1. Present Water Balance

In order to clarify the conditions of availability and requirement of surface water under the present situation of basin, the water balance is studied for the Arau, Kuranji and Air Dingin rivers.

The present water requirement is estimated as a sum of water required for the existing irrigation system and present water use for industries and municipal water supply. The irrigation water requirement is estimated for every week considering the growing stage of paddy.

Regarding the availability of surface water, the one-in-five-year dependable runoff is estimated firstly on the monthly data basis, since the statistical analysis for preparation of the flow duration with shorter duration can hardly be done due to the paucity of discharge records. The dependable runoff is estimated from the one in five year monthly rainfall at Tabing station by use of relationship between rainfall and runoff at each balance point.

On the other hand, relationship between monthly average runoff and minimum 10-day average runoff of the month is studied based on the runoff records available. The monthly average dependable runoff is converted into minimum 10-day average runoff of each month using the monthly runoff vs. 10-day runoff relationship. Finally the water requirement and the 10-day average available water are compared with each other.

1.1 Present Water Requirement

The surface water of the Arau, Kuranji and Air Dingin rivers including their tributaries is used mainly for irrigation, industrial and municipal water supply, and hydroelectric power generation.

A total of 11.6 m^3/s of surface water is required at present, which consists of 10.8 m^3/s for irrigation, 0.5 m^3/s for industry and 0.3 m^3/s for municipal water supply. The water requirement of each river is summarized in the following table, of which further description will be given in the subsequent sections :

River	Water requirement (m^3/s)			
	Irrigation	Industry	Mun. water supply	Total
Arau	1.167	0.487	-	1.654
Kuranji	5.901	-	0.250	6.151
Air Dingin	3.755	-	-	3.755
Total	10.823	0.487	0.250	11.560

1.1.1 Irrigation

In the study area there exist 12 irrigation systems totalling 7,958 ha of service area, i.e., 858 ha covered by 3 systems in the Arau, 4,339 ha by 5 systems in the Kuranji, and 2,761 ha by 4 systems in the Air Dingin. These irrigation systems are outlined in Table 0-1 with location map in Fig. 0-1.

Among these, Gunung Nago irrigation system is by far the biggest. The system has a 70 m wide non-gated weir across the Kuranji river constructed in 1973. The weir has two intakes on both right and left banks of which service areas amount to 2,478 ha in total.

The actual irrigation water use in 1982 is summarized in Table 0-2. However, the available records of irrigation water use are limited. Therefore, the amount of irrigation water requirement for the existing irrigation areas is estimated by the analytical method referring to an Internal Note on the Determination of Irrigation Water Requirements for Sawah Paddy, West Sumatra Design Unit, 1981.

The monthly unit area irrigation water requirement is estimated, firstly, employing the method and assumptions presented in the succeeding paragraphs. Then, the irrigation water requirement of each river system is estimated from the irrigation area multiplied by the unit area water requirement.

The calculation process of the unit area water requirement is shown in Table 0-3, and the estimated monthly irrigation water requirements are shown in Table 0-4. According to the estimate, the maximum irrigation water requirement occurs in July, which is summarized below :

a. Unit area water requirement : 1.36 l/s/ha

b. Water requirement

River system	Irrigation area (ha)	Water requirement (l/s)
Arau	858	1,167
Kuranji	3,489	4,745
Balimbing	850	1,156
A. Dingin	2,761	3,755
Total	7,958	10,823

Cropping pattern and Varieties of Paddy

The following cropping pattern and growing stages are assumed for the estimation :

a. Rainy season crop : 150 day variety (padi dalam) from October to February (21 weeks)

b. Dry season crop : 120 day variety (padi gadu) from May to August (17 weeks)

c. Growing stage

Stage	150 day variety	120 day variety
Land preparation	1st to 4th week	1st to 3rd week
Transplanting	4th week	3rd week
Irrigation	5th to 18th week	4th to 14th week
Draying off	19th to 20th week	15th to 16th week
Harvesting	21st week	17th week

Unit Area Irrigation Water Requirement

Qin = Qoff / Cde

Qoff = Etc + Ll - Re

where

Qin : Unit area irrigation water requirement at intake (l/s/ha)
Qin (l/s/ha) = Qin (mm/day)/8.64

Qoff : Unit area irrigation water requirement at offtake

Cde : Distribution efficiency defined as water losses in canal system between the intake and field offtake, 0.75 is assumed

Etc : Crop evaporation

Ll : Water loss for land preparation and percolation

Re : Effective rainfall

Crop Evaporation (Etc)

Etc = Eto × Cp × Cc

where

Eto : Reference crop evaporation (= Ep × Cp)

Ep : Pan evaporation reading at Gunung Nago; average of 2 years from 1977 to 1978 as shown in Table 0-5

Cp : Pan coefficient, 0.85 is taken according to FAO publication No.24.

Cc : Crop coefficient

150 day (week)	120 day (week)	Cc/1	Remark
1st to 4th	1st to 3rd	1.00	Transplanting
5th to 7th	4th to 6th	1.10	
8th to 11th	7th to 9th	1.35	
12th to 15th	10th to 12th	1.30	
16th to 18th	13th to 14th	1.05	
19th to 21st	15th to 17th	0.00	

/1 Recommended by Prosida for 150 day variety

Land Preparation and Percolation Lost (L1)

a. For land preparation period : L1 = 7.1 mm/day

b. For irrigation period :

$$L1 = Lp + Lb$$

where

Lp : Percolation losses through rice field bed
- a. For clay or loamy clay :
  - 2 mm/day for well established rice field
  - 4 mm/day for newly developed rice field
- b. For lighter soils : 6 to 8 mm/day

Lb : Percolation losses through rice field banks : 3 mm/day by experimental works.

Effective Rainfall (Re)

$$Re = R \times Cr$$

where

Re : Effective rainfall defined as a part of actual rainfall, which is of direct use to the crop

R : The 1 in 5 year low rainfall by month at Tabing station based on data for 20-year period as shown in Table 0-6

Cr : Coefficient of effective rainfall assumed to be 0.7

1.1.2 Industry

The present water uses for industry are listed in Table 0-7. These are all from the Arau river system. Regarding the Kuranji and Air Dingin, no industrial water use is inventoried.

The industrial water use amounts to 29,200 l/min (or 0.487 m^3/s) among which a cement factory in Indarung uses 14,000 l/min and other 7 factories use the remaining 15,200 l/min.

1.1.3 Municipal Water Supply

Only one public water supply system is existing in the study area, taking water from the Kuranji river at Kp. Melayu. The treatment plant is located at Gunung Pangilun near the intake pump station. This plant produces 0.25 m^3/s of water throughout the year.

1.1.4 Hydroelectric Power

There are two hydroelectric power plants, i.e., PLTA Rasak Bunga in the Arau river and PLTA Kuranji (Batu Busuk) in the Kuranji river. Both of these are operated by a cement factory in Indarung (P.T. Semen Padang). The PLTA Rs. Bunga generates 1,100 kw and the PLTA Kuranji 1,650 kw for the factory. For these plants 1,800 l/s and 2,550 l/s of water is taken in from the Arau and Kuranji rivers, respectively, and returned to the respective rivers. The water used for the hydroelectric power is not counted in the water use table, since it is returned to the original river after use without consumption. Outline of these power plants is shown in Table 0-8.

1.2 Available Water

Availability of surface flow data in the objective rivers are as follows :

Station	Recorded period (yrs)	Years of complete data (yrs)	remarks
Arau R.			
Lb. Sarik	7	4	
Kp. Baru	2	0	
Lb. Begalung	5	4	Discharge of flood relief chan. only
Kuranji R.			
G. Nago	5	2	
Kp. Melayu	5	3	
Air Dingin R.			
Lb. Minturun	4	2	

Among these only the data at Lubuk Sarik in the Arau river, Gunung Nago in the Kuranji river and Lubuk Minturun in the Air Dingin river could be used for the analysis of flow duration in consideration of the period of available data and location of the stations.

Taking account of the locations of stream gauging stations and intake facilities, the following points are selected for water balance study :

River	Balance point	Drainage area (km^2)
Arau	Lb. Sarik sta.	64
Kuranji	G. Nago weir	120
Balimbing	S. Guo weir	11
Air Dingin	Lb. Minturun sta.	116

Since the period of available surface flow data are short, statistical analysis of available water on the actual record basis can hardly be done. The available water at each balance point is estimated from the rainfall data at Tabing station by use of relationship between monthly rainfall at Tabing station and monthly runoff at each balance point. Tabing station has longer period of rainfall records since 1948.

One in Five-year Rainfall at Tabing Station

Monthly rainfalls at Tabing station are shown in Table 0-9. The 1 in 5-year rainfall at Tabing station is estimated from this table for each month as shown in Table 0-11.

Relationship between Monthly Rainfall and Runoff

Relationship between the monthly rainfall at Tabing station and monthly average runoff at each stream gauging stations is assumed to be expressed as follows :

$$Q = KR = fRA / 2{,}630$$

where

- Q : Monthly average runoff at stream gauging station (m^3/s)
- R : Monthly rainfall at Tabing station (mm/mon)
- A : Drainage area (km^2)
- f : Runoff rate
- K : $fA / 2{,}630$

In order to obtain the runoff rate, monthly average runoffs as available at Lubuk Sarik, Gunung Nago and Lubuk Minturun are plotted against the corresponding monthly rainfalls at Tabing station and shown in Fig. 0-2. From this figure the relationship at each station is expressed as follows :

River	Balance points	K-value	A (km^2)	f-value
Arau	Lb. Sarik	0.0273	64	1.12
Kuranji	G. Nago	0.0700	120	1.53
A. Dingin	Lb. Minturun	0.0391	116	0.89

Among the three points, the rainfall-runoff correlation at Gunung Nago is rather weak and the plots scatter in Fig. 0-2. This may come from the reason that the average runoff at Gunung Nago is figured out by the records measured only twice a day, while those at Lubuk Sarik and Lubuk Minturun are based on the hourly records by automatic gauges. In addition, the runoffs recorded in the evening shows, on average, 30 to 40 % bigger than those recorded in the morning as shown below, which indicates that the daily average may change depending on the time of record :

Year	Average runoff (m^3/s)		(2)/(1)
	Morning record (1)	Evening record (2)	
1979	28.8	37.6	1.31
1980	17.2	24.3	1.41
1981	21.4	29.6	1.38
1982	13.6	17.3	1.27

Therefore, the runoff rate derived from records is not applied to the estimation of available water at Gunung Nago, since the rate seems too high and considered not reliable.

For the balance points at G. Nago and S. Guo weirs, the runoff rate is assumed to be f = 1.01 taking the average of those at Lb. Sarik and Lb. Minturun, since these weirs are located between the stations. Thus, the K-value at these balance points are derived as follows :

River	Balance points	f-value	A (km^2)	K-value
Kuranji	G. Nago	1.01	120	0.0461
Balimbing	S. Guo	1.01	11	0.00422

Available Water at Each Balance Point

Based on the discharge data available at Lubuk Sarik and Lubuk Minturun stations, the ratio of minimum 10-day average runoff in a month and monthly average runoff is studied. The results are shown in Table O-10. On average, the minimum 10-day average runoff is 68 percent of the monthly average runoff.

The monthly average available water at each balance point is estimated from the rainfall data at Tabing station by use of the relationship between monthly rainfall and runoff derived in the previous paragraph. The minimum 10-day average runoff of each month is estimated from the monthly average available water multiplied by the ratio 0.68. The 10-day runoff is taken up as the available water of each month. The results of calculation are shown in Table O-11.

1.3 Water Balance

The present water requirement and available water at each balance point are shown in Table O-11 and Fig. O-3. The water balances at the maximum requirement and the minimum availability are summarized as follows :

River	Balance point	Balance at max. requirement (m^3/s)		Balance at min. availability (m^3/s)	
		Qr	Qa	Qr	Qa
Arau	Lb. Sarik	1.65	3.08	1.59	2.34
Kuranji	G. Nago	4.97	5.20	4.69	3.95
Balimbing	S. Guo	1.16	0.48	1.09	0.36
A. Dingin	Lb. Minturun	3.76	4.41	3.53	3.35

(Qr : Water requirement, Qa : Available water)

Although the study made in the previous sections are on the preliminary level, the present water balance could be concluded as follows :

a. The water in the Arau river is deemed to be enough to the present water requirement.

b. The water in the main Kuranji and Air Dingin seems to be almost enough to the present water requirement except the month of minimum availability.

c. The water at S. Guo is not enough to the present irrigation water requirement, since the catchment area is too small to supply water to the wide irrigation area between the Balimbing and Laras rivers.

2. Irrigation Water Demand

The existing irrigation systems cover almost all the irrigable flat plain of the river basins subject to the study except for the urbanized area. None of new irrigation system nor extension of the existing system is proposed in the study area.

On the contrary, the farm lands adjacent to the urban area are replaced by the housing, industrial and commercial areas in recent years. The urbanization of the study area is remarkable. According to the data from Agricultural Office (Dinas Pertanian Tanaman Pangan, Kotamadya Padang), changes of paddy field in Kotamadya Padang are shown in Table 0-12, which are summarized as follows :

District	Net paddy field (ha)			
	1966	1969	1980	1983
Kodya Padang	8,539	8,539	8,503	8,398
Old town	737	737	600	503

The paddy field in Kotamadya Padang decreases year by year. This tendency is remarkable especially in the old town consisting of Padang Barat, Padang Timur, Padang Utara and Padang Selatan.

According to the Master Plan Kotamadya Padang prepared in 1983, almost all the existing agricultural lands will be replaced by the residential and other urban areas by the year 2003. Only some agricultural lands will remain mostly in the existing Gunung Nago (right) and Lubuk Minturun irrigation systems.

In consideration of the circumstances mentioned above, it could be concluded that there is little demand for further irrigation water development in the study area. On the contrary, the existing irrigation water which shares the major part of present water use in the basin would be used for the other municipal and industrial purposes in future keeping pace with the replacement of agricultural land to municipal and industrial lands.

3. Municipal and Industrial Water Demand

Regarding the future water demand for the municipal purposes, study has been made in the Feasibility Report on Padang Water Supply Project, DGCK, prepared in November 1982. The water demand was estimated for the proposed future service area to be implemented in stages as follows :

a. Initial Stage (Immediate Measures) until 1985 : This stage includes some extension of the existing supply area in the southern part of the Municipality, especially to improve the supply conditions in the region of the Harbour Teluk Bayur.

b. First Stage until 1995 : During the first stage project the service area will be extended mainly up to the proposed ring-bypass road. However some areas within the ring-road have been excluded, i.e. north of the Air Dingin River and east of Tabing Airport. To make provision for the proposed industrial development in Lubuk Begalung and some dense residential areas the first stage service area will exceed the ring-road in the southern part of the Supply Area.

c. Second Stage until 2005 : This stage comprises the maximum possible area suitable for human settlement; excluding some scattered villages in the river valleys. Water supply outside Padang City will be limited to the settlement area mainly along roads and rivers. Insofar "coverage" is not understood in a special dimension. Also excluded from water supply considerations is the Sub-district of Bungus/Teluk Kabung, which has been provided with separate supply facilities.

The result of study is summarized in Table 0-13. In brief, the municipal water demand of Kotamadya Padang is as shown below :

Item		Year		
		1985	1995	2005
House connection (m^3/d)		24,200	44,600	78,600
Public taps (m^3/d)		3,800	6,800	9,400
Non domestic (m^3/d)		9,000	14,300	30,100
Loss and internal use (m^3/d)		17,800	23,500	27,800
Total	(m^3/d)	54,000	89,200	145,900
	(1/s)	634	1,032	1,689

The annual average demand thus figured out amounts to about 1.7 m^3/s in the year 2005. In order to fulfil the demand, a new treatment plant is to be installed at Gunung Nago to provide municipal water of 0.25 m^3/s taken from the Kuranji river. The remaining 1.2 m^3/s of water will be taken from the Air Dingin river because another treatment plant is planned to be constructed in the upper reach of the Air Dingin river in future. The both sites for treatment plants are proposed by the Padang Water Supply Project.

Other than the treated water mentioned above, the factories may need untreated water to be taken directly from the river although the amount of water is not known yet at present. It also be noted that DPU, West Sumatra has plan to take 3.0 m^3/s of water from the Kuranji river for the flushing purpose of drainage channels in the urban area such as the Jati canal.

The water demand for the municipal and industrial uses is still small compared with the existing irrigation water use which may decrease gradually keeping pace with the urbanization of the study area. The resources of surface water in the study area could be said enough to endorse Padang's municipal and industrial development.

4. Mini-hydroelectric Power Development

A preliminary study on potentiality of developing mini-hydroelectric power by use of flows in the steep slope irrigation canals is conducted for the electrification of rural villages. The study firstly outlines the current and future electric supply systems in Kotamadya Padang. Then the potential hydroelectric power is estimated for the selected irrigation canals.

4.1 Electric Supply System in Padang

Electric power in Padang area is mainly supplied by PLN (Perusahaan Listrik Negara). The service area of the PLN is still limited in the urban areas. Most of the rural villages are not served with electricity yet. Some of them have their own diesel generators of small scale. Factories, hotels and other business corporations also have their own power generation systems together with the PLN electric supply system. However, these private power systems are being replaced by the PLN power system.

Electricity by PLN in Padang area has been generated in the PLTD Simpang Haru. In last March 1983, PLTG Bandar Buat began its operation and by the end of 1983 PLTA Danau Maninjau will be in operation. These three plants are incorporated with each other and supply the electric power to Padang city and its surrounding areas. Outline of these power plants are as follows. The electic power sources in Padang area will be by far strengthened by the end of 1983 :

Item	PLTD S. Haru	PLTG B. Buat	PLTA D. Maninjau
Capacity (MW)	30	42	68
Power source	Diesel	Gas	Water
Start of operation	Existing	Mar. 1983	Sept. 1983 (partial) Dec. 1983 (full)

Notes

PLTD : Pembangkit Listrik Tenaga Diesel (Diesel electric power plant)

PLTG : Pembangkit Listrik Tenaga Gas (Gas electric power plant)

PLTA : Pembangkit Listrik Tenaga Air (Hydroelectric power plant)

PLTD Simpang Haru

Simpang Haru diesel electric power plant was the only source of the electric power for Kotamadya Padang, until the plant in Bandar Buat was constructed in 1983. The plant is located in the old town on the left bank of the flood relief channel.

The existing total capacity of Simpang Haru plant is 30.0 MW, consisting of the following generators :

Unit capacity (kw)	Operational unit	Total capacity (kw)	Year of installation
965	2	1,930	1954
1,200	1	1,200	1968
1,240	1	1,240	1973
2,440	1	2,440	1976
2,520	1	2,520	1977
4,040	2	8,080	1978
6,300	2	12,600	1983
Total	10	30,010	-

PLTG Bandar Buat

Bandar Buat gas electric power plant was constructed recently and started its operation in last March, 1983. The plant is located in Pauh Limo near Gunung Nago weir.

The total capacity is 42 MW generated by 2 units of generators (21 MW each). According to the PLN schedule, 21 MW of electric power will be supplied to the cement factory in Indarung by the end of 1983 and 34 MW by 1984. The remaining 8 MW will be used for municipal purposes.

PLTA Danau Maninjau

Danau Maninjau hydroelectric power plant is newly constructed, and the facilities are under testing now. The power generated around Lake Maninjau will be transmitted to Padang area about 90 km far apart.

The planned total capacity of this hydroelectric plant is 68 MW, consisting of 4 units of generators (17 MW each). Out of four units, one unit will be operated by September, 1983 and the remaining three by December, 1983.

Power Plants by P.T. Semen Padang

Electric power sources of the P.T. Semen Padang, one of the biggest factories and electric consumer in Padang, are hydroelectric and diesel electric power plants operated by the factory and electric from PLN. These are outlined as follows :

Source	Unit capacity (kw)	Units	Total capacity (kw)
a. Hydroelectric power			2,750
PLTA Rs. Bunga	550	2	1,100
PLTA Kuranji	550	3	1,650
b. Diesel electric power			22,944
	512	2	1,024
	520	1	520
	1,600	1	1,600
	2,400	2	4,800
	5,000	3	15,000
c. PLN electric power			
As of June, 1983			9,250
By the end of 1983			21,000

4.2 Potential Mini-hydroelectric Power

4.2.1 Methodology

The generator output is calculated by the following equation of energy :

$$P = 9.8 \times Et \times Eg \times Q \times H$$

where

P : generator output (kw)

Et, Eg : Efficiencies of turbine and generator, respectively. The product of Et and Eg is assumed to be 0.75 taking account of the expected output.

Q : Available discharge (m^3/s)

H : Effective head (m)

Effective Head

The effective head is derived from total head reducting the loss of head in the leading channel, penstock, etc. The effective head is estimated as shown below :

a. Total head : Measured on the longitudinal profile at the potential site. The potential site is selected where the higher head can be taken with shorter leading channel.

b. Loss of head in leading channel : The friction loss in the leading channel is :

$$h1 = L \times I = L/1000$$

where

h1 : Friction loss in leading channel (m)

L : Length of leading channel (m)

I : Slope of leading channel (= 1/1000)

c. Loss of head in penstock : Friction loss in the penstock is calculated by Darcy-Weisbach formula. Other head loss in penstock is assumed to be 25 % of the friction loss.

$$h2 = 1.25\left(f \times \frac{Lp}{Dp} \times \frac{V^2}{2g} \right)$$

$$= 1.25\left(0.001246 \frac{Lp \times Q^2}{Dp^{16/3}} \right)$$

where

h2 : Loss of head in Penstock (m)

f : Friction factor = $124.5\ n^2/Dp^{1/3}$; the roughness n is assumed at 0.011.

Lp : Length of penstock (m); The slope is assumed 1 on 1.5

Dp : Diameter of penstock (m), which is decided so that the velocity does not exceed 4.0 m/s

V : Velocity of flow (m/s)

Q : Discharge (m^3/s)

g : Acceleration of gravity (= 9.80 m/sec^2)

d. Other loss : Ten percent of h_1 and h_2 is counted as other loss of head (h_3)

Available Water

The irrigation water is used for electric power generation. According to the annual rainfall data at Tabing station, the year 1982 is the draughtest in recent 7 years since 1975. The flow duration of the irrigation canal in 1982 is adopted as an available water for power generation. The 75 day dependable discharge is assumed to be the maximum available water to estimate the maximum generator output.

4.2.2 Selection of Potential Sites

Judging from the irrigation water records and irrigation area of each canal system, the canals of which discharge exceed 1.0 m^3/s are (a) Limau Manis, (b) Gunung Nago left, (c) Gunung Nago right, (d) Sungai Latung, (e) Koto Tuo left, and (f) Koto Tuo right irrigation canals.

On these irrigation canal systems, site conditions were inspected. As a result of inspection the Sungai Latung, Koto Tuo left and right canals are those of milder slope and are not considered suitable for hydroelectric power generation. Accordingly the following canals are selected for the study of potential site of mini-hydroelectric power plant.

a. Limau Manis canal from Limau Manis weir to Kel. Jawa Gadut

b. Gunung Nago left canal from G. Nago weir to Kel. Pasar Baru

c. Gunung Nago right canal from G. Nago weir to Kp. Kuranji.

On the above irrigation canals selected, hydrographic survey is conducted by the Study Team. The longitudinal profiles of these canals are shown in Figs. 0-4 through 0-6. The potential sites are selected at the following places where the canal slope is more than 1/50 and the higher head can be obtained with shorter leading channel.

a. Limau Manis-1 power plant : on the Limau Manis irrigation canal around 350 m downstream from its intake.

b. Limau Manis-2 power plant : on the Limau Manis irrigation canal around 1,000 m downstream from its intake.

c. Gunung Nago left power plant : on the Gunung Nago left irrigation canal around 550 m downstream from its intake.

d. Gunung Nago right power plant : on the Gunung Nago right irrigation canal around 1,100 m downstream from the right bank of Gunung Nago weir.

4.2.3 Hydroelectric Power to be Generated

The flow duration curves at the potential hydroelectric power plants are shown in Fig. 0-7. These are the intake discharges recorded in each irrigation canal in the year 1982 which was the draughtest in recent 7 years since 1975. Since the Gunung Nago left irrigation canal separates downstream from the intake, the discharge at Gunung Nago left power plant is estimated from the intake discharge multiplied by 62 percent, the ratio of the irrigation area downstream of the plant site and the total.

As seen from the Fig. 0-7, all of these flow duration curves get small abruptly at around 345-day. The minimum available water for power generation is decided as the 345-day dependable discharge. On the other hand, the 75-day dependable discharge is assumed to be the maximum available water to estimate the maximum generator output. The dependable discharges for different duration are as follows :

Duration (day)	Dependable discharge (m^3/s)		
	L. Manis 1 and 2	G. Nago left	G. Nago right
75	0.75	2.04	2.35
95	0.74	2.04	2.35
180	0.60	1.67	1.61
275	0.44	1.10	0.98
345	0.27	0.67	0.68

Based on the canal profile and flow duration, the maximum output and annual production of electricity are estimated as shown in Table 0-14. The results are summarized as follows :

Item	L. Manis 1	L. Manis 2	G. Nago left	G. Nago right
Leading chan. length (m)	217	358	250	301
Penstock				
Length (m)	21	20	10	13
Diameter (m)	0.50	0.50	0.85	0.90
Total head (m)	11.6	11.0	5.2	6.8
Max. output (kw)	105	97	128	194
Annual production (MWh)	385	357	462	640

4.2.4 Utilization of Electricity

Near the Limau Manis-1 and 2 plant sites Kel. Jawa Gadut having about 170 households exists. The village is not electrified yet. The village has scheme to construct a diesel electric power plant within a frame of Bantuan Desa (Bangdes) Project for the year 1983/84 by Walai Kota. The diesel plant will have capacity 15 kw and the scheduled budget is Rp. 1,400,000. In addition, the newly constructed PLTG Bandar Buat is located in about 4 km distance.

Kel. Pasar Baru which is located along Gunung Nago left irrigation canal has been already electrified. Kp. Kuranji located near the Gunung Nago right power plant on the opposite side bank of Kel. Pasar Baru crossing the Kuranji river has around 1,500 households. The village is not electrified yet. According to the village office, there is no electrification scheme at present. However the village could be electrified by the PLN system, since the PLTG Bandar Buat is located only about 2 km apart.

Judging from the circumstances mentioned above, the mini-hydroelectric power projects in these sites are not deemed to be of higher priority at present. From the viewpoint of development of natural energy under the difficulty in acquisition of oil, the project might be taken up in future for electrification of agricultural works as well as village houses.

Table 0-1 Existing Irrigation Systems

NO.	Irrigation system	Intake structure		Service area (ha)
		Structure	Source of water	
1.	Kepala Hilalang	Permenent weir	Kepala Hilalang river/ Air Dingin	610
2.	Sei. Latung	Permanent weir	Latung river/ Air Dingin	861
3.	Lubuk Minturun	Free intake	Air Dingin river	300
4.	Koto Tuo	Gabion weir with concrete crest	Air Dingin river	990
5.	Bandar Duku	Free intake	Kuranji river	75
6.	Tunggul Surian	Free intake	Guo river/ Balimbing river/ Kuranji river	200
7.	Sei. Guo	Rip-rap with concrete crest	Guo river/ Balimbing river/ Kuranji river	650
8.	Limau Manis	Rip-rap with concrete crest	Kuranji river	936
9.	Gunung Nago	Permanent weir	Kuranji river	2,478
10.	Padayo	Free intake	Padayo river/ Arau river	100
11.	Ulu Gadut	Rip-rap with concrete crest	Padayo river/ Arau river	300
12.	Lubuk Lawas	Gabion weir with concrete crest	Arau river	458
	Total			7,958

Source :

1. Proyek Pembangunan Jaringan Irigasi Tersier Sumatera Barat
2. Rekapitulasi Buku Pintar Daerah Irigasi PU, Propinsi Sumatera Barat, September 1981
3. Peta Situasi, Irigasi Tersier Sumatera Barat dari tahun 1978/1979 - 1980/1981, PU Sumatera Barat

Table 0-2 Record of Irrigation Water Use

Irrigation System		Intake Water (Lt/sec) in the Year 1982											
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1. Lubuk Lawas	Min	953	826	842	687	983	414	266	674	291	1,151	1,151	575
(458 ha)	Ave	1,085	1,049	1,062	1,067	1,041	963	497	1,064	841	1,151	1,151	1,114
	Max	1,151	1,116	1,082	1,082	1,082	1,082	1,052	1,151	1,151	1,151	1,151	1,151
2. Ulu Gadut /1	Min	-	-	-	-	-	501	-	80	99	-	-	-
(300 ha)	Ave	-	-	-	-	-	631	-	101	116	-	-	-
	Max	-	-	-	-	-	804	-	109	129	-	-	-
3. Gunung Nago	Min	2,877	3,333	3,549	2,605	4,093	2,125	1,528	1,385	1,570	2,866	2,658	2,005
(2478 ha)	Ave	4,753	5,614	5,147	4,837	5,389	4,122	2,590	2,795	3,126	5,347	4,193	4,769
	Max	7,165	7,395	6,947	7,884	6,510	6,510	4,489	5,946	7,176	7,790	6,948	5,312
4. Bandar Duku /2	Min	-	-	-	-	649	327	187	16	25	68	245	-
(75 ha)	Ave	-	-	-	-	818	889	294	158	165	94	430	-
	Max	-	-	-	-	1,027	2,942	367	279	332	129	722	-
5. Limau Manis	Min	94	488	423	334	266	266	266	217	98	47	403	272
(936 ha)	Ave	649	696	649	572	698	521	497	460	374	557	642	699
	Max	1,052	944	902	790	1,052	771	1,052	902	753	829	755	1,050
6. Sei Guo	Min	185	230	280	268	66	106	38	79	45	154	112	92
(650 ha)	Ave	346	414	392	350	245	258	114	200	134	259	197	276
	Max	664	514	490	384	532	415	309	532	364	420	415	309
7. Koto Tuo	Min	-	1,752	1,919	1,752	706	1,666	1,752	1,611	1,277	1,708	1,872	1,872
(990 ha)	Ave	-	2,002	2,155	2,043	706	2,100	2,007	1,966	1,717	1,887	1,985	1,907
	Max	-	2,167	2,167	2,167	706	2,167	2,167	2,167	2,167	2,000	2,000	2,000
8. Sei Latung /2	Min	-	-	2,677	1,404	1,352	1,300	627	528	445	836	627	627
(861 ha)	Ave	-	-	2,744	2,333	2,064	1,755	704	654	615	836	815	827
	Max	-	-	2,784	2,784	2,688	2,688	836	836	836	836	836	1,068

Min, Ave, Max : The minimum, average and maximum water intake in respective months

/1 : Free intake

/2 : No discharge measurement weir

Table 0-3 Calculation of Unit Area Irrigation Water Requirement

Mon.	Week no	Evapotranspiration Eto (mm/day)	Cc	Etc (mm/day)	Losses L1 (mm/day)	Rainfall Re (mm/day)	Water requirement Qoff (mm/day)	Qoff (l/s/ha)	Qin (l/s/ha)	Remarks
Sep.	1	-	-	-	-	-	-	-	-	
	2	-	-	-	-	-	-	-	-	
	3	-	-	-	-	-	-	-	-	
	4	-	-	-	-	-	-	-	-	
Oct.	5	3.7	1.00	3.70	7.10	5.90	4.90	0.57	0.76	Land prep
	6	3.7	1.00	3.70	7.10	5.90	4.90	0.57	0.76	
	7	3.7	1.00	3.70	7.10	5.90	4.90	0.57	0.76	
	8	3.7	1.00	3.70	7.10	5.90	4.90	0.57	0.76	
	9	3.7	1.10	4.07	5.00	5.90	3.17	0.37	0.49	Irrigation
Nov.	10	3.1	1.10	3.41	5.00	6.60	1.81	0.21	0.49	
	11	3.1	1.10	3.41	5.00	6.60	1.81	0.21	0.28	
	12	3.1	1.35	4.19	5.00	6.60	2.59	0.30	0.40	
	13	3.1	1.35	4.19	5.00	6.60	2.59	0.30	0.40	
Dec.	14	3.6	1.35	4.86	5.00	4.20	5.66	0.66	0.88	
	15	3.6	1.35	4.86	5.00	4.20	5.66	0.66	0.88	
	16	3.6	1.30	4.68	5.00	4.20	5.66	0.66	0.88	
	17	3.6	1.30	4.68	5.00	4.20	5.66	0.66	0.88	
Jan.	18	4.1	1.30	5.33	5.00	4.70	5.63	0.65	0.87	
	19	4.1	1.30	5.33	5.00	4.70	5.63	0.65	0.87	
	20	4.1	1.05	4.31	5.00	4.70	4.61	0.53	0.71	
	21	4.1	1.05	4.31	5.00	4.70	4.61	0.53	0.71	
	22	4.1	1.05	4.31	5.00	4.70	4.61	0.53	0.71	
Feb.	23	-	-	-	-	-	-	-	-	Dryoff
	24	-	-	-	-	-	-	-	-	
	25	-	-	-	-	-	-	-	-	Harvesting
	26	-	-	-	-	-	-	-	-	
Mar.	27	-	-	-	-	-	-	-	-	
	28	-	-	-	-	-	-	-	-	
	29	-	-	-	-	-	-	-	-	
	30	-	-	-	-	-	-	-	-	
Apr.	31	-	-	-	-	-	-	-	-	
	32	-	-	-	-	-	-	-	-	
	33	-	-	-	-	-	-	-	-	
	34	-	-	-	-	-	-	-	-	
	35	-	-	-	-	-	-	-	-	
May	36	3.8	1.00	3.80	7.10	3.80	7.10	0.82	1.09	Land prep
	37	3.8	1.00	3.80	7.10	3.80	7.10	0.82	1.09	
	38	3.8	1.00	3.80	7.10	3.80	7.10	0.82	1.09	
	39	3.8	1.10	4.18	5.00	3.80	5.38	0.62	0.83	Irrigation
Jun.	40	3.9	1.10	4.29	5.00	2.00	7.29	0.84	1.12	
	41	3.9	1.10	4.29	5.00	2.00	7.29	0.84	1.12	
	42	3.9	1.35	5.27	5.00	2.00	8.27	0.96	1.28	
	43	3.9	1.35	5.27	5.00	2.00	8.27	0.96	1.28	
Jul.	44	3.9	1.35	5.27	5.00	1.50	8.77	1.02	1.36	
	45	3.9	1.30	5.07	5.00	1.50	8.57	0.99	1.32	
	46	3.9	1.30	5.07	5.00	1.50	8.57	0.99	1.32	
	47	3.9	1.30	5.07	5.00	1.50	8.57	0.99	1.32	
	48	3.9	1.05	4.10	5.00	1.50	7.60	0.88	1.17	
Aug.	49	3.9	1.05	4.10	5.00	3.70	5.40	0.63	0.84	
	50	-	-	-	-	-	-	-	-	Dryoff
	51	-	-	-	-	-	-	-	-	
	52	-	-	-	-	-	-	-	-	Harvesting

Notes :
Eto : Reference crop evaporation
Cc : Crop coefficient
Etc : Crop evaporation
L1 : Water loss for land preparation and percolation
Re : Effective rainfall
Qoff : Water requirement at offtake
Qin : Water requirement at intake

Table 0-4 Estimated Irrigation Water Requirement

Month	Unit area req. (1/s/ha)	Water requirement (1/s)				
		Arau (858 ha)	Kuranji (3,489 ha)	Balimbing (850 ha)	A. Dingin (2,761 ha)	Total (7,958 ha)
Jan.	0.87	746	3,035	740	2,402	6,923
Feb.	0	0	0	0	0	0
Mar.	0	0	0	0	0	0
Apr.	0	0	0	0	0	0
May	1.09	935	3,803	927	3,009	8,674
Jun.	1.28	1,098	4,466	1,088	3,534	10,186
Jul.	1.36	1,167	4,745	1,156	3,755	10,823
Aug.	0.84	721	2,931	714	2,319	6,685
Sept.	0	0	0	0	0	0
Oct.	0.76	652	2,652	646	2,098	6,048
Nov.	0.49	420	1,710	417	1,353	3,900
Dec.	0.88	755	3,070	748	2,430	7,003

Table 0-5

Reference Crop Evaporation

Month	Ep (mm/day)	Eto (mm/day)
Jan.	4.8	4.1
Feb.	4.6	3.9
Mar.	4.8	4.1
Apr.	4.7	4.0
May	4.5	3.8
Jun.	4.6	3.9
Jul.	4.6	3.9
Aug.	4.6	3.9
Sept.	4.7	4.0
Oct.	4.4	3.7
Nov.	3.6	3.7
Dec.	4.3	3.6
(Ave.)	(4.5)	(3.8)

* Based on records at G. Nago sta.

Table 0-6

One in Five Year Rainfall

Month	1 in 5 yr rainfall (mm/day)
Jan.	4.7
Feb.	3.2
Mar.	3.2
Apr.	4.3
May	3.8
Jun.	2.0
Jul.	1.5
Aug.	3.7
Sept.	4.7
Oct.	5.9
Nov.	6.6
Dec.	4.2
(Ave.)	(3.98)

* Based on records at Tabing sta.

Table 0-7 Present Industrial Water Use

Industry	Water source	Water use (1/min)	Duration of use (hrs.)	Drainage into	Location
P.T. Kilang Lima Gunung	Arau river	2500	8	Arau river	Banuaran kec. Lubuk Begalung
P.T. Teluk Luas	Arau river	2500	8	Arau river	Jln. bay pass Lubuk Begalung
P.T. Batang Hari Baru	Arau river	2500	2	Arau river	Jln. bay pass Lubuk Begalung
P.T. M. Kelapa Lembah Karya	Flood relief channel	2000	24	Public channel	Simpang Haru
P.T. Rubber Lembah Karya	Flood relief channel	2500	10	Public channel	Simpang Haru
P.T. Pamili Raya	Arau river	2500	8	Arau river	Gurun Lawas kec. Lubuk Begalung
P.T. Semen Padang I, II	Arau river	8000	24	Arau river	Indarung
P.T. Semen Padang III, IV	Padang Besi river	6000	24	Padang Besi river	Indarung
P.T. Sumatex	Arau river	700	22	Arau river	Bandar Buat

Table 0-8 Outline of Existing Hydroelectric Power Plants

Item	PLTA Rs. Bunga	PLTA Kuranji
Intake water	1,800 l/s	2,550 l/s
Intake	Arau R.	Kuranji R.
Offtake	Arau R.	Kuranji R.
Leading channel		
Length	1,520 m	3,200 m
Depth	1.60 m	1.50 m
Width	1.60 m	1.95 m
Drop height	70 m	90 m
Turbin		
Nos	2 units	3 units
Capacity	2 x 900 l/s	3 x 850 l/s
Generator		
Nos	2 units	3 units
Capacity	2 x 550 kw	3 x 550 kw

Source : P.T. Semen Padang

Table 0-9 Monthly Rainfall in Tabing Station

(Unit : mm)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1948	450	672	379	-	-	-	-	-	-	-	-	390	-
1949	-	321	313	334	165	120	88	239	439	398	-	-	-
1950	328	170	428	476	434	-	212	578	302	474	-	255	-
1951	319	336	-	364	282	253	201	292	368	-	597	546	-
1952	473	351	334	429	346	165	-	-	460	-	487	368	-
1953	248	236	389	302	151	258	421	233	390	653	492	538	4311
1954	438	258	346	414	259	183	311	263	136	414	654	298	3974
1955	189	327	389	520	448	196	252	304	424	379	294	553	4275
1956	281	237	155	276	100	351	291	300	430	267	515	585	3788
1957	208	249	494	429	258	290	398	281	-	325	312	642	-
1958	286	-	-	-	-	253	-	578	216	-	-	-	-
1959	173	178	405	-	233	-	-	177	-	668	586	418	-
1960	358	204	184	355	134	149	502	214	-	395	329	360	-
1961	-	-	152	121	-	426	77	84	-	-	-	158	-
1962	379	180	354	-	326	-	227	-	259	-	646	-	-
1963	-	38	96	174	369	110	376	-	-	-	-	562	-
1964	497	-	-	405	301	211	-	37	349	530	-	-	-
1965	-	-	467	252	-	96	71	-	397	-	434	-	-
1966	-	386	-	-	-	-	-	-	-	-	-	-	-
1967	-	-	137	373	-	170	260	94	-	-	613	-	-
1969	-	-	-	-	-	414	192	-	304	745	643	646	-
1970	291	172	-	375	332	198	385	349	-	568	349	-	-
1971	263	200	356	241	182	360	169	514	392	331	426	705	4139
1972	187	416	247	320	782	197	213	266	264	217	706	640	4455
1973	212	215	395	390	235	445	389	277	435	293	388	411	4085
1974	251	154	153	616	387	454	183	464	598	314	566	266	4406
1975	272	333	170	373	256	126	288	319	290	311	166	315	3219
1976	161	257	178	346	105	238	352	268	349	890	465	179	3788
1977	358	297	108	295	446	192	152	147	257	476	741	434	3903
1978	493	341	312	207	388	387	467	364	398	685	247	145	4434
1979	240	329	238	525	280	307	352	224	516	416	696	190	4313
1980	276	232	363	523	278	297	254	468	355	595	807	479	4927
1981	185	313	220	557	295	99	461	177	611	891	512	311	4632
1982	195	464	661	369	189	75	154	253	286	381	369	359	3755
Ave.	297	281	301	370	295	242	275	288	369	484	502	414	4118

Source : Pusat Meteorologi dan Geofisika

Table 0-10 Relationship between Ten-day Runoff and Monthly Runoff

Month	Qiod / Qmon		
	Lb. Sarik	Lb. Minturun	Average/1
Jan.	0.71	0.72	0.71
Feb.	0.79	0.83	0.80
Mar.	0.72	0.79	0.75
Apr.	0.63	0.77	0.69
May	0.68	0.78	0.73
Jun.	0.67	0.66	0.67
Jul.	0.55	0.65	0.59
Aug.	0.66	0.63	0.65
Sept.	0.74	0.73	0.73
Oct.	0.56	0.58	0.57
Nov.	0.70	0.53	0.62
Dec.	0.69	0.54	0.62
Average	0.68	0.68	0.68

Notes

Qiod : Average of minimum ten-day runoff in each month (m^3/s)

Qmon : Average of monthly runoff (m^3/s)

/1 : Weighted average against member of data

Table 0-11 Present Water Balance

Month	Rain fall at Tabing (mm/mon)	Lb. Sarik		Gn. Nago		S. Guo		Lb. Minturun	
		Qr (m^3/s)	Qa (m^3/s)	Qr (m^3/s)	Qa (m^3/s)	Qr (m^3/s)	Qa (m^3/s)	Qr (m^3/s)	Qa (m^3/s)
Jan.	193	1.23	3.58	3.26	6.05	0.74	0.55	2.40	5.13
Feb.	180	0.49	3.34	0.22	5.64	0	0.52	0	4.79
Mar.	155	0.49	2.88	0.22	4.86	0	0.45	0	4.12
Apr.	271	0.49	5.03	0.22	8.50	0	0.78	0	7.21
May	175	1.42	3.25	4.02	5.49	0.93	0.50	3.01	4.65
Jun.	126	1.59	2.34	4.69	3.95	1.09	0.36	3.53	3.35
Jul.	166	1.65	3.08	4.97	5.20	1.16	0.48	3.76	4.41
Aug.	177	1.21	3.29	3.15	5.55	0.71	0.51	2.32	4.71
Sep.	268	0.49	4.98	0.22	8.40	0	0.77	0	7.13
Oct.	314	1.14	5.83	2.87	9.84	0.65	0.90	2.10	8.35
Nov.	337	0.91	6.26	1.93	10.56	0.42	0.97	1.35	8.96
Dec.	259	1.24	4.81	3.29	8.12	0.75	0.74	2.43	6.89
D.A. (Km^2)			64		120		11		116
K-value			0.0273		0.0461		0.00422		0.0391

Notes

Qr : Water requirement

Qa : Available Water (= (Rainfall at Tabing) x K x 0.68)

K : Qa / (rainfall at Tabing)

Table 0-12 Historical Paddy Field in Kodya Padang

District	Net paddy field (ha)			
	1966	1969	1980	1983
Kota lama	737	737	600	503
Padang Barat	6	6	0	0
Padang Timur	302	302	278	278
Padang Utara	342	342	241	144
Padang Selatan	87	87	81	81
Kec. Koto Tangah	2,083	2,083	2,083	2,083
Kec. Nanggalo	310	310	434	432
Kec. Kuranji	2,118	2,118	1,993	1,993
Kec. Pauh	1,141	1,141	1,167	1,167
Kec. Lb. Begalung	831	831	835	835
Kec. Lb. Kilangan	584	584	596	596
Kec. Bungus Tl. Kabung	735	735	795	789
Kotamadya Padang	8,539	8,539	8,503	8,398

Source : Dinas Pertanian Tanaman Pangan, Daerah Tingkat II, Padang

Table 0-13 Municipal and Industrial Water Demand

Items	Year	1985	1995	2005
House connection				
Population (per.)		193,228	318,699	524,303
Unit demand (1/c/d)		125	140	150
Demand (m^3/d)		24,153	44,618	78,645
Public taps				
Population (per.)		126,549	226,662	314,492
Unit demand (1/c/d)		30	30	30
Demand (m^3/d)		3,796	6,800	9,435
Non-Domestic				
Demand (m^3/d)		9,035	14,349	30,108
GROSS DEMAND (m^3/d)		(36,984)	(65,767)	(118,188)
Uncounted-for water				
% of grose demand		38	29	17
Quantity (m^3/d)		13,974	18,952	20,427
NET PRODUCTION (m^3/d)		(50,958)	(84,719)	(138,615)
Internal use				
% of total production		7	5	5
Quantity		3,836	4,459	7,296
TOTAL PRODUCTION				
(m^3/d)		54,794	89,178	145,911
(1/s)		634	1,032	1,689

Source : Feasibility Report on Padang Water Supply Project, Nov. 1982, DGCK.

Table 0-14 Calculation of Annual Production of Electricity

Power plant		Discharge (m^3/s)	Duration (day)	Head loss h1 (m)	Head loss h2 (m)	Head loss h3 (m)	Effect. head (m)	Output (kw)	Annual Product (MWh)	Total Annual Product (MWh/yr)
LIMAU MANIS -1										
Total head	: 11.6 m	0.75	75	0.22	0.74	0.10	10.54	58.1	105	
Leading chan. length	: 217 m	0.74	20	0.22	0.72	0.09	10.57	57.5	28	
Penstock length	: 21 m	0.67	85	0.22	0.59	0.08	10.71	52.7	108	
Penstock diameter	: 0.50 m	0.52	95	0.22	0.36	0.06	10.96	41.9	96	
		0.35	70	0.22	0.16	0.04	11.18	28.8	48	385
LIMAU MANIS -2										
Total head	: 11.0 m	0.75	75	0.36	0.71	0.11	9.82	54.1	97	
Leading chan. length	: 358 m	0.74	20	0.36	0.69	0.11	9.84	53.5	26	
Penstock length	: 20 m	0.67	85	0.36	0.56	0.09	9.99	49.2	100	
Penstock diameter	: 0.50 m	0.52	95	0.36	0.34	0.07	10.23	39.1	89	
		0.35	70	0.36	0.15	0.05	10.44	26.9	45	357
GUNUNG NAGO LEFT										
Total head	: 5.2 m	2.04	75	0.25	0.15	0.04	4.76	71.4	128	
Leading chan. length	: 250 m	2.04	20	0.25	0.15	0.04	4.76	71.4	34	
Penstock length	: 10 m	1.85	85	0.25	0.13	0.04	4.78	65.0	133	
Penstock diameter	: 0.85 m	1.39	95	0.25	0.07	0.03	4.85	49.6	113	
		0.89	70	0.25	0.03	0.03	4.89	32.0	54	462
GUNUNG NAGO RIGHT										
Total head	: 6.8 m	2.35	75	0.30	0.20	0.05	6.25	108.0	194	
Leading chan. length	: 301 m	2.35	20	0.30	0.20	0.05	6.25	108.0	52	
Penstock length	: 13 m	1.98	85	0.30	0.14	0.04	6.32	92.0	188	
Penstock diameter	: 0.90 m	1.30	95	0.30	0.06	0.04	6.41	61.2	140	
		0.83	70	0.30	0.02	0.03	6.45	39.3	66	640

Fig. 0-1 Existing Irrigation Systems

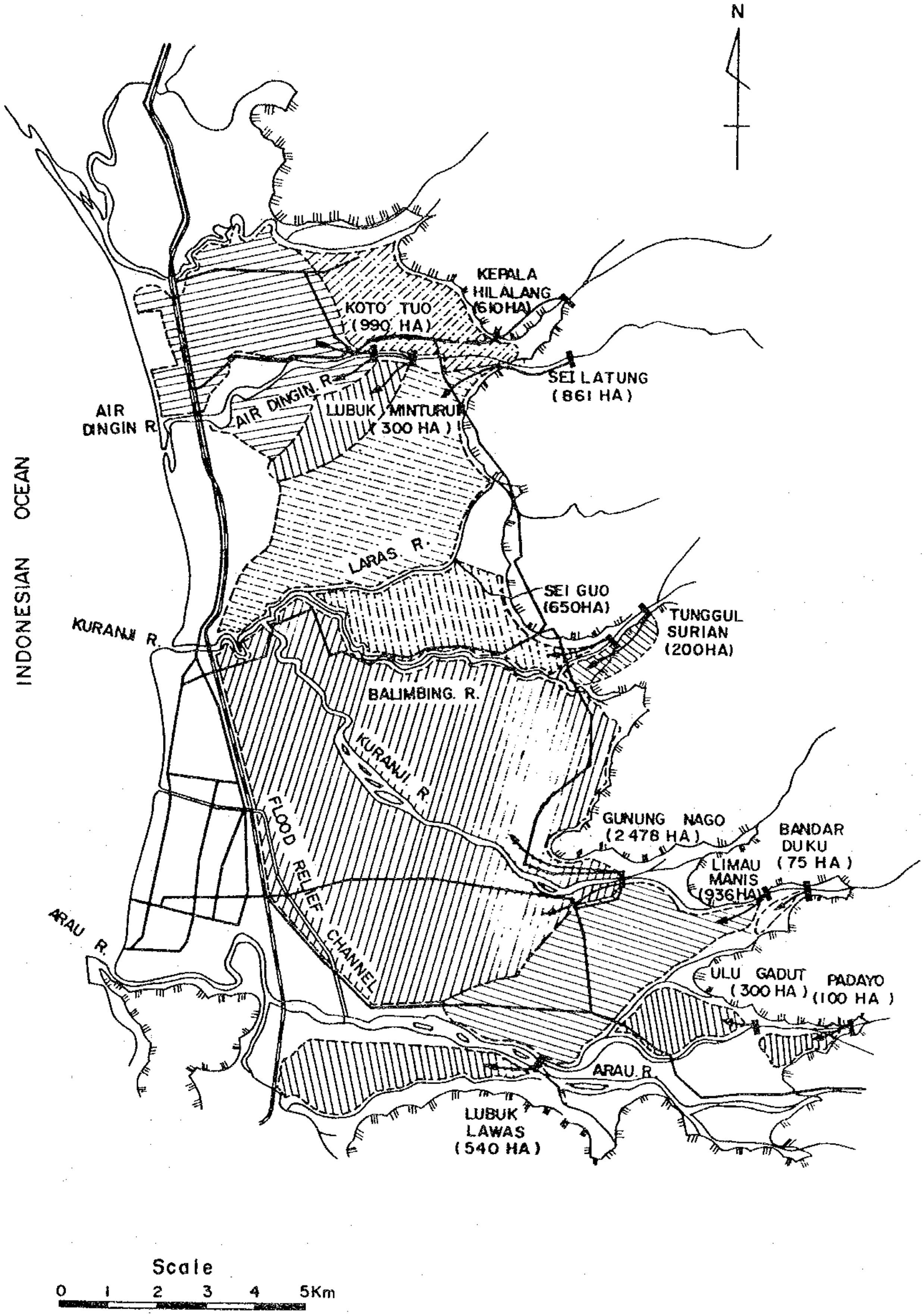
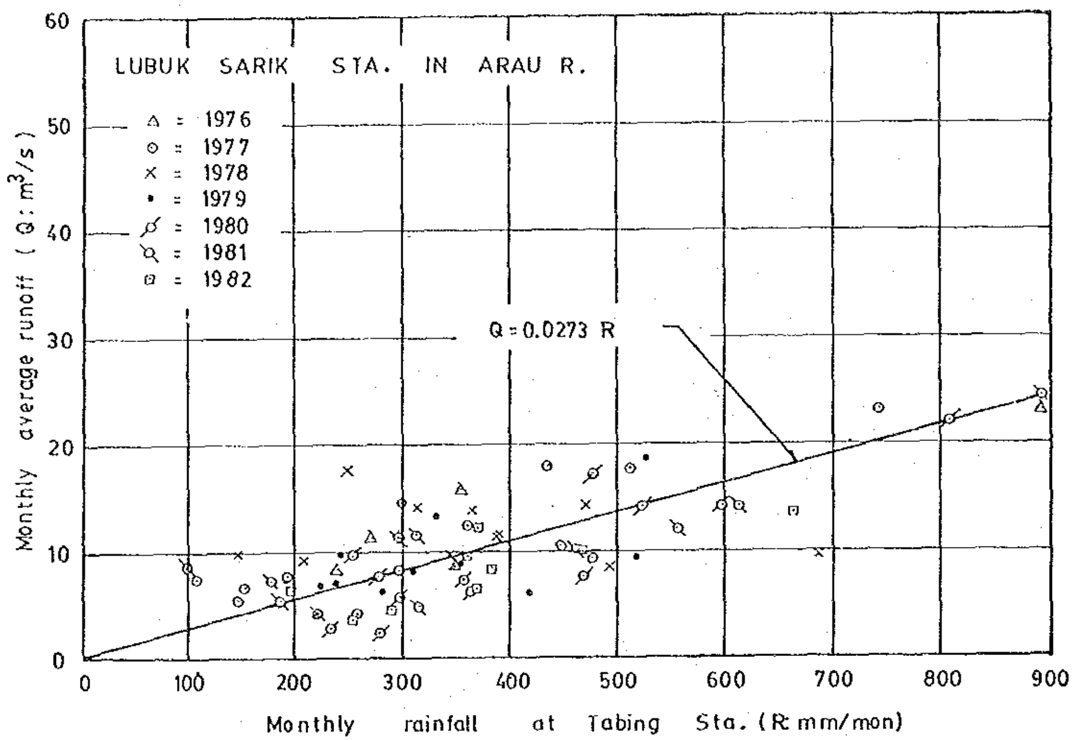


Fig. 0-2(1) Relationship between Monthly Rainfall and Runoff



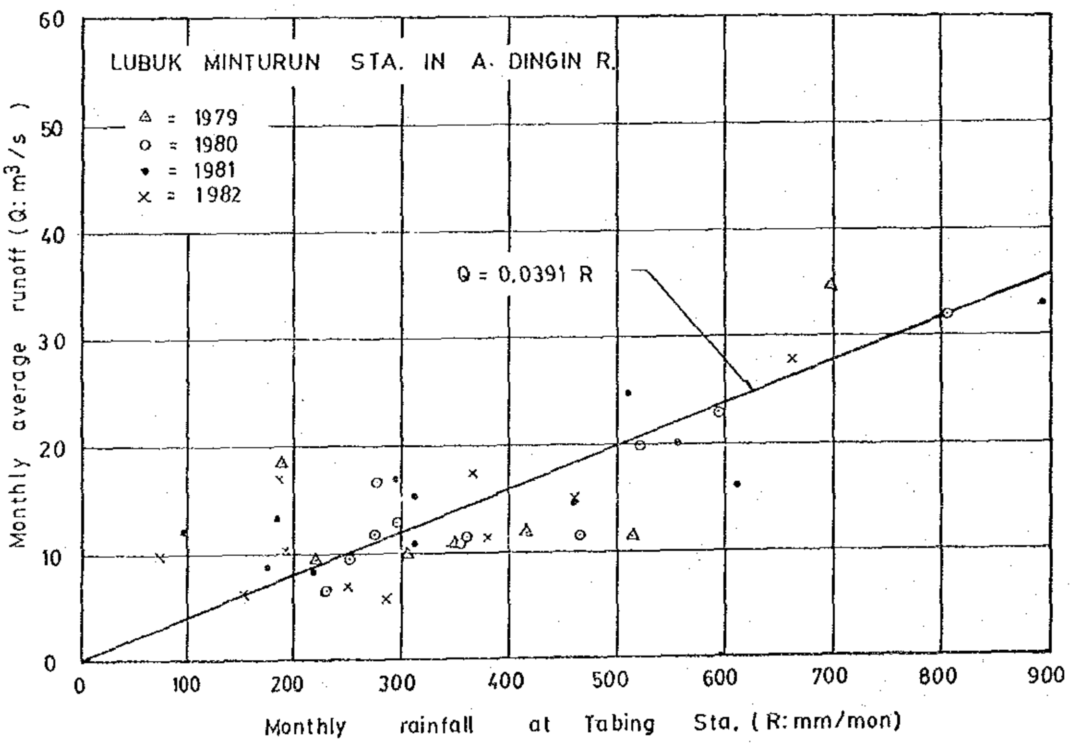


Fig. 0-2(2) Relationship between Monthly Rainfall and Runoff

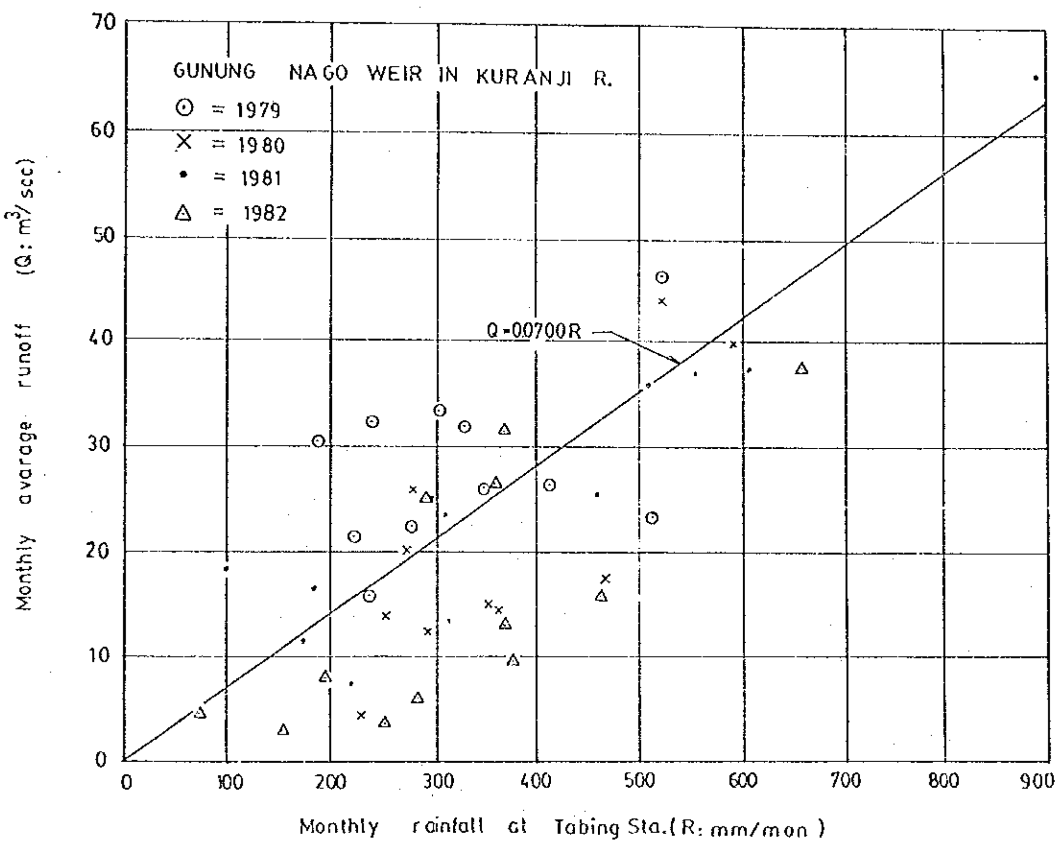


Fig. 0-3 Present Water Balance

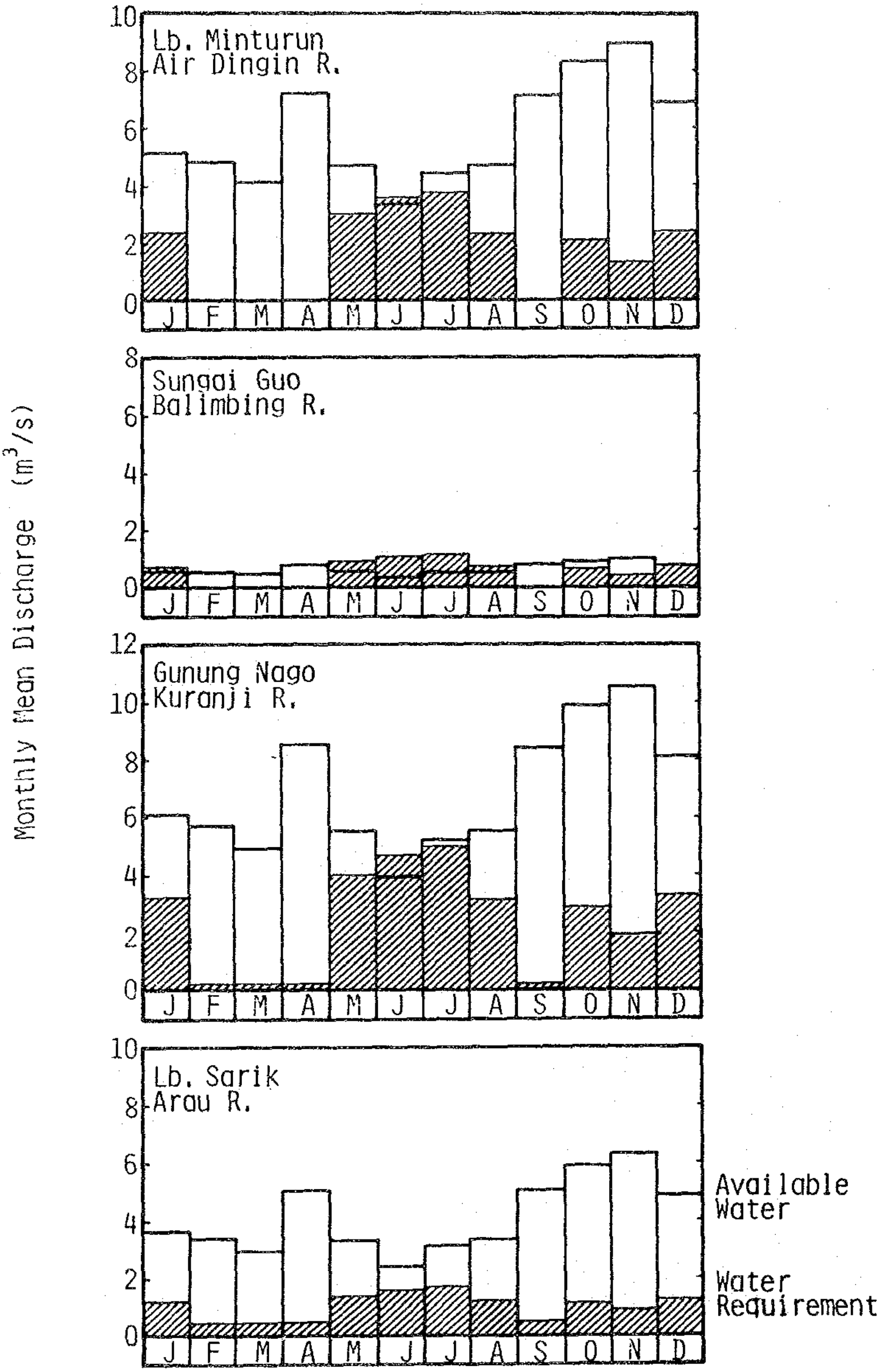


Fig. 0-4 Longitudinal Profile of Limau Manis Irrigation Canal

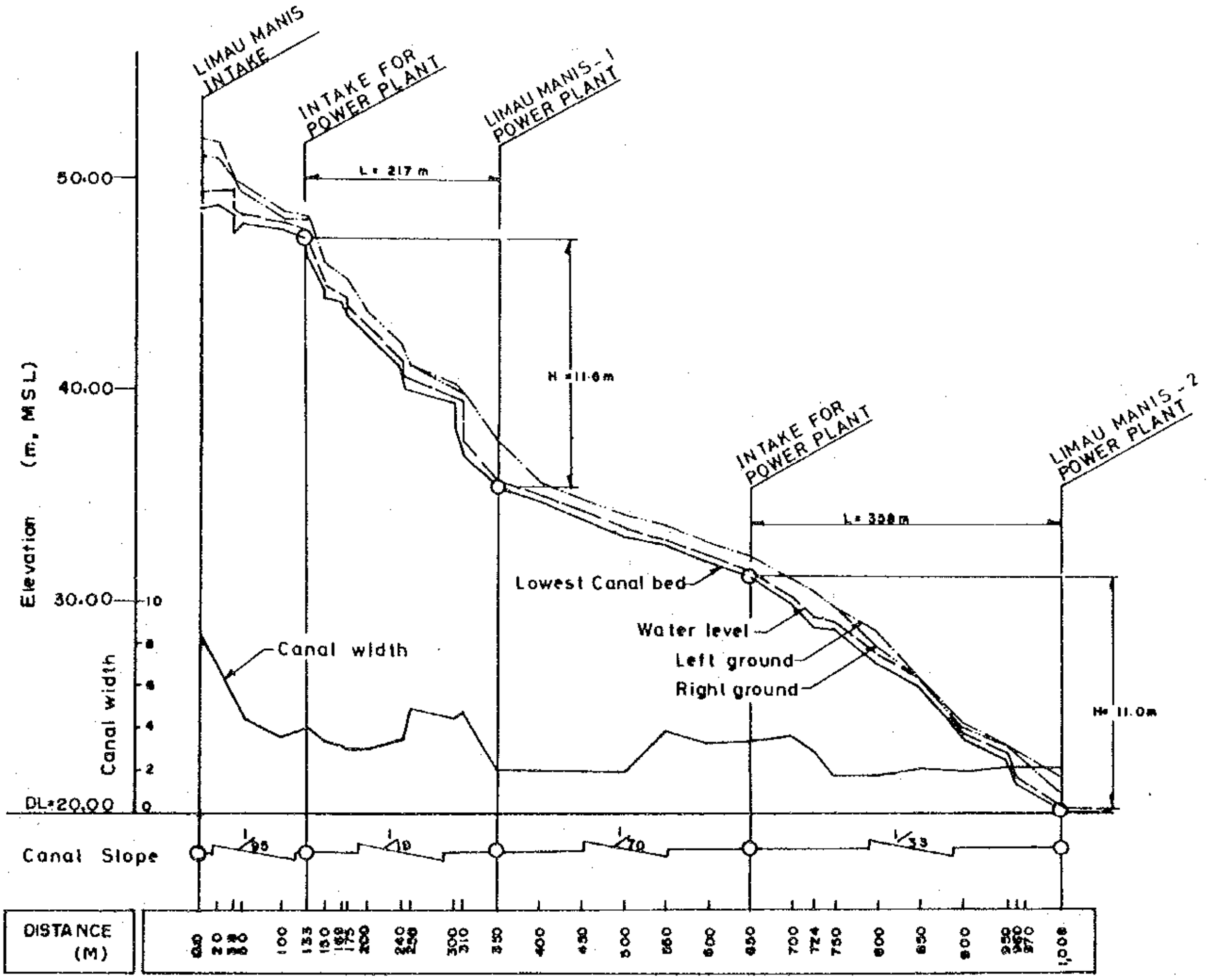


Fig. 0-5 Longitudinal Profile of G. Nago Left Irrigation Canal

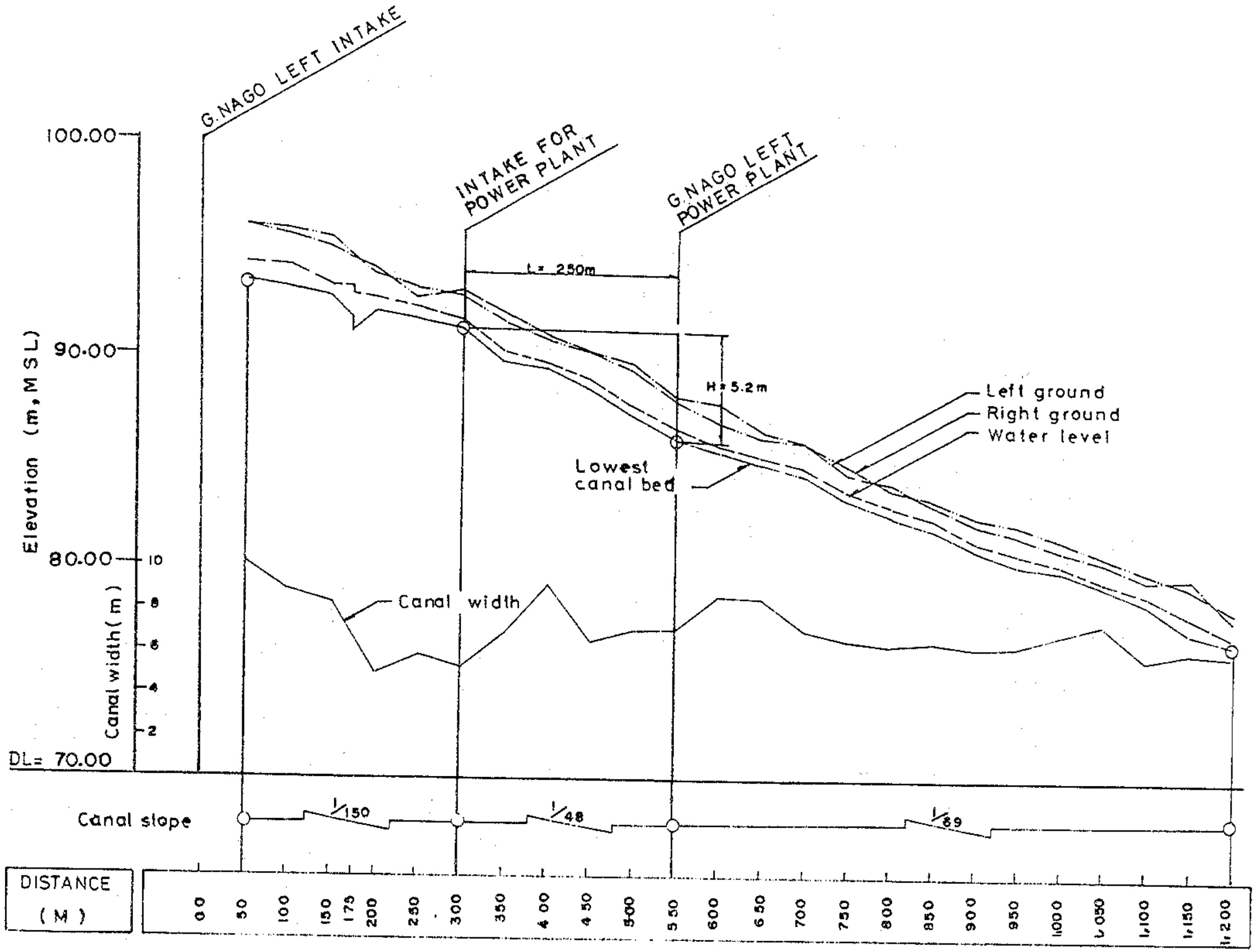


Fig. 0-6 Longitudinal Profile of G. Nago Right Irrigation Canal

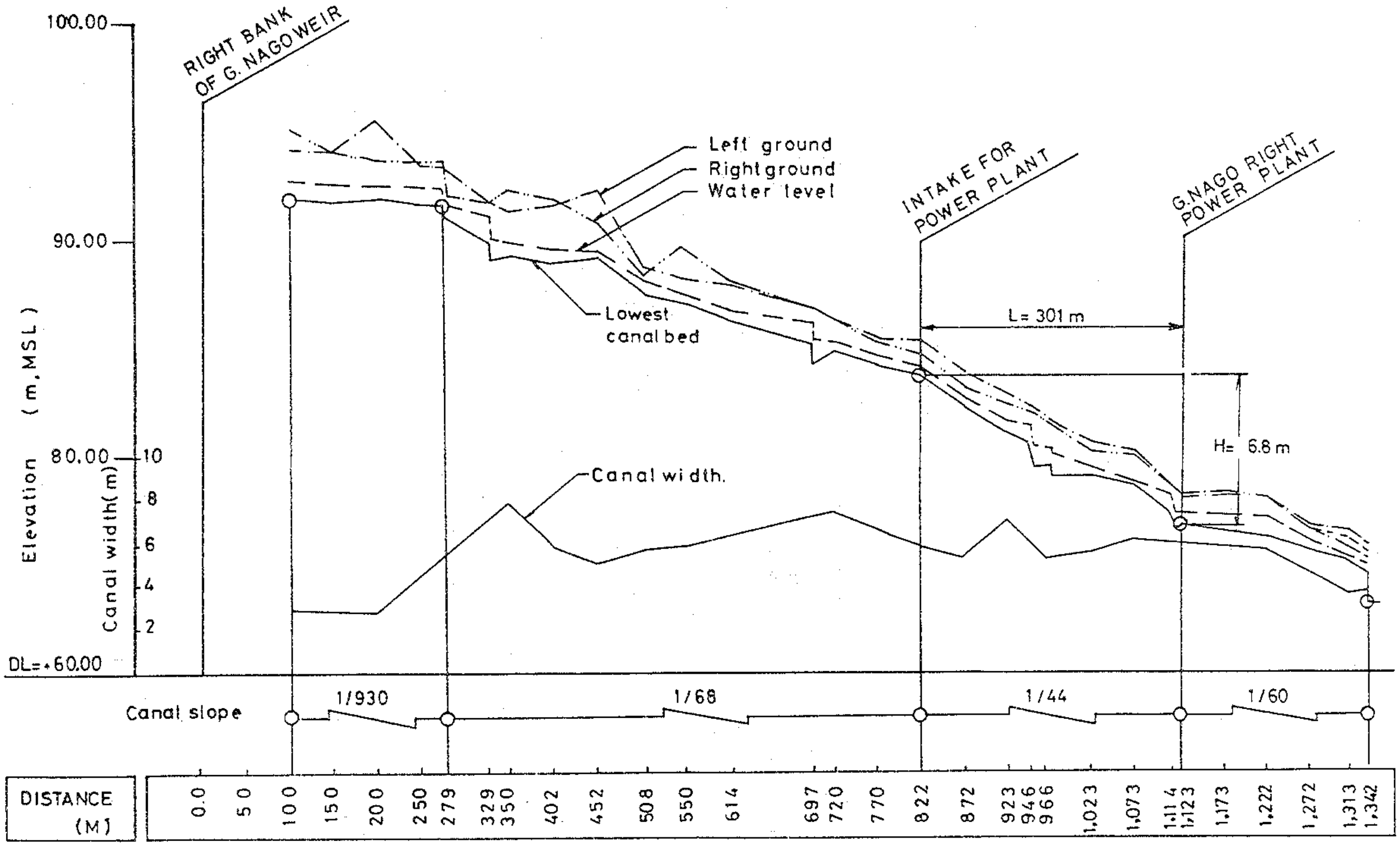
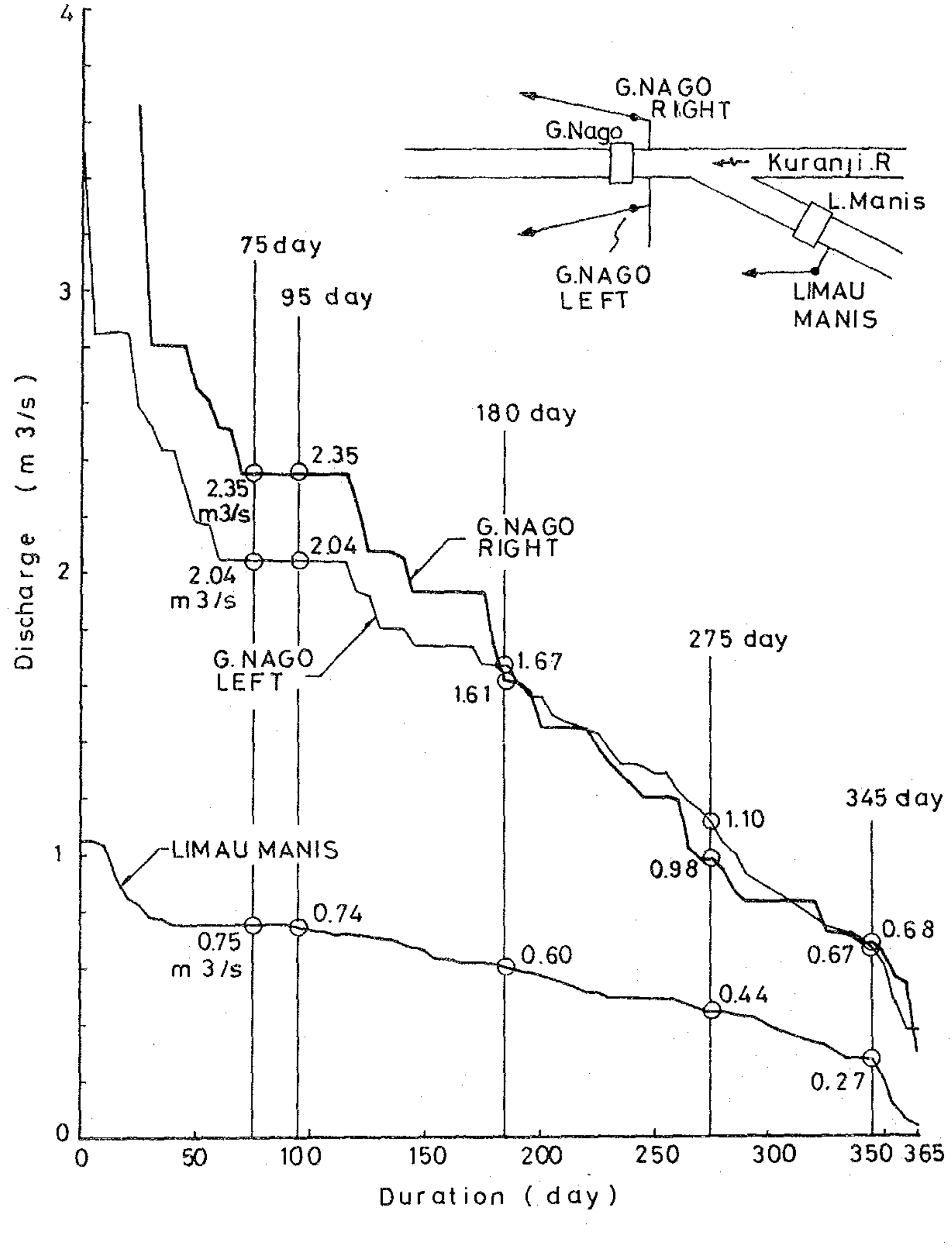


Fig. 0-7 Flow Duration Curve at Potential Mini-hydro Power Sites



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