	160
- Culvert	5	15	5	10
- Drop	10	20	20	20
- Cross drain	-	-	1	-
Total	42	208	116	190
2. Drainage Canal				
(1) Main drain				
- Culvert	-	5	-	5
- Drop	-	10	-	10
Total	0	15	0	15
(2) Secondary drain				
- Culvert	3	16	5	4
- Drop	2	20	20	20
Total	5	36	25	24
(3) Tertiary drain				
- Culvert	2	5	15	15
- Drop	6	10	5	10
Total	8	15	20	25

- continued -

Table VII-17(2) LIST OF RELATED STRUCTURES

Unit: Nos.

	Miwaleni Pump Lift Scheme	Himo River System: Makuyuni Scheme	Himo River System: Ghona & Kileo Scheme
1. Irrigation Canal			
(1) Main Canal			
- Turnout	14	7	4
- Check gate	9	3	2
- Culvert	1	6	2
- Syphon	3	1	1
- Drop	-	20	-
- Cross drain	4	-	2
- Spillway	4	2	2
Total	35	39	13
(2) Secondary Canal			
- Turnout	65	9	16
- Checkgate	48	9	12
- Culvert	21	10	16
- Syphon (aqueduct)	-	-	1
- Drop	13	20	6
- Cross drain	1	2	2
- Spillway	11	4	4
Total	159	54	47
(3) Tertiary Canal			
- Division box	459	176	106
- Culvert	54	54	4
- Drop	36	-	-
- Cross drain	1	-	-
Total	550	230	110
2. Drainage Canal			
(1) Main drain			
- Culvert	-	-	-
- Drop	5	-	-
Total	5	0	0
(2) Secondary drain			
- Culvert	25	3	2
- Drop	35	10	14
Total	60	13	16
(3) Tertiary drain			
- Culvert	27	42	6
- Drop	200	120	43
Total	227	162	49

Table VII-18 FLOW CAPACITY OF RIVERS

River	SECTION[1/] NO.	DISTANCE[2/] (km)	SLOPE[3/]	N[4/]	FLOW AREA m^2	Flow Capacity (m^3/sec)
Rau	1	0		0.11	19	
	2	2.8	1/900	0.11	15	5
	3	6.8	1/570	0.11	18	5
	4	12.3	1/1040	0.11	17	4
	5	15.7	1/340	0.11	5	1
	6	21.9	1/790	0.11	4	1
	7	24.8	1/620	0.08	10	2
	8	30.3	1/900	0.06	33	6
	9	34.3	1/710	0.06	21	20
	10	35.7	1/400	0.06	22	22
	11	38.8	1/340	0.06	8	6
	12	42.7	1/430	0.06	34	7
	13	45.5	1/120	0.04	19	41
	14	48.3	1/140	0.04	23	46
	15	49.2	1/50	0.04	24	104
	16	50.4	1/120	0.04	47	161
Mue	1	0		0.045	30	
	2	8.0	1/860	0.045	35	16
	3	11.7	1/770	0.045	23	26
	4	15.2	1/590	0.03	33	35
	5	20.8	1/280	0.03	18	65
	6	22.7	1/60	0.03	40	140
Himo	1	2.8		0.06	7	
	2	4.3	1/460	0.06	12	4
	3	9.6	1/390	0.045	43	105
	4	13.7	1/450	0.03	90	210
	5	19.5	1/290	0.03	780	865
	6	23.6	1/50	0.03	280	980

1/: Surveyed section (refer to Figure VII-17 to VII-20).

2/: Distance of watercourse from the junction with the Ruve river.

3/: Calculated slope between two sections.

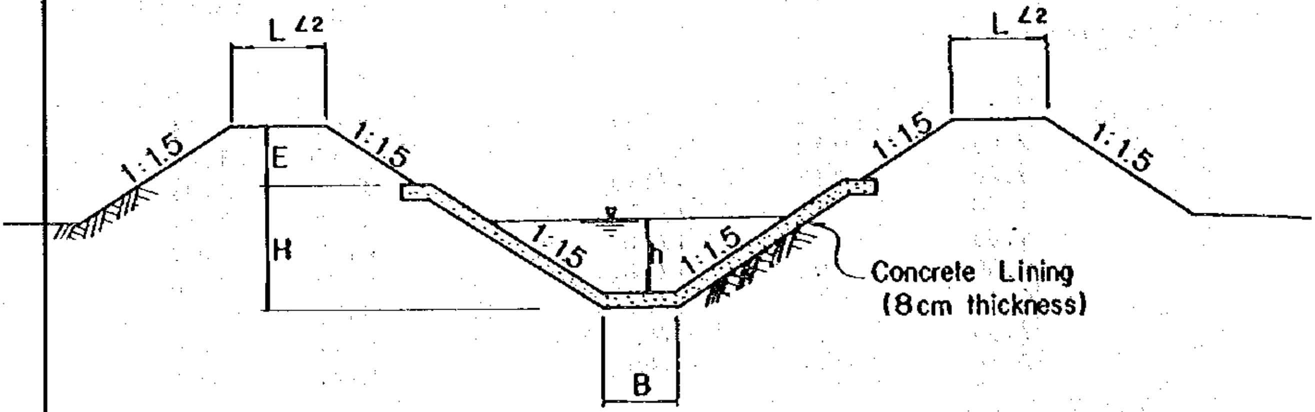
4/: Coefficient of roughness.

Table VII- 19 HYDRAULIC PROPERTIES OF FLOODWAY

NAME OF FLOODWAY	DISTANCE FROM BP. (km)	DESIGN DISCHARGE (m^3/sec)	GRADIENT	BOTTOM WIDTH (m)	WATER DEPTH (m)	FLOW VELOCITY (m/sec)
Mandaka Floodway						
	0	132				
	1.25	132	1/400	35	1.61	2.14
	2.95	132	1/120	35	1.13	3.14
	3.28	132	1/150	35	1.21	2.93
	4.40	110	1/150	35	1.08	2.74
	5.85	110	1/110	35	0.99	3.02
	6.00	93	1/110	30	0.98	2.98
	6.60	71	1/130	25	0.97	2.71
	7.30	71	1/60	25	0.77	3.46
	7.78	71	1/90	25	0.87	3.05
No.1 Tributary						
	0	22				
	2.00	22	1/120	15	0.64	2.12
	2.22	22	1/60	15	0.52	2.64
No.2 Tributary						
	0	17				
	0.80	17	1/75	13	0.52	2.34
No.3 Tributary						
	0	22				
	0.45	22	1/90	15	0.59	2.32
	0.75	22	1/60	15	0.52	2.64
Nanga Floodway						
	0	46				
	1.00	46	1/600	20	1.34	1.51
	4.55	46	1/130	20	0.86	2.48
Miwaleni Floodway						
	0	40				
	2.70	40	1/400	20	1.10	1.64
	5.60	40	1/230	20	0.93	1.96
	6.30	40	1/60	20	0.62	3.02
Mue Floodway						
	0	160				
	3.0	160	1/190	40	1.60	2.30
Uchira Floodway						
	0	56				
	2.75	56	1/150	25	1.00	2.00

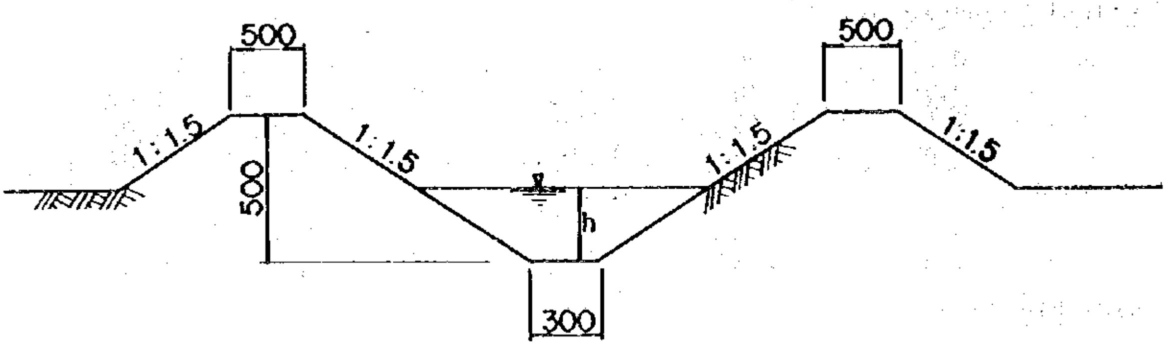
Fig. VII-1 TYPICAL CROSS SECTION OF IRRIGATION CANAL

(A) Lined Canal for Main & Secondary Canal



Type	B (m)	hmax ∠1 (m)	H (m)	E (m)
A1	0.60	0.90	1.10	0.30
A2	〃	0.80	1.00	〃
B1	0.40	0.65	0.85	0.20
B2	〃	0.55	0.75	〃
C1	0.30	0.48	0.70	0.20
C2	〃	0.35	0.55	〃

(B) Earth Canal for Tertiary Canal



∠1: Maximum water depth
∠2: Main canal = 1.0m, Secondary canal = 0.50m

Fig.VII-2 TYPICAL CROSS SECTION OF DRAINAGE CANALS

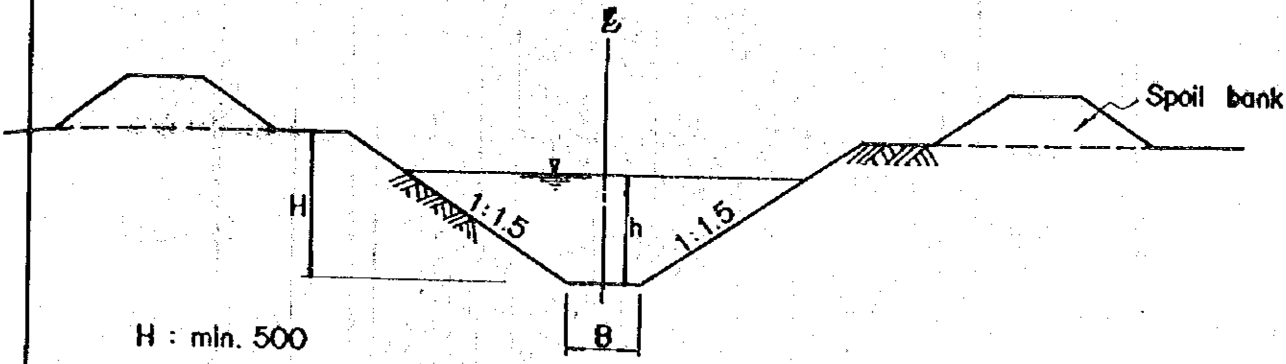
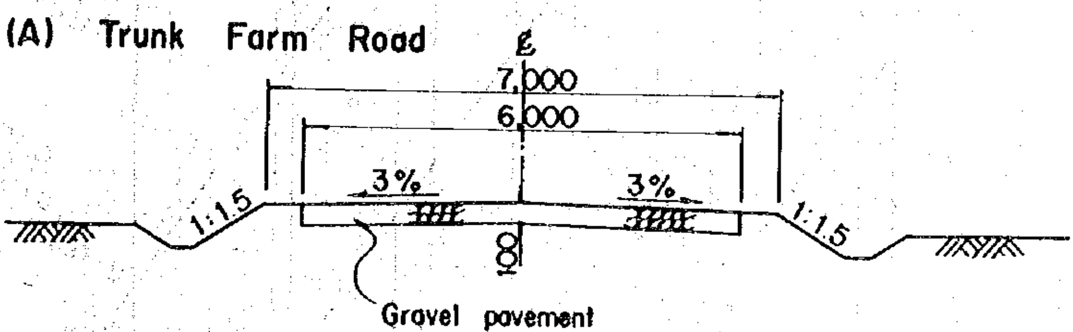
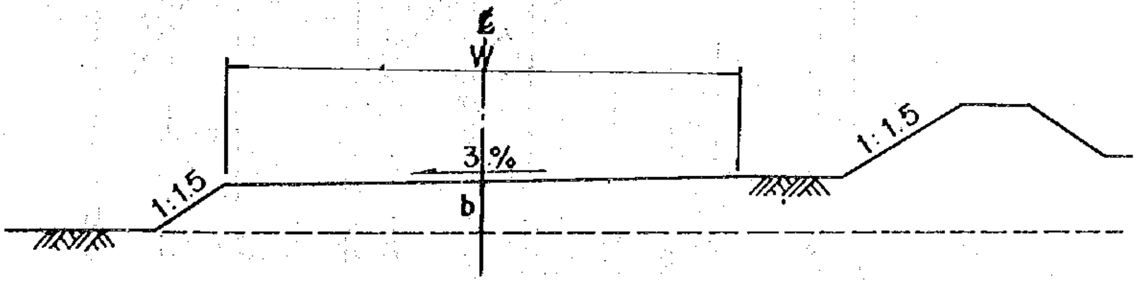


Fig.VII-3 TYPICAL CROSS SECTION OF FARM ROAD

(A) Trunk Farm Road



(B) Main, Secondary & Tertiary Farm Road



	W (m)	b (m)
Main	7.0	0.5
Secondary	5.0	0.4
Tertiary	4.0	0.3

Fig.VII-4 Determination of Canal Type, Irrigation Canal.

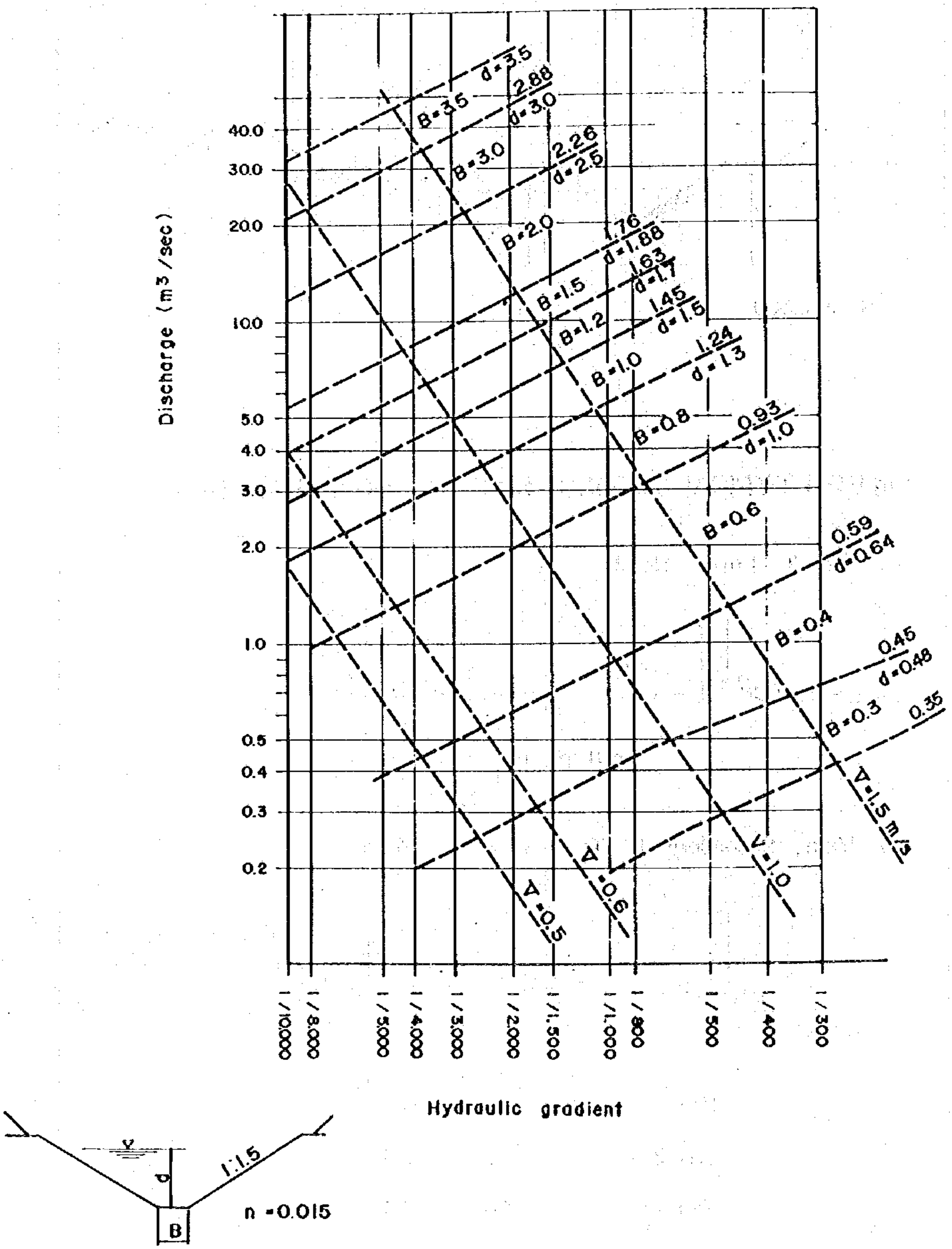


Fig.VII-5 Determination of Canal Type, Drainage Canal

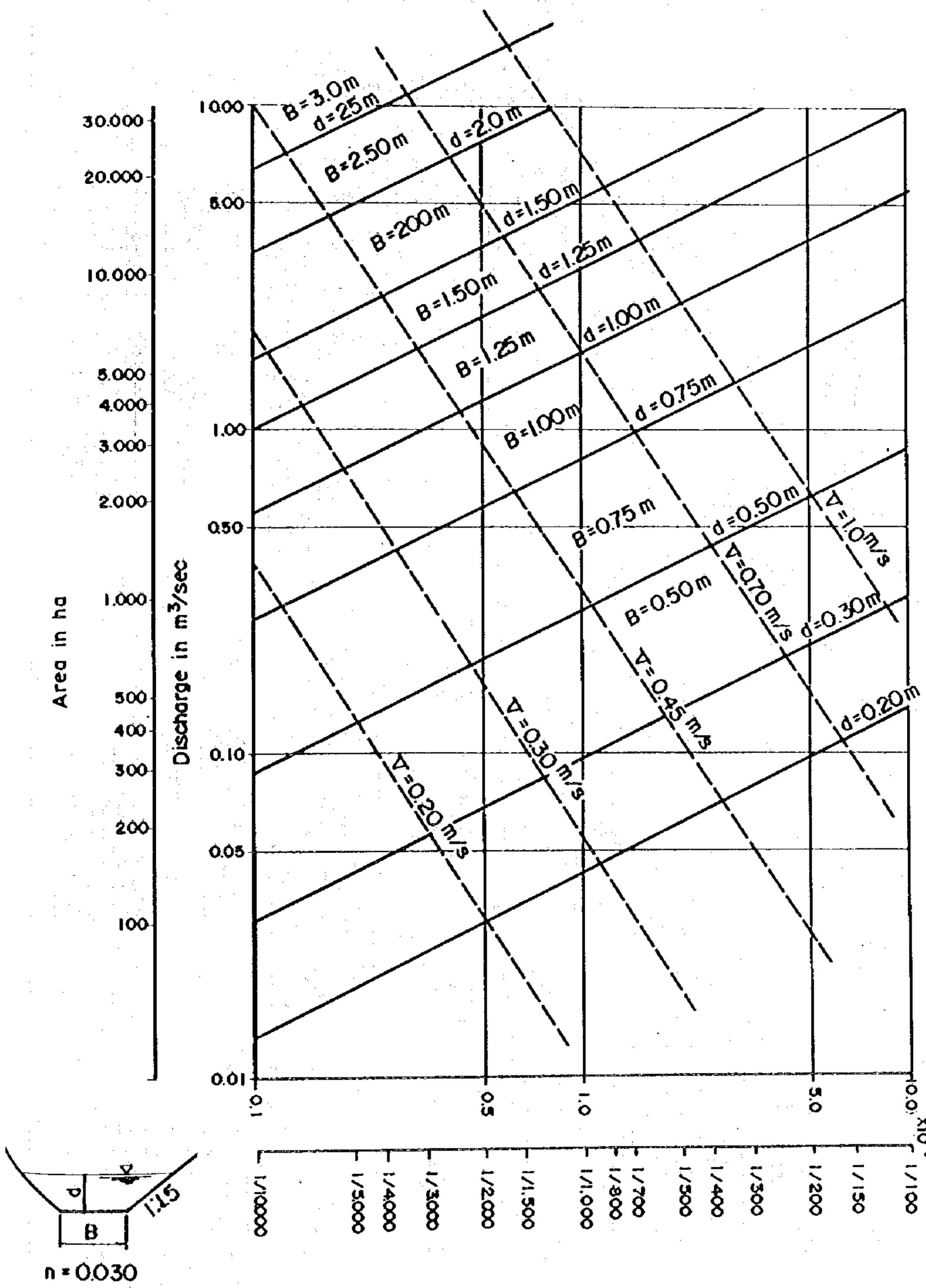


Fig VII-6 IRRIGATION DIAGRAM FOR RAU RIVER SYSTEM (1/2)

Proposed Land Use (ha)

	Upper Mabogini	Mabogini
Paddy Field	150	750
Perenial Crops Field	—	30
Others	—	70
Total	150	850

Canal Length (Km)

	Upper Mabogini	Mabogini
Main Canal	0.60	3.53
Secondary Canal	0.45	7.98
SC - 1	—	1.18
SC - 2	0.45	1.35
SC - 3	—	0.98
SC - 4	—	0.47
SC - 5	—	1.55
SC - 6	—	0.90
SC - 7	—	1.55
Tertiary Canal	7.01	28.71
TC - 0 n	1.58	3.66
TC - 1 n	2.66	1.30
TC - 2 n	2.77	5.32
TC - 3 n	—	3.31
TC - 4 n	—	2.45
TC - 5 n	—	3.22
TC - 6 n	—	6.00
TC - 7 n	—	3.45

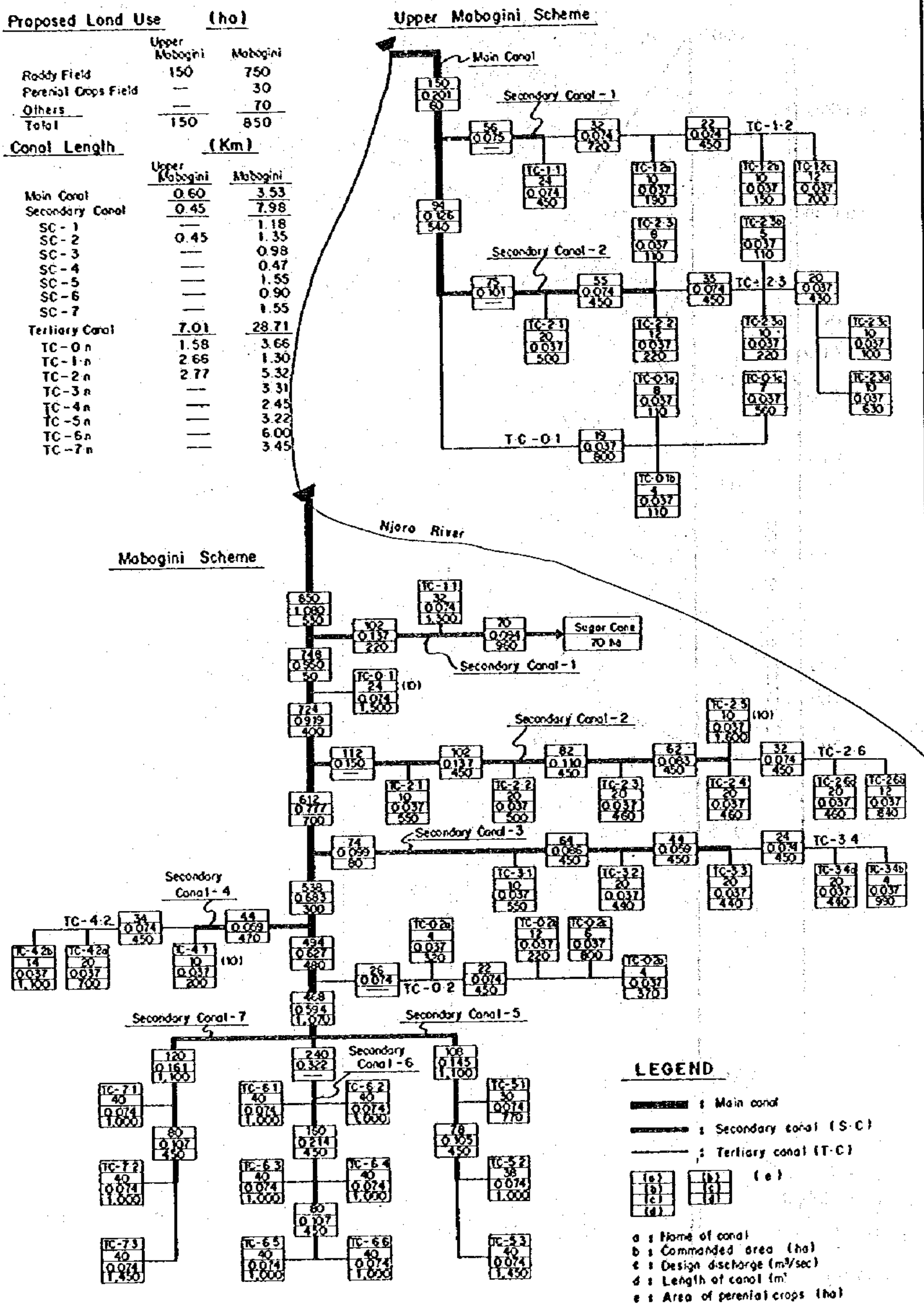
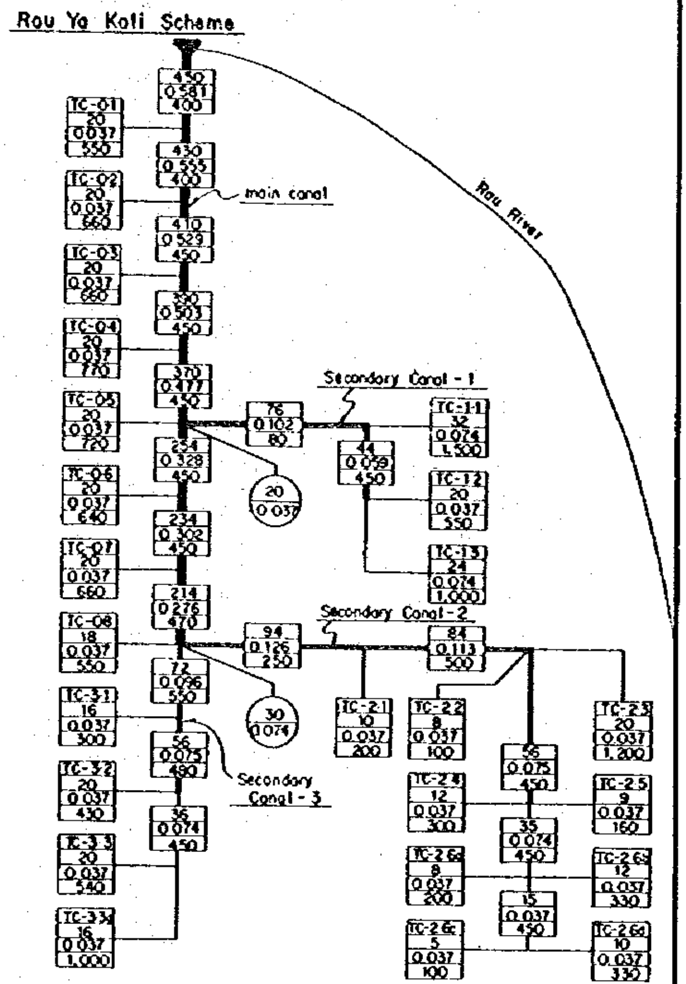


Fig.VII-7 IRRIGATON DIAGRAM FOR RAU RIVER SYSTEM (2/2)



Proposed Land Use (ha)

	Rau Ya Kati	Chekereni
Paddy Field	400	700
Perenial Crops Area	50	70
Others	—	80
Total	450	850

Canal Length (Km)

	Rau Ya Kati	Chekereni
Main Canal	3.52	3.55
Secondary Canal	3.21	7.45
SC - 1	0.53	3.81
SC - 2	1.20	0.94
SC - 3	1.48	2.70
Tertiary Canal	14.35	22.98
TC - 0 - n	5.21	—
TC - 1 - n	3.05	12.20
TC - 2 - n	3.82	4.45
TC - 3 - n	1.27	6.33

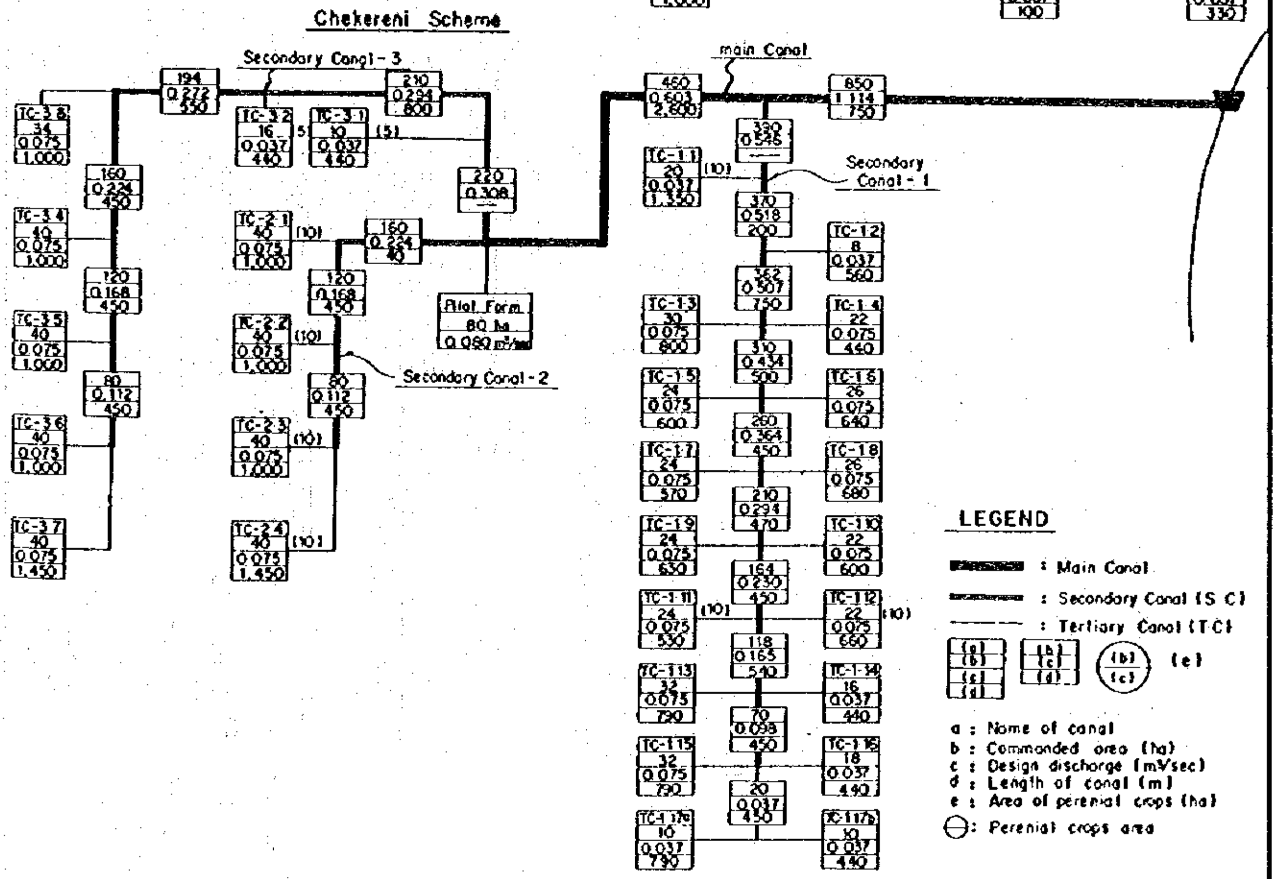
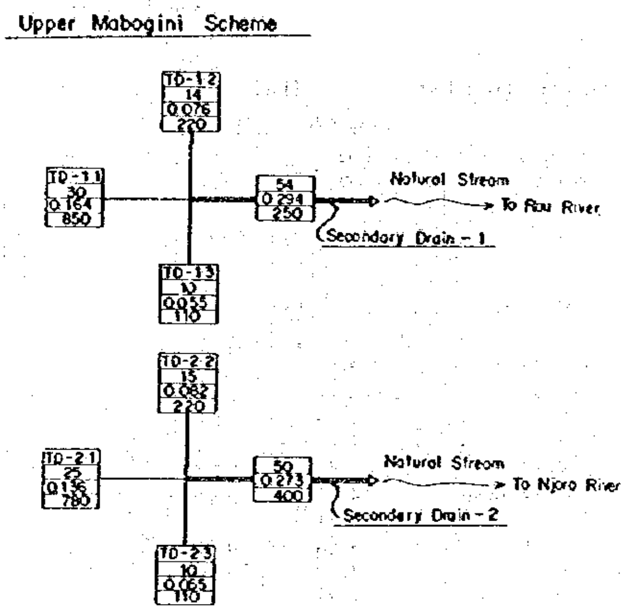


Fig.VII-8 DRAINAGE DIAGRAM FOR RAU RIVER SYSTEM (1/2)

Canal Length (km)

	Upper mabogini	Mabogini
o Main Drain	—	5.10
M.D-1	—	3.20
M.D-2	—	1.90
o Secondary Drain	0.65	11.89
S.D-1	0.25	4.74
S.D-2	0.40	3.10
S.D-3	—	3.60
S.D-4	—	0.45
o Tertiary Drain	2.29	24.27
T.D-1n	1.18	9.34
T.D-2n	1.11	6.38
T.D-3n	—	4.60
T.D-4n	—	2.45
T.D-0n	—	1.50
o Catch Drain	—	2.90



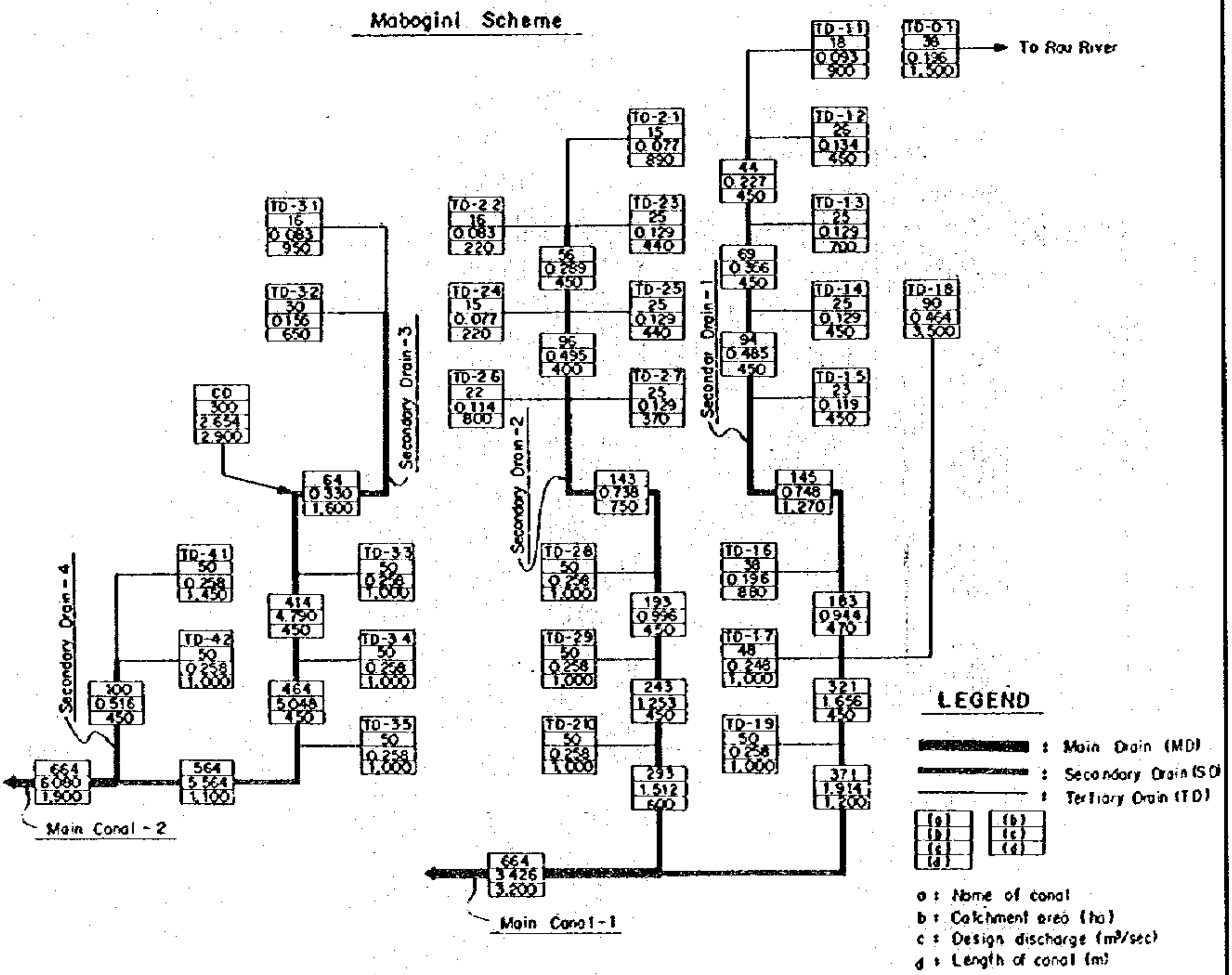


Fig.VII-9 DRAINAGE DIAGRAM FOR RAU RIVER SYSTEM (2/2)

Canal Length (km)

	Rau Ya Kati	Chekereni
Main Drain	0.25	5.08
MD-1	—	1.08
MD-2	—	4.00
Secondary Drain	8.67	12.15
SD-1	2.15	2.95
SD-2	1.57	4.65
SD-3	4.95	3.20
SD-4	—	1.35
Tertiary Drain	13.69	21.00
TD-1·n	3.72	4.10
TD-2·n	1.00	6.40
TD-3·n	8.97	6.05
TD-4·n	—	4.45
Catch Drain	—	1.70

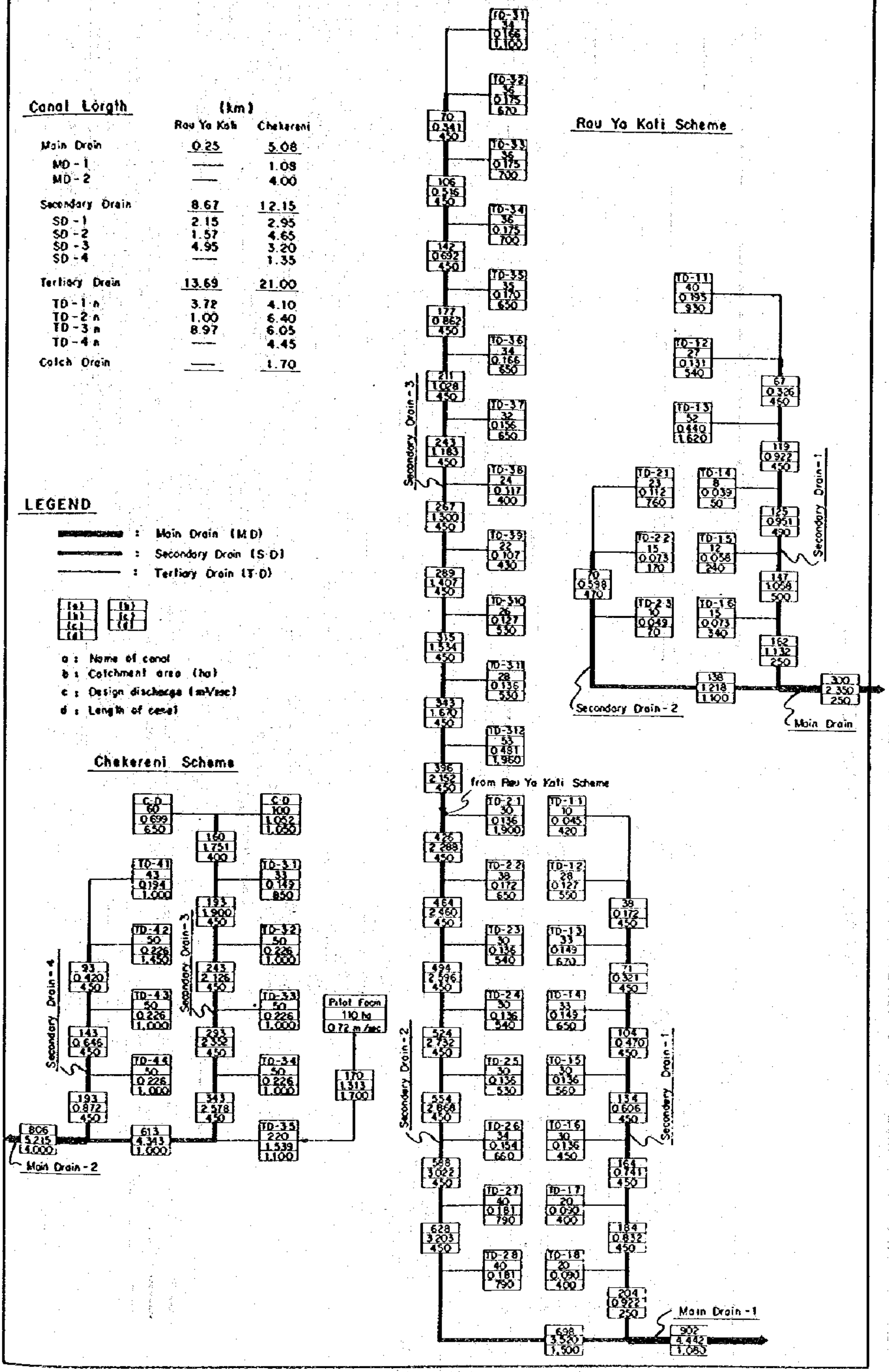
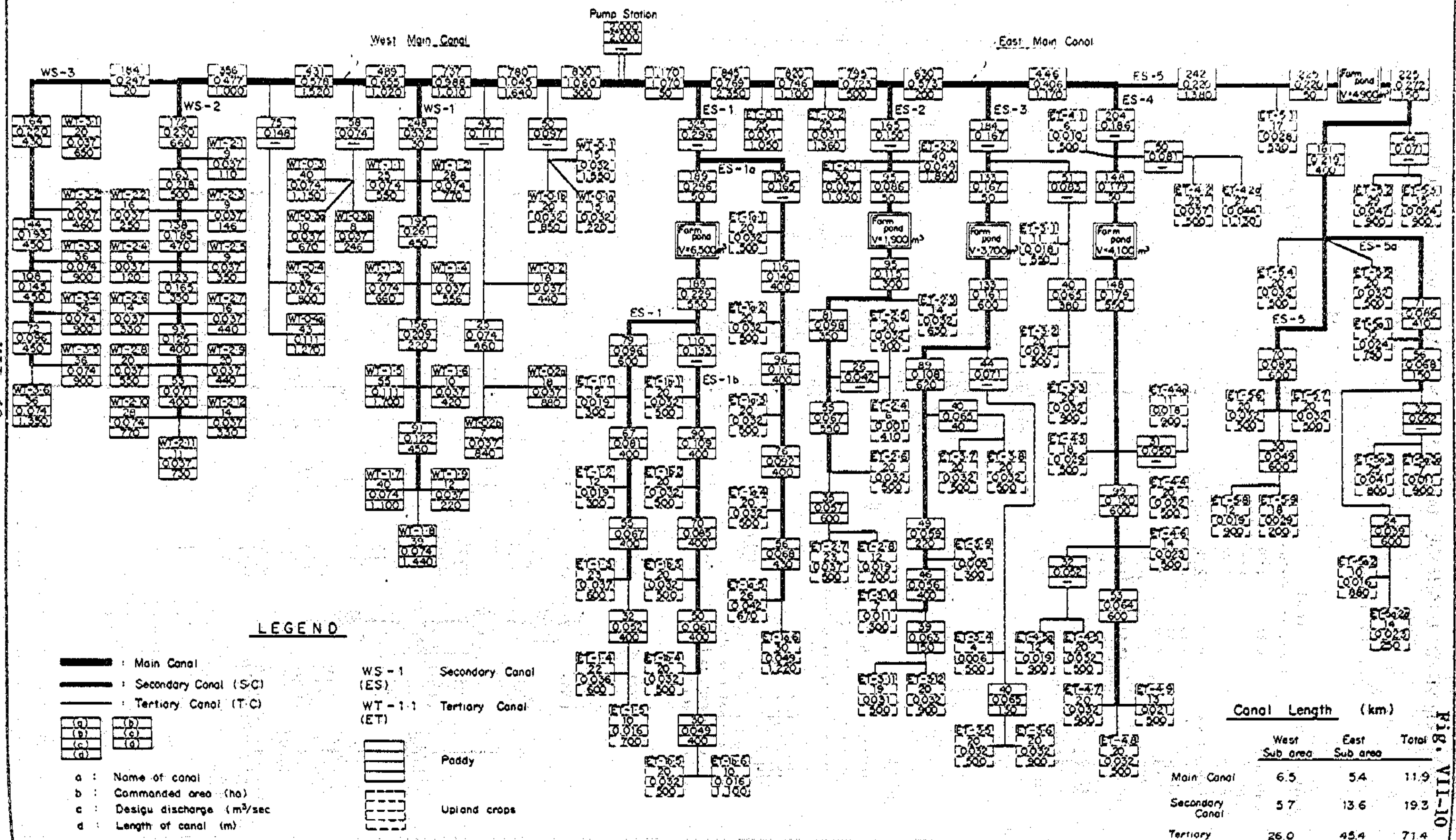


Fig VII-10 IRRIGATION DIAGRAM FOR MIWALENI PUNP LIFT SCHEME



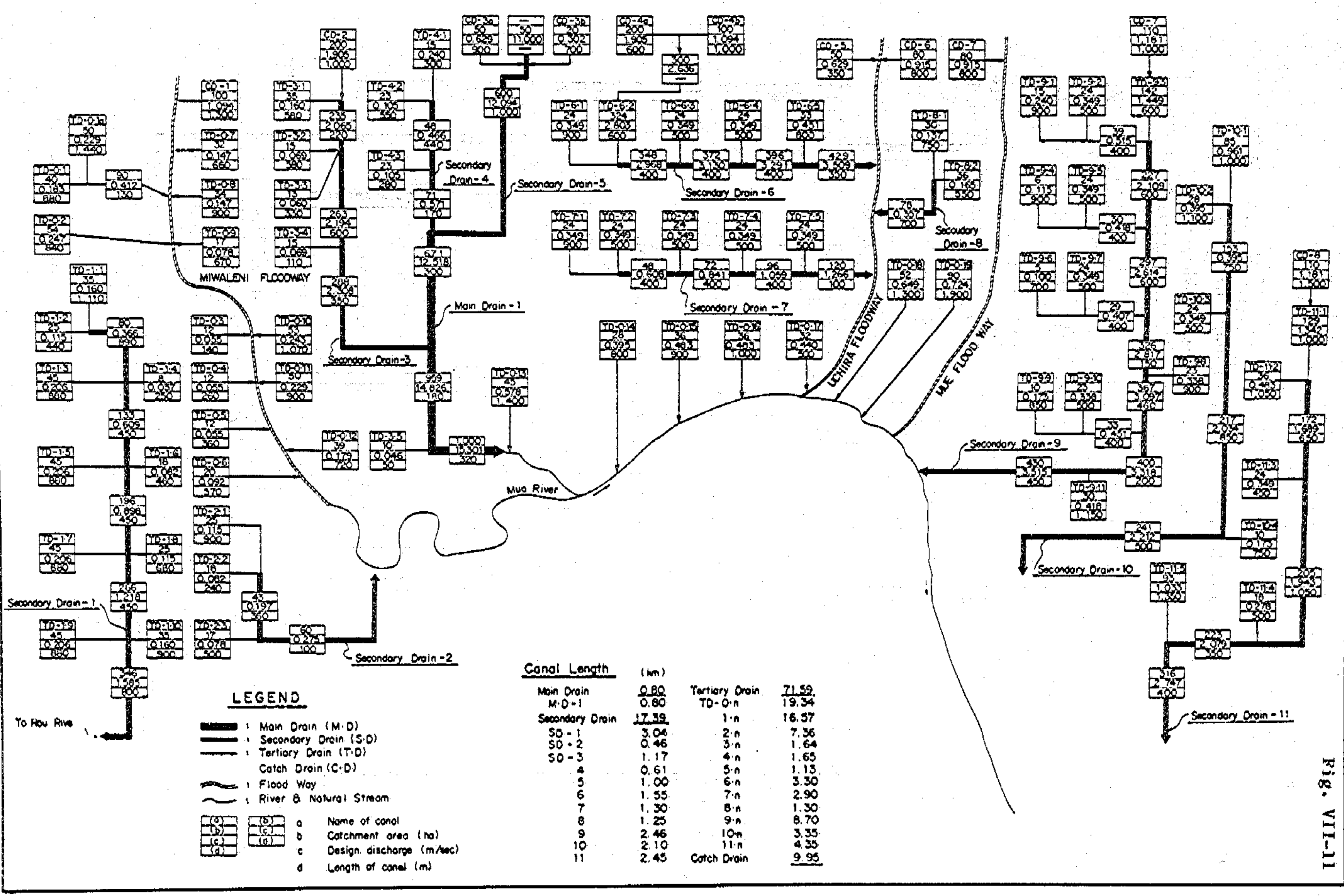
Canal Length (km)

	West Sub area	East Sub area	Total
Main Canal	6.5	5.4	11.9
Secondary Canal	5.7	13.6	19.3
Tertiary Canal	26.0	45.4	71.4

Fig. VII-10

Fig. VII-11

Fig VII-11 DRAINAGE DIAGRAM FOR MIWALENI SCHEME

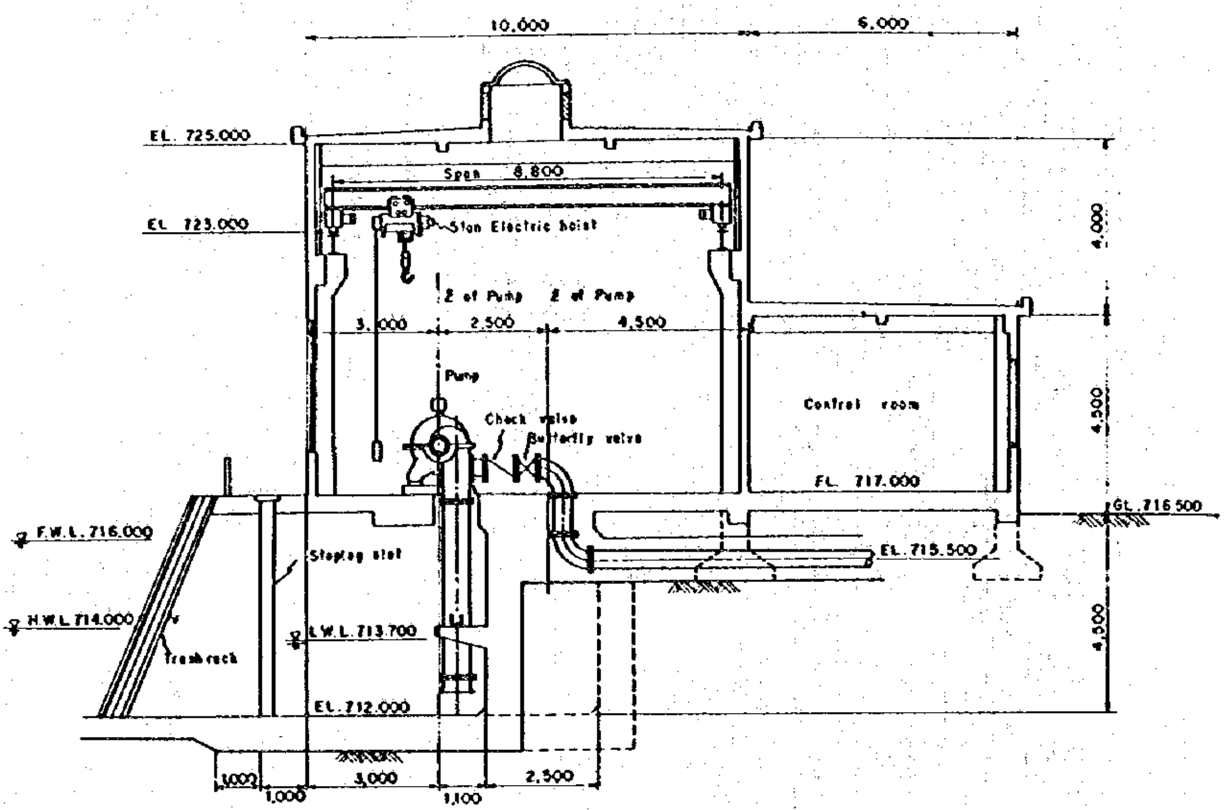


Canal Length

	(km)		
Main Drain	0.80	Tertiary Drain	71.59
M·D·1	0.80	TD-0·n	19.34
Secondary Drain	17.39	1·n	16.57
SD·1	3.04	2·n	7.36
SD·2	0.46	3·n	1.64
SD·3	1.17	4·n	1.65
4	0.61	5·n	1.13
5	1.00	6·n	3.30
6	1.55	7·n	2.90
7	1.30	8·n	1.30
8	1.25	9·n	8.70
9	2.46	10·n	3.35
10	2.10	11·n	4.35
11	2.45	Catch Drain	9.95

Fig.VII-12 ALTERNATIVE PUMP TYPE

(Horizontal Shaft Double Suction Volute Pump)



(Vertical Shaft Mixed-flow Pump)

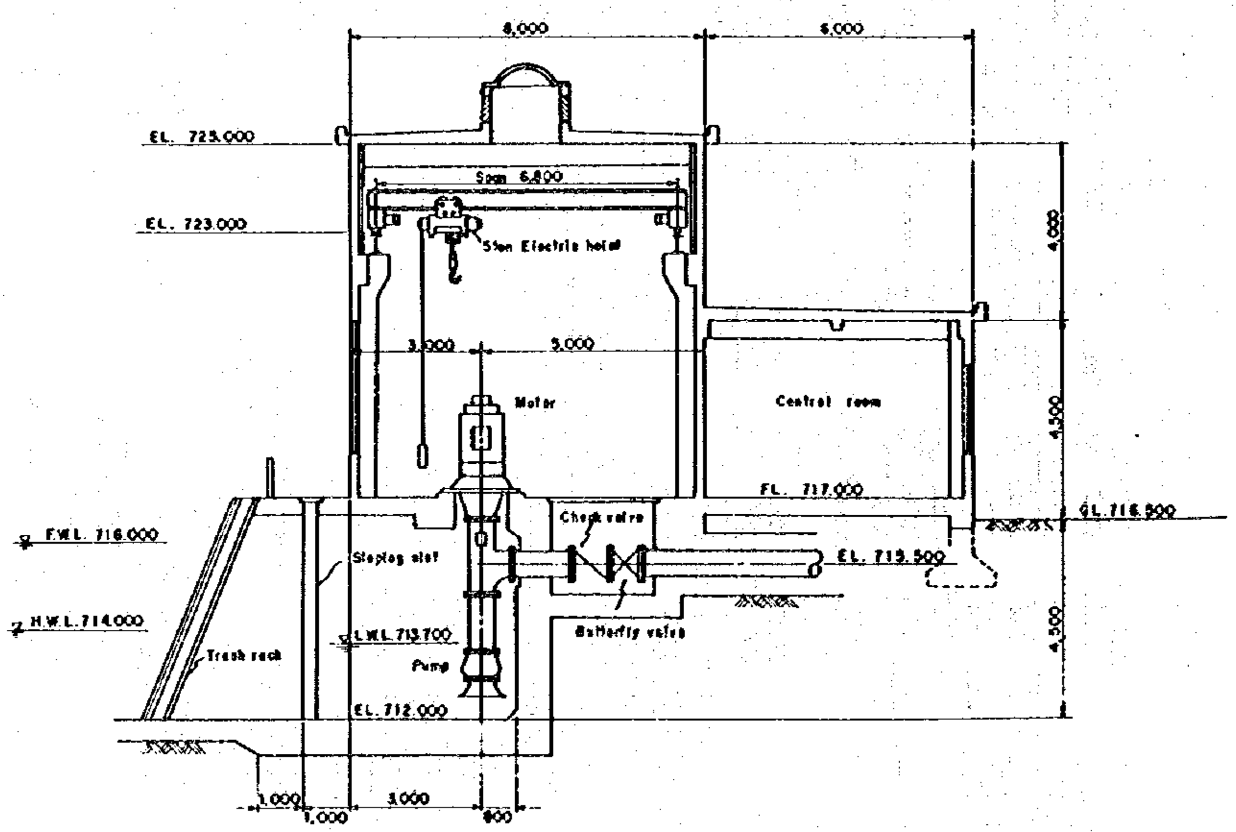


Fig. VII -13 PRESSURE DIAGRAM OF WATER HAMMER

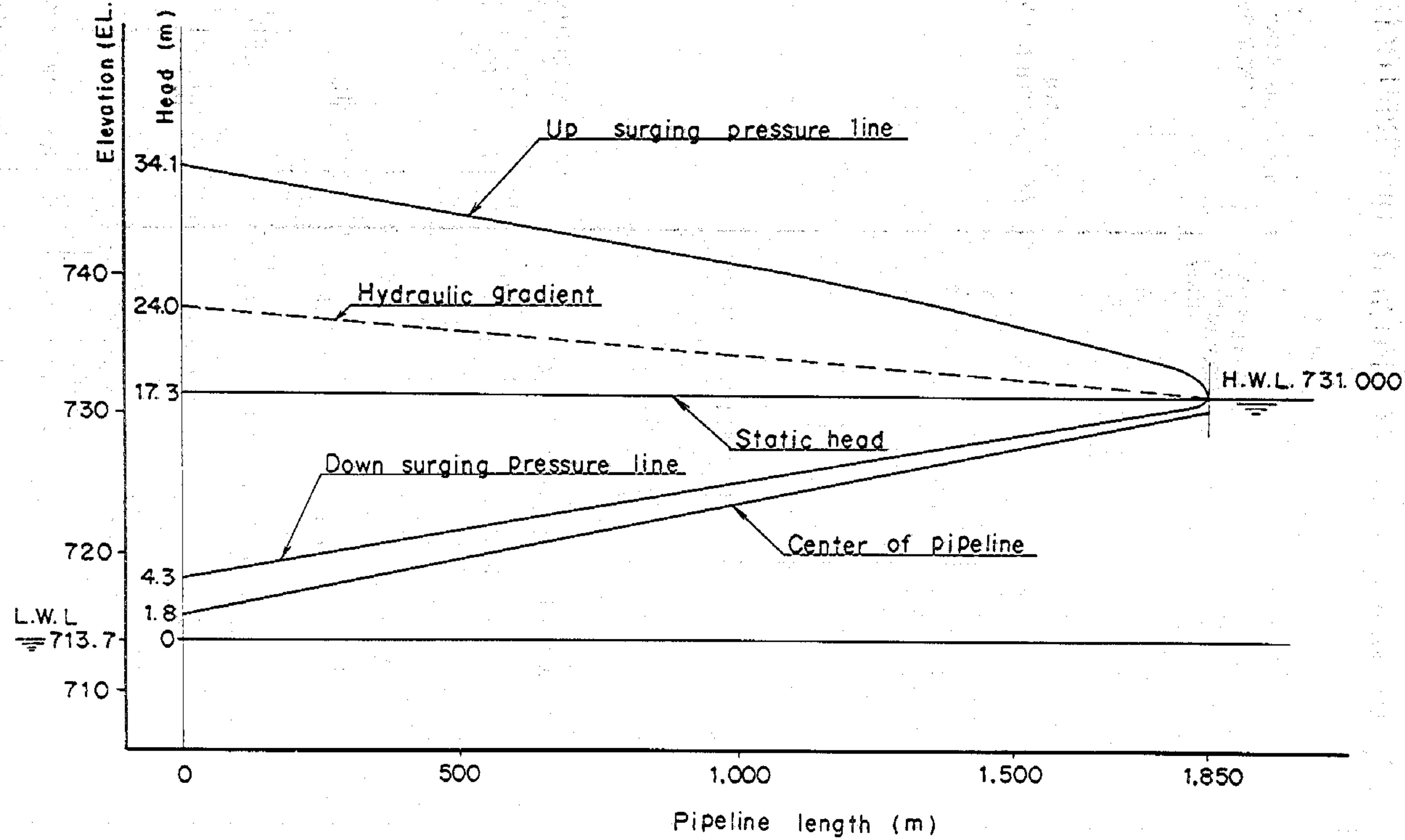


Fig. VII-14 LAYOUT OF POWER DISTRIBUTION LINE

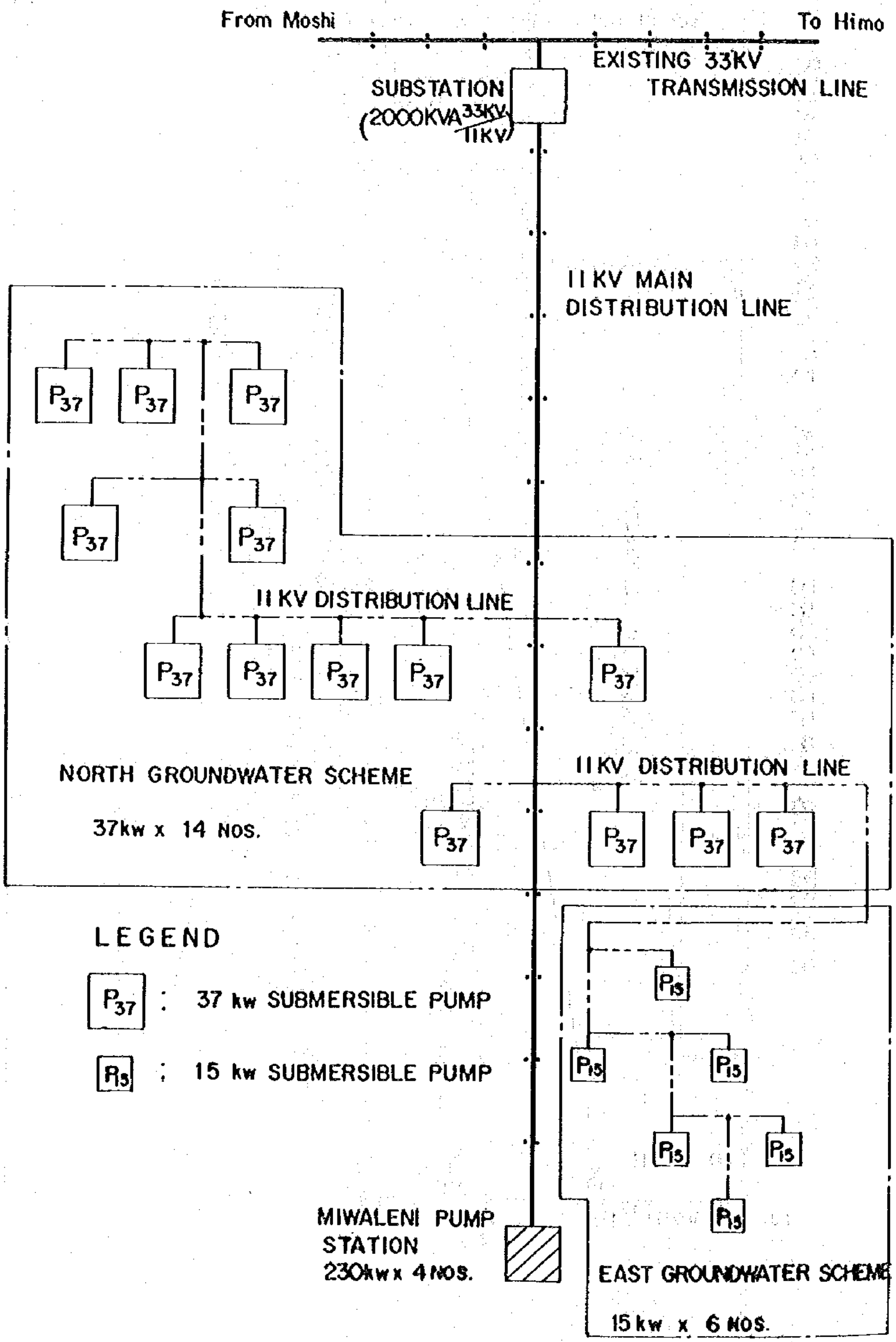
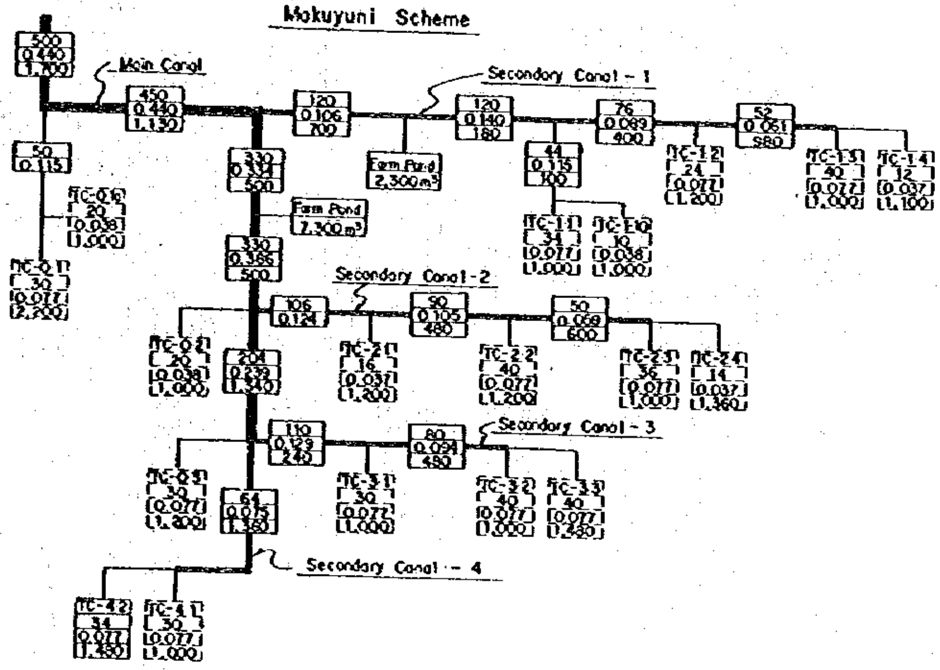
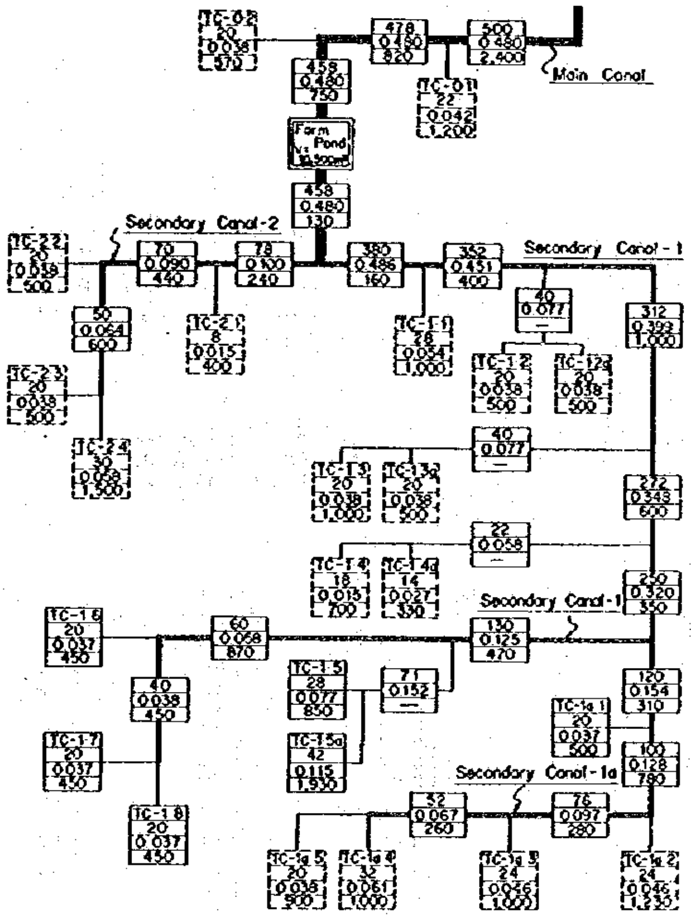


Fig VII-15 IRRIGATION DIAGRAM FOR HIMO RIVER SYSTEM

Mokuyuni Scheme



Ghona & Kileo Scheme



Canal Length (km)

	Mokuyuni	Ghona & Kileo
Main Canal	5.17	4.10
Secondary Canal	5.42	7.21
SC - 1	2.26	4.30
SC - 1a	—	1.63
SC - 2	1.08	1.28
SC - 3	0.72	—
SC - 4	1.36	—
Tertiary Canal	21.52	17.96
TC - 0·n	5.40	1.77
TC - 1.n	5.40	8.66
TC - 1a·n	—	4.63
TC - 2·n	4.76	2.90
TC - 3·n	3.48	—
TC - 4·n	2.48	—

LEGEND

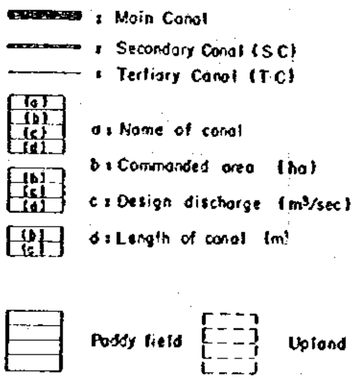
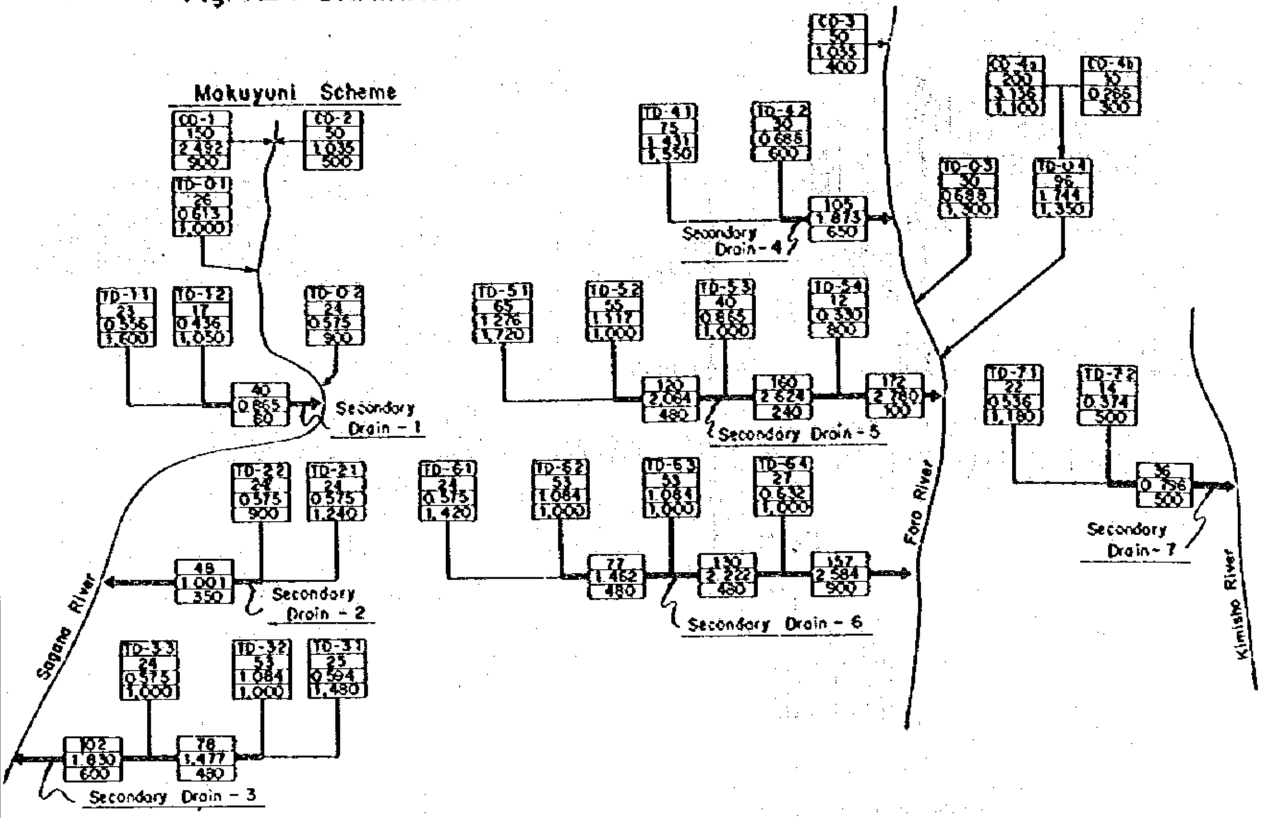
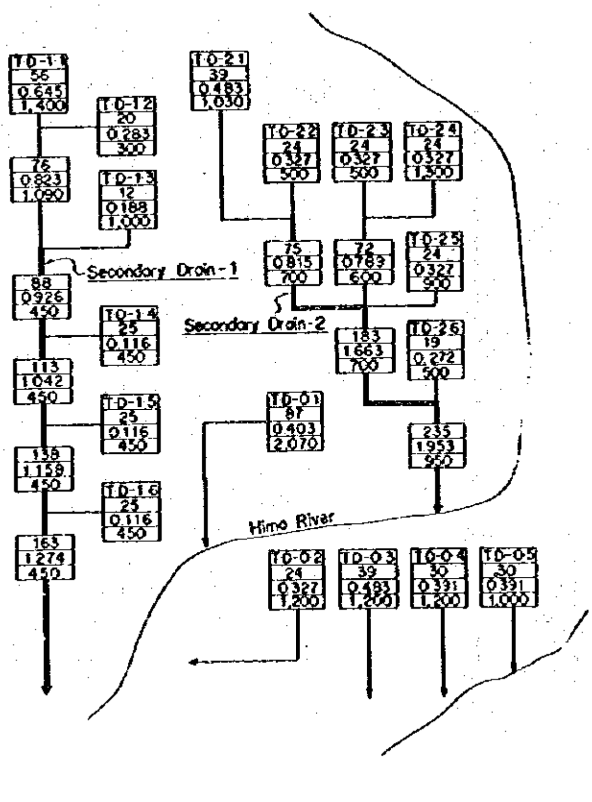


Fig. VII-16 DRAINAGE DIAGRAM FOR HIMO SCHEME





LEGEND

- Main Drain (M·D)
- Secondary Drain (S·D)
- Tertiary Drain (T·D)

a : Name of canal
b : Catchment area (ha)
c : Design discharge (m³/sec)
d : Length of canal (m)

Canal Length	(km) Mokuyuni	Ghona & Kileo
Secondary Drain	4.64	4.15
SD - 1	0.08	1.80
SD - 2	1.35	2.35
SD - 3	1.08	—
SD - 4	0.65	—
SD - 5	0.82	—
SD - 6	1.16	—
SD - 7	0.50	—
Tertiary Drain	25.59	17.14
TD - 0·n	4.55	6.67
TD - 1·n	2.65	5.14
TD - 2·n	2.14	5.33
TD - 3·n	3.48	—
TD - 4·n	2.15	—
TD - 5·n	4.52	—
TD - 6·n	4.42	—
TD - 7·n	1.68	—
Catch Drain	3.20	

Fig. VII - 17 CROSS SECTION OF THE RAU RIVER

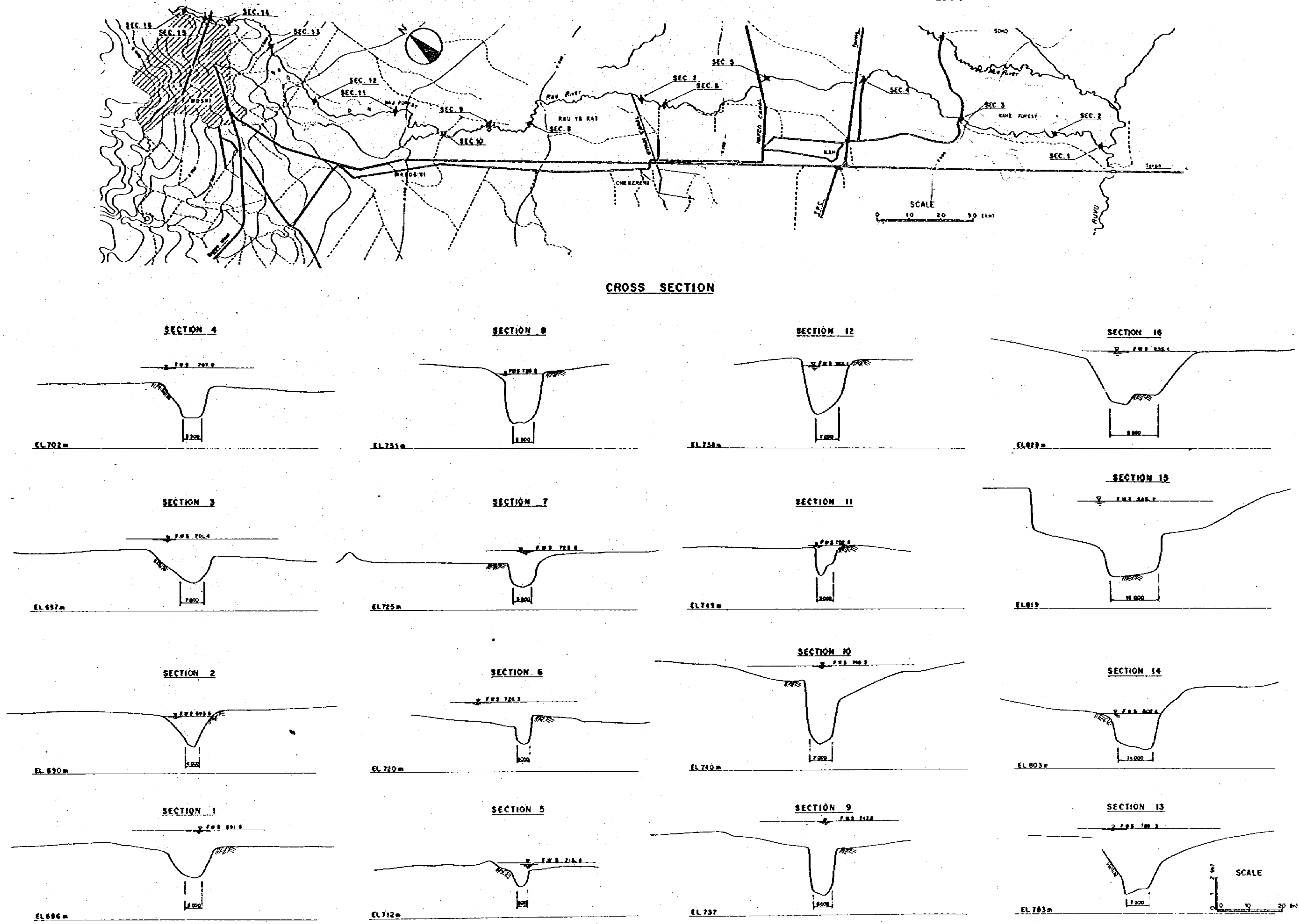


Fig. VII - 18 PROFILE OF THE RAU RIVER

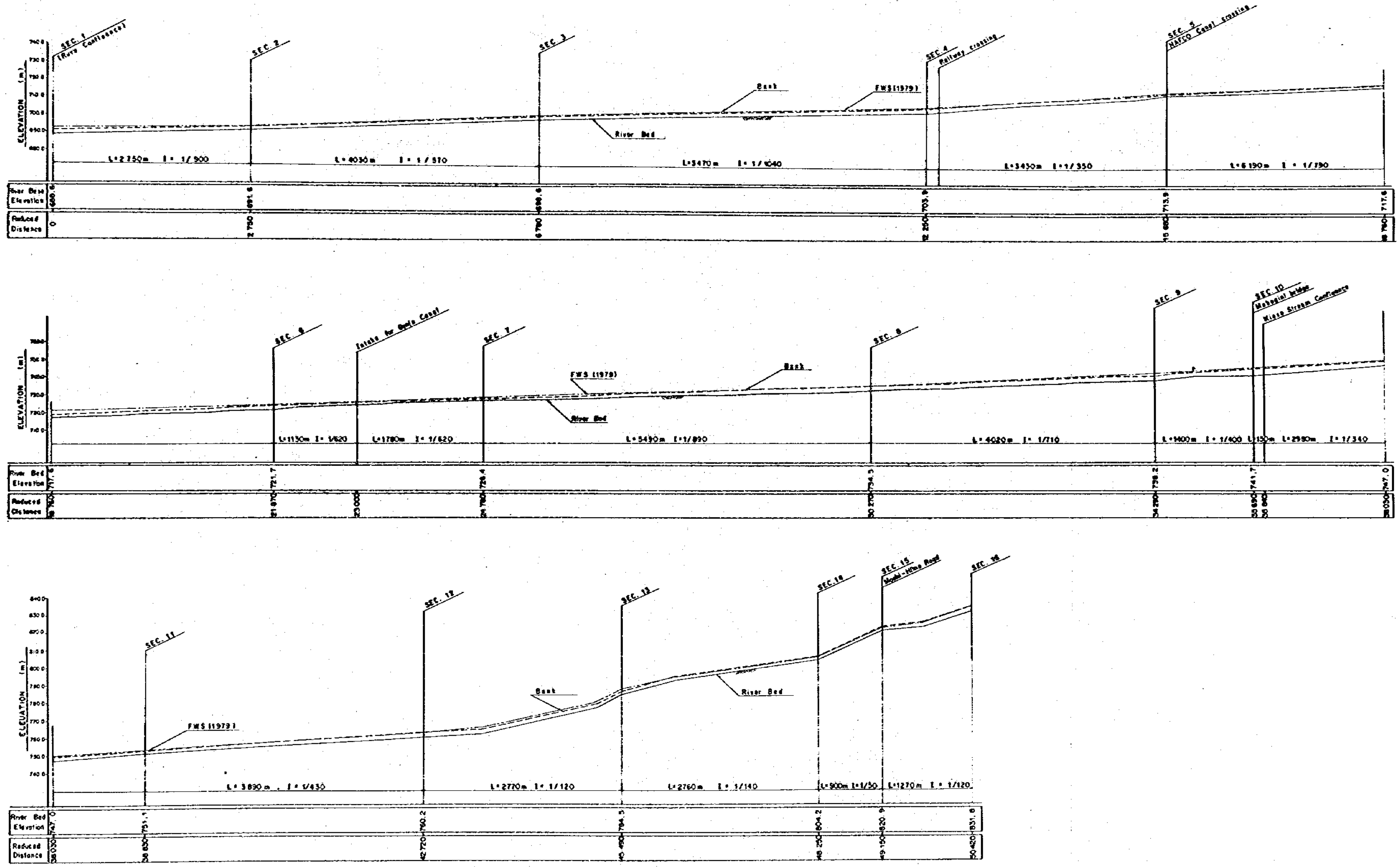


Fig.VII - 19 PROFILE AND CROSS SECTION OF THE MUE RIVER

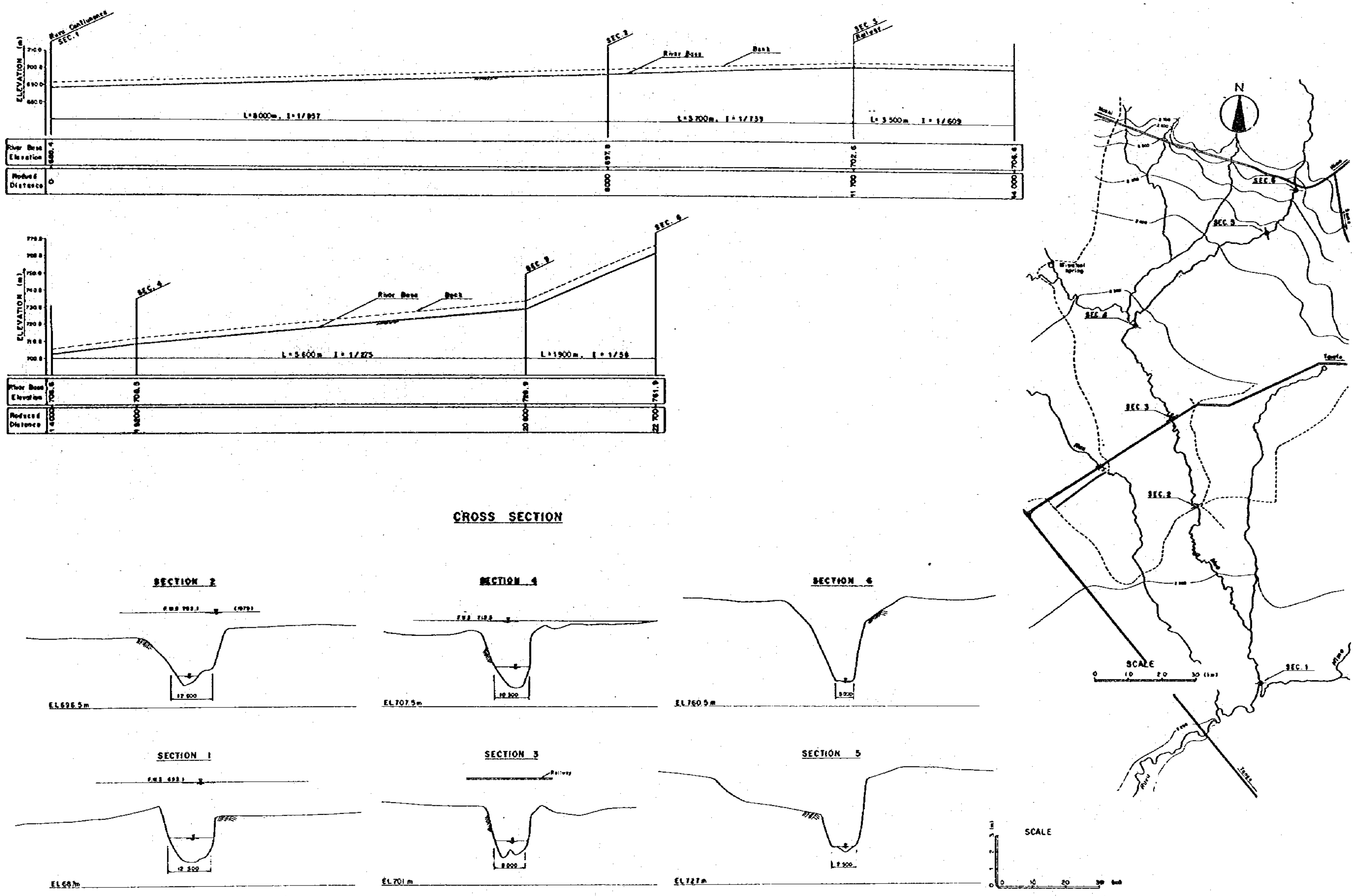
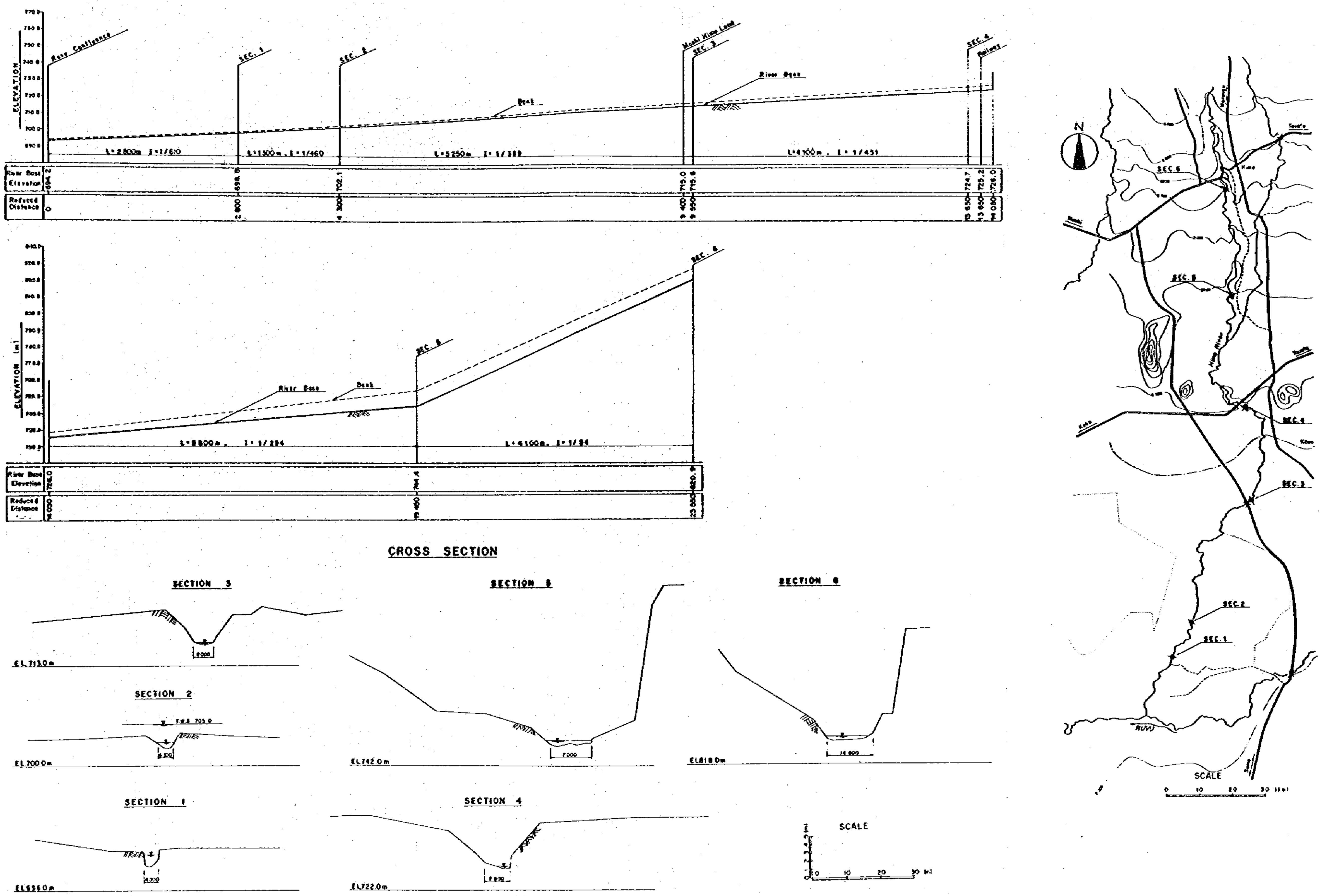


Fig.VII- 20 PROFILE AND CROSS SECTION OF THE HIMO RIVER



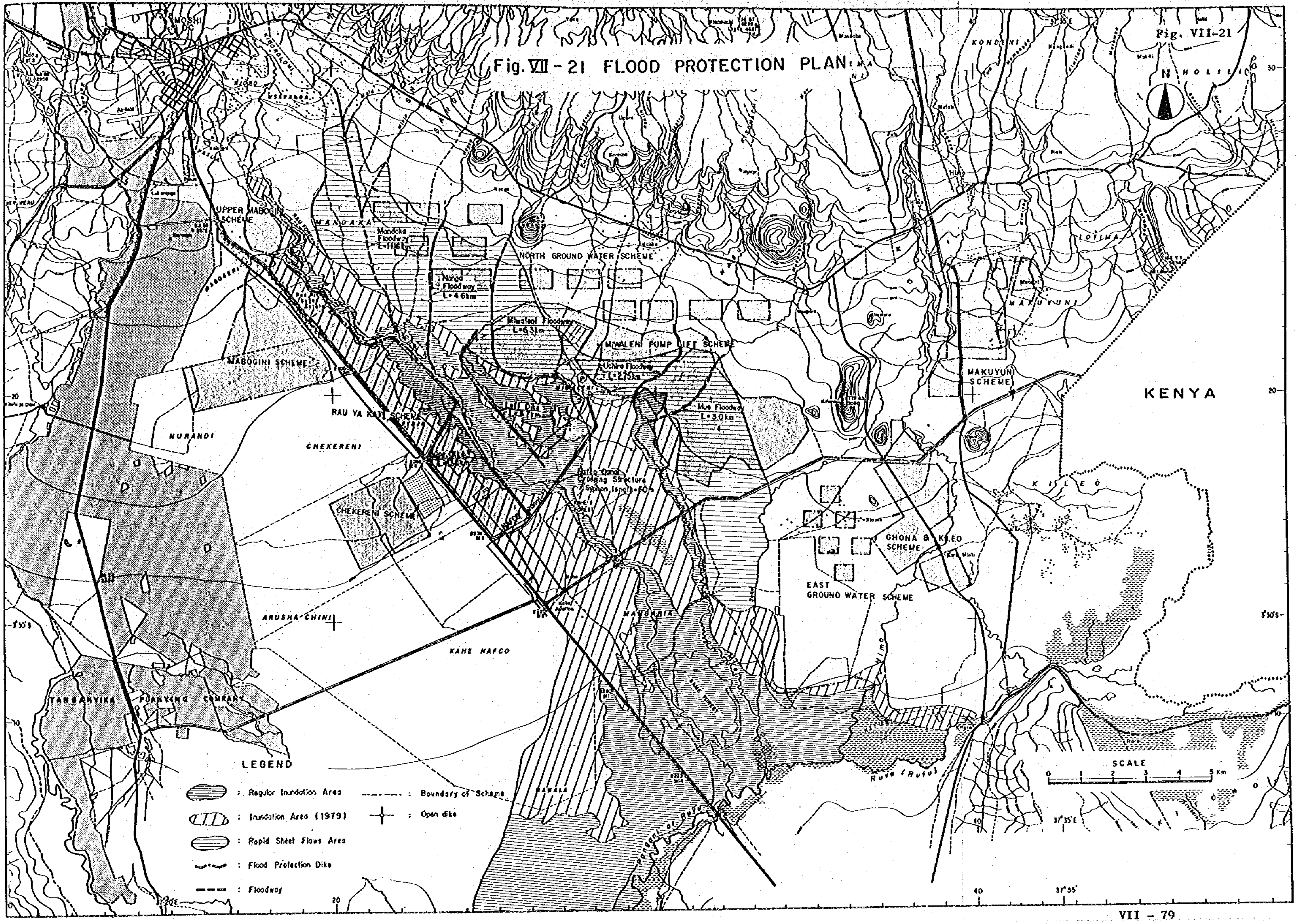


Fig. VII - 21 FLOOD PROTECTION PLAN

Fig. VII - 22 SCHEMATIC PLAN FOR FLOOD PROTECTION FACILITIES

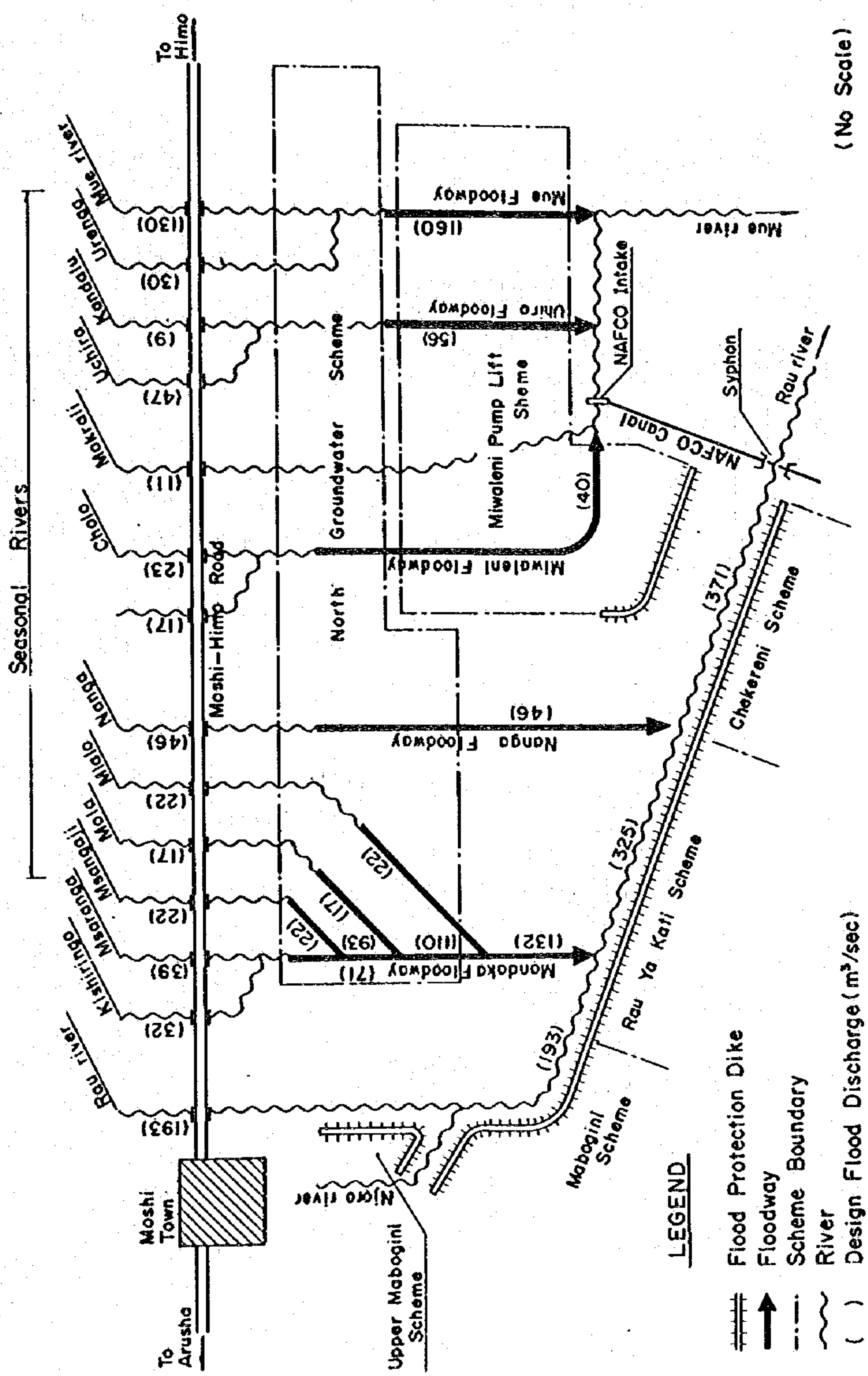
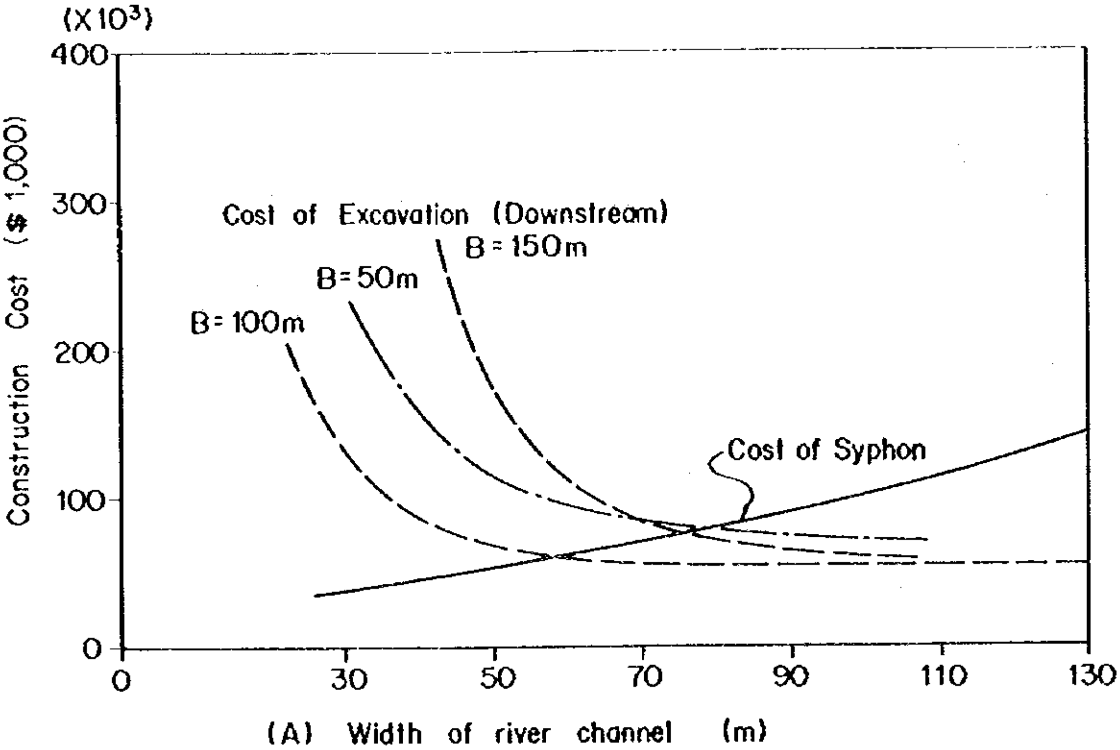
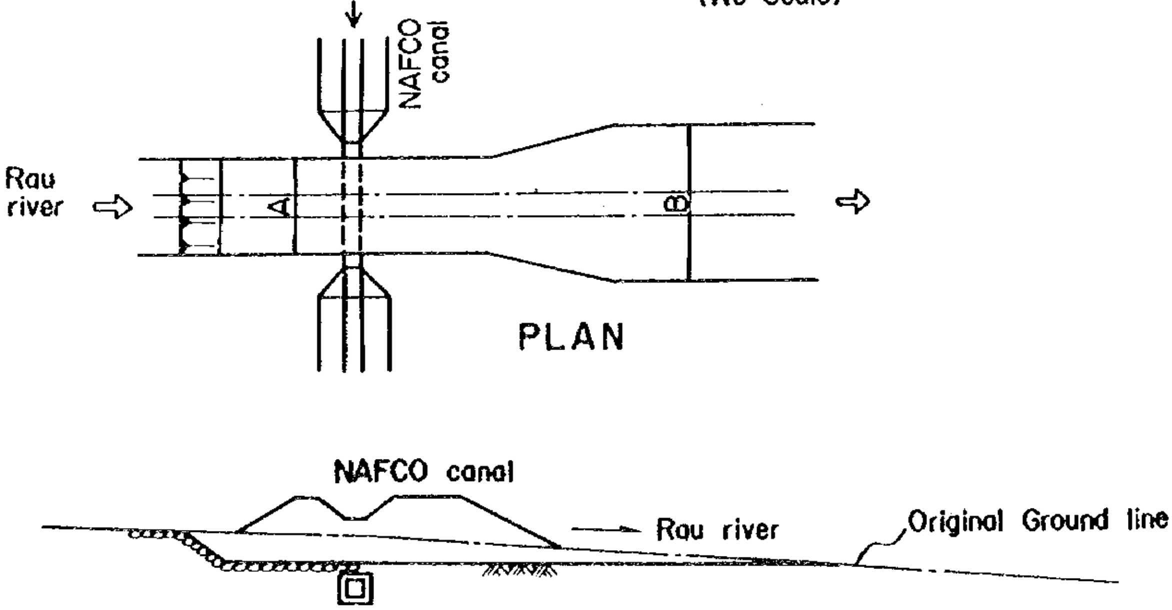


Fig. VII - 23 SELECTION OF RIVER CHANNEL WIDTH AT NAFCO CANAL CROSSING



SCHEMATIC PLAN

(No Scale)



PROFILE

ANNEX VIII

PROJECT ORGANIZATION
IMPLEMENTATION SCHEDULE
AND PROJECT COSTS

FEASIBILITY REPORT

ON

THE LOWER-MOSHI AGRICULTURAL DEVELOPMENT PROJECT

ANNEX VIII PROJECT ORGANIZATION, IMPLEMENTATION SCHEDULE AND PROJECT COST

CONTENTS

LIST OF TABLES

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ANNEX VIII

PROJECT ORGANIZATION, IMPLEMENTATION SCHEDULE AND PROJECT COSTS

1. Project Organization and Management

1.1 Proposed Organization

For the construction and the management of the Lower-Moshi Agricultural Development Project, it is proposed to establish an Executing Organization tentativety called the Project Office under the jurisdiction of the Regional Development Director (RDD). To coordinate, guide and assist the Project Office in the Project implementation and its operation and management, an Executive Committee will also be organized under the RDD. The Committee will constitute of the representatives concerned, such as Regional Planning Officer, Regional Manpower Management Officer, Regional Accountant, Regional Irrigation Engineer, Regional Agricultural Development Officer, Regional Officer of Tanzanian Rural Development Bank, District Development Director, Village Chiefs, etc.

The Project office will have the following functions:

- Construction of irrigation and drainage facilities and farm road networks for the Project with engagement of civil engineering contractor(s).

- Operation and maintenance of the irrigation and drainage facilities and farm road networks.

- Accounting and administration of the Project construction works and operation and management of the Project as well as office operation.

At the implementation stage of the project, the Project Office will organize four working sections, such as (1) Design Section, (2) Implementation Section, (3) Mechanical Section and (4) Administrative Section under the management of the Project Manager to be appointed by the RDD. Each Section except Administrative Section will be, further, organized into sub-working sections, i.e. Main Facilities and On-farm Facilities Sub-sections for both Design and Implementation Sections, and Operation and Motor Pool Sub-section for Mechanical Section. The organization chart of the above is as given in Fig. VIII-1.

After the completion of the Project construction works, the Project Office will be re-organized into three working sections, i.e., Operation Section, Maintenance Section and Administrative Section as shown in Fig. VIII-2. The Project office will be responsible for operation and maintenance of the Project facilities.

The Kilimanjaro Agricultural Development Center (KADC), which is now under construction in the Chekereni village under the technical and financial assistance of the Japanese Government, will directly coordinate and assist the Project Office in operation and maintenance of the Project.

At the farmers' level, the Irrigation Associations will be organized in each scheme to operate and maintain the on-farm facilities with assistance and guidance of the Project Office. The Irrigation Association will be a farmers' group like the present communal working group organized in each village. The Irrigation Association would have to coordinate and to maintain good communication with the Project Office in water supply management and maintenance of facilities.

1.2 Staffing and Expatriate Assistance

Number of staff required in the Project Office is estimated paying due attention to the working quantities, construction methods, implementation schedule, and number of the tertiary irrigation units. Total number of staff at the implementation stage of the Project is estimated to be 85 which mainly consist of administrative staff, specialists, engineers and field attendants.

Required number of staff at the full operation stage of the Project will be 36. In addition, a considerable number of seasonal employees will be required for the field operation, although the farmers' association will provide the manpower in certain extent.

Severe shortage in experienced personnel exists in the country, at present; thus some specialists will have to be engaged from abroad for the assistance and guidance to the project staff during the project preparation stage and construction stage.

Project Preparation Stage M/M

	Speciality	Man - Months Field	Home	Total
1.	Team Leader	7	5	12
2.	Irrigation Engineer	6	5	11
3.	- do -	6	5	11
4.	Drainage Engineer	6	5	11
5.	Soil Mechanical Engr.	3	1	4
6.	Foundation Engineer	3	1	4
7.	Design Engineer	6	6	12
8.	- do -	6	6	12
9.	Survey Engineer	6	-	6
10.	Hydrogeologist	6	3	9
11.	Drilling Expert	6	-	6
12.	Building Engineer	2	3	5
13.	Pump Engineer	-	3	3
14.	Electric Engineer	-	3	3

(continued)

Speciality	Man - Months Field	Home	Total
15. Mechanical Engineer	-	3	3
16. Construction Engineer	2	3	5
Total	65	50	115

Construction Stage

	Field	Home	Total
for Main facilities			
1. Team Leader	68	-	68
2. Construction Engineer	68	-	68
3. Hydrogeologist	10	-	10
4. Mechanical Engineer	5	-	5
5. Electrical Engineer	5	-	5
for On-farm facilities			
6. Construction Engineer	62	-	62
7. Design Engineer	62	-	62
8. Surveying Export	10	-	10
Total	290	-	290

The terms of reference of the engineering services of the Consultants to be engaged by the Project Office will be as follows:

A. General Terms of Reference

1) Review and evaluate all data and reports relating to the proposed project and examine the proposed project plan.

2) Prepare a complehensive implementation plan of the Project comprising surface water development and groundwater development works.

3) Prepare detailed designs, cost estimates, construction schedule and tender documents for the main construction works.

4) Assist and advise the Project Office on tender evaluation and contract awards procedures.

5) Assist and advise the Project Office on construction supervision of the main construction works.

6) Assist and advise the Project Office on design and construction of the on-farm development works.

7) Undertake on-the-job training of the local staff in designing, construction supervision and construction procedure of on-farm development.

B. Specific Terms of Reference

Detailed Design Stage

1) Team Leader

- Review and evaluate all available data and reports on the Project giving attention to project formulation, preliminary design of the Project works and project implementation schedule.

- Prepare detailed work programs and schedules for the Project works including the survey and design of the on-farm works.

- Maintain liaison with the Project Office and Government authorities concerned for the Project if such need arises.

- Represent the consultants in all matters pertaining to the Project.

- Coordinate activities of other experts with the Project management.

2) Irrigation Engineers

- Review all previous studies and relevant technical data on the irrigation development plan of the Project.

- Identify locations of intake structures and pumping stations.

- Prepare detailed layouts of irrigation and drainage canals and road networks down to the tertiary systems.

- Prepare the typical design of on-farm development works.

- Prepare detailed design, cost estimate, construction schedule and tender documents including specifications for the main construction works in collaboration with the other experts.

3) Drainage Engineer

- Review all previous studies and relevant technical data on drainage and floods.

- Establish design criteria on the drainage and flood control.

- Prepare the detailed design of flood protection dikes, floodways and related structure and cost estimates for them.

4) Soil Mechanical Engineer

- Assess the suitability of soils for embankment materials, the properties and availability of concrete aggregates and road metalling materials with additional investigation including field and laboratory testing, where necessary.

- Provide the data on soil mechanical conditions to the other experts.

5) Foundation Engineer

- Assess existing data on foundation of intake structures, pumping station and embankment with additional field and laboratory testing where necessary.

- Provide the data to the other expert for proper design of the weirs, pump stations and embankments.

6) Design Engineers

- Collect and review data.

- Establish the design criteria for weirs and pump stations.

- Prepare the detailed design, cost estimate, specifications and construction schedules of weirs, pump stations and related canal structures.

7) Hydrogeologist and Drilling Expert

- Prepare the implementation schedule of the groundwater development schemes.

- Assist and advise the Project Office in performing the test drilling.

- Prepare the design criteria of tubewells.

8) Pump Engineer

- Review mechanical design criteria for the pumping stations.

- Prepare design and tender documents for pumping plants and gates for canals.

9) Electrical Engineer

- Collect and review data.

- Prepare design and specifications for electrical facilities of pumping station and power distribution line.

10) Building Engineer

- Prepare design and specifications of pump houses and project office and quarters.

11) Mechanical Engineer and Construction Engineer

- Review the construction method and schedule prepared by respective experts.

- Prepare the procurement schedule of O & M equipment.

- Assess and prepare the list of construction equipment taking into account the construction schedule and method.

- Prepare tender documents including technical specification of O & M equipment.

12) Survey Engineer

- Make topographic survey of canal routes and major canal structure sites, and pump stations and weirs sites.

Construction Stage

1) Team Leader

- Assist the Project Office in evaluation of tenders and award of contracts for the construction works and procurement of O & M equipment and relevant equipment in collaboration with the other experts.

- Assist the Project Office in supervision of the Project implementation including timely land acquisition.

- Assist the Project Office in management of project implementation progress.

2) Construction Engineers

- Review and prepare construction plans and works programs and check preparatory works, and the design of canals roads and dikes.

- Assist the Project Office in the preparation of ammendments of the design.

- Assist the Project Office in supervision of the main, construction and on-farm development works.

3) Hydrogeologist

- Assist the Project Office in selection of drilling site and in construction of the tubewells.

4) Pump Engineer

- Assist the Project Office in evaluation of tender of pump and other steel works.

- Assist the Project Office in inspections of pumps and other steel works in manufacturer's shops before shipping and in checking of manufacturers' specifications.

- Assist the Project Office in supervision of installation of pumping plants in collaboration with the construction engineer.

- Assist in preparation of operation and maintenance manuals of the pumping plants.

5) Electrical Engineer

- Assist the Project Office in supervision of installation of electrical equipment for pumping station and power distribution line.

6) Design Engineer

- Review of the design of the on-farm works and assist the Project Office in preparation of the detailed design of the on-farm development works based on the topographic survey.

7) Surveying Expert

- Guide and assist the Project Staff in topographic survey for the on-farm development works.

2. Implementation Schedule

2.1 Basic Considerations of Project Implementation

The civil works to be constructed by the Project are broadly divided into two categories; the main civil works and the on-farm development works.

The main civil works consist of main project facilities such as intake structures, pump stations, main and secondary irrigation canals, main and secondary drains, trunk farm roads, main and secondary farm roads, and flood protection facilities.

The on-farm development works includes all facilities below the tertiary outlets such as tertiary irrigation canals and related structures, tertiary drains, tertiary farm roads, farm ditches and drains, farm roads, land levelling or grading, and land consolidation.

The Project will construct both the main construction works and the on-farm development works simultaneously, so that upon completion of construction works immediate benefits can be envisaged.

As the civil works of the Project include a large volume of earth work, the mechanized construction method will be introduced. The required kind and number of equipment and machinery are shown in Table VIII-12.

Since there are few local contractors in Tanzania who have sufficient experience and enough equipment for this kind of work, it is proposed that both the main civil works and the on-farm development works be undertaken by a qualified international contractor/contractors selected through competitive bidding. The scale of the work for which a tender is called would be large enough to attract the interest of international contractors.

Construction equipment and machinery needed for the Project works will be imported by the contractor and re-exported when the construction is completed. The Project Office will procure equipment and vehicles necessary for supervising contractors works and for operating and maintaining the Project facilities.

The consultant will be engaged by the Project Office for preparation of the design and the tender documents and for assistance and guidance in supervision of the construction works.

Since the ownership of all lands in Tanzania belongs to the Government, no compensation will be required for the land acquisition for the right of way of Project facilities.

The Project will undertake the land levelling for paddy fields and the land grading for upland fields, together with the boundary realignment of the existing farm plots. The land levelling and grading, however, will be done only roughly, leaving the precise finishing to farmers. In executing the boundary realignment, the Project would have authority to change the existing farm boundaries to more rational ones without any legal procedure nor negotiation with the farmers, which will much ease the difficulty normally encountered by the planner and executor of on-farm works.

2.2 Implementation Schedule

The project implementation schedule is shown in Fig. VIII-3. It includes the project preparatory works and the construction works. The project preparatory works will last 18 months including the time necessary for survey works, detailed design works, project mobilization and procurement of operation equipment. The construction works will last 62 months for the main construction works and the on-farm development works.

The project mobilization which includes financing, legalization, establishment of the project organization would have to be completed by the middle of 1982. In order to facilitate the early commencement of the construction works, tender calling for the construction works and procurement of operation equipment is to be promoted in the middle of 1982.

Test well drilling for the groundwater development is to be carried out by use of drilling machines available in Tanzania during the survey and design stage.

2.3 Construction Plan

The construction works of the Project are classified as the main construction works and the on-farm development works depending on the construction procedure. As the development schemes are scattered in the Lower-Moshi area, staged development is introduced for each river system in order to expedite the commencement of the Project operation. The on-farm works are scheduled to parallel the progress of the main construction works. The construction time schedules of the Rau river system, Miwaleni pump lift scheme, Himo river system and groundwater scheme are as shown in Figs. VIII-4, VIII-5, VIII-6 and VIII-7, respectively.

In establishing the construction time schedule, the work days for each month are estimated based on the following assumptions:

(1) The following time lengths to suspend the works are set for the respective ranges of daily rainfall.

Daily rainfall depth (mm)	Time to be suspended (day)
0 - 10	0
10 - 30	0.5
30 - 50	1.0
more than 50	2.0

(2) Holidays including national holidays are deducted from the work days.

(3) Main construction works consisting embankment and concrete works are suspended during the rainy season of March to May.

The work days for the main construction works and the on-farm development works are estimated to be 210 days and 250 days, respectively as shown in Table VIII-1.

2.3.1 Main construction works

(1) Rau river system

The main construction works of the Rau river system consist of construction of 4 intake structures, main and secondary irrigation and drainage canals, main and secondary farm road to be constructed in each scheme and the Chekereni trunk farm road and the flood protection dike. The commencement of the works is preferably made in the upper part of the system. The construction works of the Rau river system will last 36 months, starting in January 1983.

The construction of the upper Mabogini and Mabogini schemes will commence in January 1983. The construction of the upper Mabogini and Mabogini intake structures will be started by construction of diversion channels and coffering works to be provided on the intake sides. After diversion of the Njoro river flow, the weirs and the related structures such as intakes, scouring sluices, stilling basins and river protection works will be constructed. Immediately following to completion of these works, the river water is to be diverted to the scouring sluices by changing coffering, then the remaining concrete and earth works will be completed.

The Rau Ya Kati and Chekereni schemes will commence in June 1984 and be completed by the end of 1985. Intake structures are to be constructed in the short-cut portions of meanders in dry conditions. After construction of diversion weirs and the related structures, the river courses are to be closed.

The flood protection dike will be constructed from the upper part. The dike for the upper Mabogini and Mabogini schemes will be started in June 1983 and completed by February 1984. The Chekereni trunk farm road will commence in July 1983. Immediately after earth works, the gravel metalling will follow.

The earth works for main canals will start from January 1983, and they will be followed by secondary canals. Construction of canal structures and concrete lining will be executed in conformity with the earth works. Since most of the farm roads are to be provided alongside irrigation canals, their earthworks will be performed concurrently with those of irrigation canals.

Generally, excavation for canal will be carried out by means of backhoes, and trimmed by hand labour or trimming machine. The compacted embankment for both canals and roads will be generally constructed in stretches of 100 to 200 m in length. All the suitable materials obtained from adjacent canals and drains excavation will be directly placed in the embankment. Additional materials to be obtained from other excavations or from borrow pits will be brought by means of dump trucks. Compaction of the fill will be made by tamping roller after conditioning the materials to have a moisture content in the required range.

Concrete lining will be placed by means of a longitudinally operating slip-farm machine. This machine will be of automatic control type. All concrete for lining will be ready mixed concrete manufactured in the batching plant.

(2) Miwaleni pump lift scheme

The construction works of the Miwaleni pump lift scheme include the construction of a pump station, discharge pipeline, power distribution line with sub-station equipment, main and secondary irrigation and drainage canals, main and secondary farm roads, Miwaleni trunk farm roads, Miwaleni and Mue floodways and flood protection dike.

The construction of the Miwaleni pump station will be initiated with excavation works for the pump house foundation and inlet channel in May 1984. As soon as the excavation works are completed, concrete works will commence. Concreting for the pump house substructure and suction pit will be started in July 1984 and completed by October 1984. The building works will be initiated from October 1984 so that the overhead crane can be installed for the use of erection of pumping equipment. The construction of the discharge pipeline will be started in May 1984 and completed by the end of September 1985.

The Miwaleni and Mue floodways will be initiated in May 1984 from the lower reaches located in the scheme. Excavation of channels will be made mostly by means of bulldozers. The excavated materials will be used for their embankment. The flood protection embankment is provided along the irrigation canals. Construction will be completed by the end of February 1985. Embankment will be constructed by means of bulldozer by use of the materials obtained from the borrow areas around the route.

The construction of irrigation canals, drainage canals and farm road will be carried out keeping pace with the progress of each work by means of the same procedure as the other schemes.

(3) Himo river system

The construction works of the Himo river system include the improvement of intake structures and head reaches, construction of main and secondary irrigation and drainage canals, and main and secondary