ANNEX III : MORAGAHAKANDA DAM

ANNEX III. MORAGAHAKANDA DAM

3.1 Suitable Layout of Main Structures

A comparative study to seek the most suitable layout of the dams and other main structures is made among four alternatives all to keep H.W.L. at El.195 m. These alternatives are prepared in conformity with the design criteria as shown in the attached Table III.1.

UNDP/FAO Master Plan envisaged the main dam of concrete, the first saddle dam of rockfill, the second saddle dam of earthfill, the spillway to be provided in the middle part of the main dam and the powerstation just at the foot of the main dam. In this plan, the second saddle dam is designed to have the axis in "S" shape. Since the alignment of dam axis protruding toward downstream is not favorable and the rock material for the embankment is available in a close distance, the design of the second saddle dam is reviewed on the dam axis and the type. In order to select the best dam axis and the type, three alternative lines as shown in DWG. No.III.2 including UNDP/FAO proposal are compared first in the section of rockfill dam. The attached Table III.3 shows that the work quantities of the main items would be the least on the B-line about 200 m upstream of the UNDP/FAO proposal. A comparative study on the types of the second saddle dam between earthfill and rockfill is done along the B-line and the result reveals that the rockfill type is more economical in the second saddle dam, as seen in the attached Table III.2.

Four alternative layouts of the main dam and the first saddle dam including UNDP/FAO Plan are compared in the construction cost for main items.

Alternative 1 (layout as referred to DWG. No.III.3): this is UNDP/FAO Plan reviewed to the design criteria set forth in Table III.1. consisting of the main dam of concrete gravity and the first and second saddle dams of rockfill and providing the spillway on the main dam and the powerstation at the foot of the main dam. The construction is planned to commence on the right bank by coffering the Amban Ganga in the earlier stage and then on the left bank after the provision for by-passing the river on the right bank is ready.

Alternative 2 (referred to DWG. No. III.4): this comprises of the main dam of rockfill, the first saddle dam of concrete gravity, the spillway on the first saddle dam and the powerstation at the foot of the first saddle dam. The diversion canal is dug along the valley of the first saddle dam for the construction. By this diversion canal the construction will become far easier than that in the Alternative 1 in view of that

i. the construction of dam foundation can be made in dry and spacious conditions,

ii. uncertainty of water tightness in river deposit involved in the coffering of the Amban Ganga in the Alternative 1 will be dissolved or the countermeasure can be taken far easier,

iii. and adjustment against delay in the works and quality control of the works will be made easier and more quickly than in the Alternative 1.

Furthermore, there is another merit that the countermeasure against unexpected seepage through dam foundation can be taken easier in the concrete dam than in the rockfill, even if it would happen through limestone strata on the left bank of the first saddle dam.

Alternative 3 (referred to DWG.No.III.5): all dams of rockfill type, spillway on a ridge between the main and first saddle dams and powerstation at the right bank just downstream of the main dam. Two tunnels of 12 m diam. are planned on the right bank for diversion of 20 year flood and one of them is utilized as the waterway to the powerstation.

Alternative 4 (referred to DWG.No III.6): this consists of three rockfill dams same as the Alternative 3, and, however, the axis of the main dam is moved up and the first saddle dam moved down. The spillway is provided on the hill slope between the main and first saddle dams and the diversion tunnels are driven into the ridge on the left bank of the main dam, the powerstation being located on the left bank downstream of the main dam utilizing one of the diversion tunnels. This entails shorter tunnels than the Alternative 3 and consequently smaller construction cost.

The result of comparison among four Alternatives is tabulated as seen in the attached Table III.4. In this table the following items which are considered common or insignificant difference among the Alternatives are not included in the account: power house, generating equipment, intakes and grouting into the dam foundation.

The Table III.4 indicates the Alternative 2 the most economical and therefore, further study on the dam and main structures and on the optimal scale of dam will be done along the layout of Alternative 2.

3.2 Irrigation Dam

The attached DWG.No. III.7 shows a layout of the irrigation dam and the incidental facilities. The layout does not include power generating equipment and powerhouse, but two sets of intake facilities to release irrigation water. Each system has the intake with a screen and roller gate, a steel pipe line and a hollow jet valve discharging the water into the stilling basin of spillways. The sill of intake is set at El.150 of 100-year silt sediment surface and the L.W.L. is taken at El.154 m (505'). The design discharge of each intake is taken at 28.3 m^3/sec (1,000 cusec) under the L.W.L. The H.W.L. is chosen at El.188 m to secure the required storage capacity of 606 million cubic meters (mcm). The crest elevation is at 190.7 m in non-overflow section of the first saddle dam and at 192.2 m at the main and the second saddle dams. The approximate construction cost is estimated as shown in a column "Scheme No.1" of the attached Table III.6.

3.3 Power Schemes

In case the hydropower development is incorporated in the Project, the cost of Irrigation Dam stated in the previous section is considered to be borne by the Irrigation sector of the Project and only the increment of cost, which is entailed by providing generating facilities and heightening the dams, is taken into account when the viability of the power scheme is examined. The power schemes subject to the comparative study for seeking the optimal scale of the Project are tabulated in the attached Table III.5.

Scheme No.2 consists of one unit of generating equipment of 22.5 MW. This is planned to generate power by the water released for the irrigation requirements under the head obtained by the Irrigation Dam. In this case, the generating equipment is designed to work under the higher waterlevel than El.165 m of the reservoir, because of difficulty in design of water turbine to run efficiently under such a wide range of head from 10 m to 44 m. The turbine conceivable in this case is to work under the head from 21 m to 44 m and maximum discharge at 56.6 m^3/sec. Irrigation intake system is left as designed in the Irrigation Dam.

When are introduced the other power schemes than the Scheme No.2 above, the irrigation intake facilities are not provided since the irrigation water is discharged through the turbines. The river outlets, however, are provided in the first saddle dam for release of water in such case as inspection or repairing on the generating equipment or stoppage of the powerstation for some reasons. Schemes No.3 and No.5 have the generating equipment designed to the maximum discharge of 56.6 m^3/sec which corresponds just to the maximum capacity of Elahera - Minneriya Canal downstream and causes no provision of regulation pond downstream of the powerstation. Schemes No.4 and No.6 are the peak powerstation of 4 hours operation which are considered as the maximum scale of installed capacity in the respective schemes. These two schemes entail construction of regulation pond (afterbay) to regulate the peak discharge from the powerstation to the maximum capacity of Elahera - Minneriya Canal.

Approximate construction cost in each scheme is tabulated in the attached Table III.6 together with the Irrigation Dam.

3.4 <u>Elahera Afterbay</u> (No consideration to NCP Canal)

As described in the previous section, the Scheme No.4 and No.6 entail the construction of the afterbay to regulate the peak discharge from the powerstation down to 56.6 m^3/sec corresponding to the maximum capacity of the existing Elahera - Minneriya Canal. The peak discharge from the powerstation is worked out 114 m^3/s (3,228 cusec) in the Scheme No.4 and 165 m^3/sec (4,672 cusec) in the Scheme No.6 the duration being about 4 hours in both cases.

The capacity of the afterbay required for the regulation is calculated at 2,450,000 m^3 in the Scheme No.4 and at 3,140,000 m^3 in the Scheme No.6. The weir of the afterbay can be built just downstream of the existing Elahera diversion weir. The outline of the afterbay weir are as follows:

	Scheme No.4	Scheme No.6
H.W.L. (El. m)	143.4	144.6
L.W.L. (El. m)	138.7	138.7
Effective capacity (m^3)	2,450,000	3,140,000
Crest El. of weir (m)	147.8	149.0
Height of weir (m)	17.8	18.8
Length of weir (m)	1,000	1,100
(Spillway section m)	(200)	(200)
Crest El of Spillway (m)	143.4	144.6
Type of spillway	Non-gated, free overflow type	
Design flood (m^3/sec)	3,400	
Irrigation intake	Overflow weir with 1-flapgate 20 m wide x 3 m high	
Approximate cost (Million US$)	14.6	17.1

A sketch of the weir envisaged is shown in Fig.III.2.

3.5 Optimal height of the Dam

An optimal height of the Dam is judged upon the comparison between the incremental cost and the benefit available in the power schemes.

The construction cost in each alternative scheme is approximately estimated as given in the attached Table III.6. Tentative disbursement of the incremental construction cost from the Irrigation Dam is scheduled and the present worth of the cost for the power sector (capital plus O & M cost) is calculated on the basis of a discount rate of 10 % and economic life of 35 years for the generating equipment and 50 years for other structures. The power benefit is also computed as the present worth of the cost of thermal plant with a scale to the dependable peak output and the energy production of the hydroplant, the economic life of the thermal plant being taken for 25 years.

The economic comparison among the power schemes are shown in Table III.7. As seen in the above Table, the Scheme No.3 indicates the most promising in the net benefit among the alternatives. Further study, therefore, will be made in the scale of Scheme No.3, i.e. the H.W.L. of the Reservoir at El.195 m (640').

3.6 Kongetta Oya Afterbay

As described in the Main Report, a heavy burden of investment to the Elahera Afterbay spoils an economic viability of development of the Moragahakanda Powerstation as peak powerstation, and it is concluded that the best is to install one unit of 26 MW without the afterbay.

UNDP/FAO's Master Plan proposed the development of the NCP Area with the water from the Moragahakanda Reservoir. The released water was planned to be carried on the NCP Canal with the headworks built around the existing Elahera Anicut.

When the NCP Canal is taken into consideration, a consideration comes up whether a suitable site for the afterbay along the NCP Canal can be found. Topography around the Kongetta Oya about 5 km of the Moragahakanda Dam seems like to be good. Hereinafter described is a study on a possibility of an afterbay on the Kongetta Oya (called the Kongetta Oya Afterbay against the Elahera Afterbay) and consequently, a possibility of development of peak powerstation.

Unless the development of peak powerstation is incorporated, there are two alternatives conceivable for intake of the NCP Canal: one is to build a diversion weir around the existing Elahera Anicut and the other to construct a diversion weir just downstream of the Moragahakanda Powerstation with the longer canal by 1.6 km.

To compare the above alternatives, a point is chosen on the proposed NCP Canal route where the waterlevel is coincided between them. The point is just downstream of the Kongetta Oya to which a distance along the Canal route is measured at 4.6 km from the Elahera Weir and at 6.2 km from the Moragahakanda Weir. Construction costs, though roughly estimated, are worked out and compared as follows:

Alternative	Construction Cost (million US$)
i. Elahera Weir (refer to Fig.V.3)	14.6
Canal 4.6 km, concrete lined	5.4
Total	20.0

ii.	Moragahakanda Weir	8.1
	Canal 6.2 km, gentler slope	8.0
	Total	16.1

This means that the NCP headworks had better to consist of the Moragahakanda Weir plus the longer canal. The cost increment arising from construction of the Kongetta Oya Afterbay will be considered as a balance between the cost for the Moragahakanda Weir with the longer canal and that of the Kongetta Oya Afterbay.

The Kongetta Oya Valley has a spacious depression around El. 140 - 142 m (450'- 460'). Stage-available capacity relation as shown in Fig. III.4 indicates that the required capacity of 2.45 MCM for regulation of the peak discharge of 113 m^3/s to 56.6 m^3/s can be taken between El. 141.5 m and El. 139.8 m. A schematic illustration of the Kongetta Oya Weir, the Moragahakanda Weir and the widened canal is given in Fig.III.4.

The construction cost of the Kongetta Oya Afterbay is estimated at the preliminary planning level.

Items	Cost (million US$)
Moragahakanda Weir	8.5
Wide Canal of 3.2 km capable for 113 m^3/s	5.1
Kongetta Oya Afterbay	8.3
Total	21.9

The cost increment for the Kongetta Oya Afterbay is worked out as follows:

i. Kongetta Oya Afterbay, including the Moragahadanda Weir and 3.2 km wide canal = 21.9 million US$

ii. Moragahakanda Weir plus 6.2 km canal for 56.6 m^3/s = 16.1 million US$

iii. Cost increment for the Afterbay = 5.8 million US$

The peak powerstation is designed to install two units of 26 MW, the maximum discharge through which becomes 113.2 m^3/s. The generating unit is considered same design as that in the optimal scale. Available power from this peak powerstation is estimated as follows:

Dependable peak power	33.4 MW
Annual energy output	153.1 GWh

A financial evaluation of the peak powerstation is made in the assumptions as follows:

1. Future generating unit will be commissioned in the beginning of year 1992, and
2. All energy produced in the station will become salable.
3. Other conditions can be taken as same as in the optimization study, such as discount rate 10%, evaluation period 50 years since 1980, economic life 25 years of thermal, 35 years of hydroplant etc.

The calculation is shown in Table III.8. The result reveals that the peak powerstation with two units of generating equipment each of 26 MW will be economically viable in case that the NCP canal will be constructed in future. The last column indicates a case that the future unit would not be installed.

The conclusions drawn from the study are that a stage development of the Moragahakanda Powerstation is very promising and therefore, a provision necessary for installation of future unit should be made at the first stage. The provision will include the following works:

1. power intake with screen, guide metal of gate, and hoist deck,
2. penstock just upstream of main turbine valve and a blind cover,
3. draft tube of future unit and blind cover, and
4. space of generator bay.

Since the study is made on the topographical maps of 1 inch to 4 chains, perhaps by aerial mapping, the result is of a preliminary nature. Further investigations and study at least at feasibility study level are required before implementation.

3.7 Construction Plan and Time Schedule

The construction plan is established on the basis that all works involved in the construction of the Moragahakanda Dam and Powerhouse will be made by the hand of well experienced and competent contractors who can manage the construction well and mobilize enough forces of construction equipment and plants as well as necessary labour.

Access to the site from the port Colombo can be made on the existing highways. Almost all of the equipment and materials will be carried through the route A-6 to Dumbulla and A-9 to Nalanda and a provincial road to the site, while the cement will be transported from Kankesanthurai through the route A-9.

As the critical path of whole works is on the installation of aggregate and concrete plants, excavation of diversion channel, concrete placing of first saddle dam up to some height, construction of primary cofferdams, excavation of riverbed, embankment of main cofferdam and embankment of the main dam, as shown in DWG No. III.8.

In establishing the time schedule the main points taken into consideration are as follows:

i. To perform with a constant force of equipment as far as possible such earth moving works as excavation of all kinds and embankment,

ii. To make coffering on the riverbed in the beginning of dry season i.e. April and construct the main cofferdam within a dry season,

iii. To limit embankment of core zone within the dry season, while the embankment of rock and filter can be done for whole year round and

iv. To place concrete of the first saddle dam with steel trestle and movable jib cranes running on the trestle, because of difficulty in installation of cable crane.

The materials such as earth for core zone, sand for filter and fine aggregate of concrete, rock for embankment and coarse aggregate of concrete are planned to be taken from the sites as shown in DWG.No.III.1. Rockfill materials of the second saddle dam will be taken mainly from the excavation in the diversion channel. Proposed quarry Q-I is main source of rock materials both for the main dam rock zone and coarse aggregate of concrete. The earth materials for core zone will be collected by bulldozer and loaded by wheel loader, because available layer is so small as 1.8 to 2.5 m. Massive and thick deposit of the earth materials are not found around the damsite. The river sand will be dredged up by pump barge.

Construction roads of about 15 km in total length with 6 m effective width will be required within the site. Three bridges, one accross the Amban Ganga downstream of the junction with the diversion channel and other two across the diversion channel will be needed.

Major construction equipment and plants envisaged are listed in Table III.9 and main construction materials required are summarized in Table III.10.

The cement will be transported with the contractor's own carriers from a cement factory at Kankesanthurai in a distance of 317 km. The fuel and lubricants will also be transported with contractor's own tankers from an oil refinary at Kelaniya in a haul of 190 km.

Power for construction use is considered to be generated by the contractor's generator at the site. An installation of 2,250 kW in total will be required.

Timber will be available in the vicinity of Kandy City about 80 Km far from the damsite. The explosives and the reinforcement steel bars are considered available in Colombo, while all structural steel are presumed imported from abroad.

Closure of diversion conduits is scheduled in the beginning of the wet season i.e. October, because the available runoff in the dry season is required for the existing farm land of 40,000 ha. The behaviors of waterlevel of the Reservoir are studied in such a condition as mentioned above, as shown in Section 7.2. The results reveal that an advance impounding of the Reservoir will not be recommendable, because of so quick rise of the waterlevel as 3 to 4 months to reach the H.W.L. when the runoff is comparatively rich.

3.8 Cost Estimate and Investment Schedule

The construction is proposed to be performed principally on the basis of international competitive bidding except for construction of relocated highway and administrator's quarter which are proposed to be done by the local contractors.

The works subject to international bidding will be divided as follows:

1. Civil works
2. Hydromechanical works
3. Generating equipment and transmission line

Maximum use of locally available materials and labour is considered. Cement, reinforcement steel bars, timbers, fuels and lubricants and explosives with detonators are considered available in the local market. Operators of equipment and plants, formen of all categories and unskilled laborers are assumed locally available.

The costs of basic items of materials and labour, on which the unit cost estimate is based, are listed in Table III.11. The materials will be carried to the site with the contractor own carriers from the place where they are available.

Almost all of the construction equipment and plants, hydromechanical works, generating equipment and accessaries, structural steel, concrete admixture and other materials imported by the contractors will be unloaded at Colombo Port and transported by the contractor's carriers to the site.

A summary of the construction cost estimate is shown in Table III.12 and the details on unit price - work quantity basis are given in Table III.13.

The unit costs include all expenses of materials; fuel and lubricants; depreciation, repairing and maintenance of construction equipment and plants; labour required for the work; transportation charges of goods and equipment and overhead and general expenses of the contractors, but no taxes, duties levies, social impositions and the like are included.

Physical contingency is provided at a rate of 10 % of total sum of civil works and hydromechanical works in order to cover uncertainty of local conditions, but no provisions for price escalation are included.

The local currency component are estimated to cover locally available materials and labour, the foreign component will cover all expenses of imported equipment and plants, materials and contractors' staff, engineers and technicians.

Based upon the construction time schedule, an investment schedule is worked out as shown in Table III.14. In an assumption that the future unit of 26 MW is completed by the end of year 1990, a tentative investment schedule of only incremental cost for power sector including the Kongetta Oya Afterbay is prepared as given in Table III.15 for the financial analysis of the stage development.

Table III.1 Design Criteria of Dams for Alternative Study

1. Freeboard:

The following formula are applied, and the bigger is taken as the freeboard:

H_1 = hw + he + ha + hi, or

H_2 = hw + ha + hi + Δ h

where,

H_1:H_2: Freeboard above normal high water level,

hw: Height of wind due to wind, including the up-rushing on the slope of dam,

he: Height of wind due to earthquake

ha: Allowance against mis-operation of spillway gates (usually 0.5 m)

hi: Allowance for type of dam (1.0 m for fill type and nil for concrete dam)

Δh: Surcharge from the high water level against design flood

In this project, the following are adopted in the calculation:

Wind velocity (10-min average) = 20 m/s

Fetch of dam = 9 Km

Seismic coefficient = 0.05

2. Design flood:

For spillway design: 1.2 times the 200-year probable flood both in the peak discharge (4,654 m^3/sec) and total run-off of 348 million cubic meters.

For river diversion during construction: 2,500 m^3/sec of 20-year probable flood during flood season and 570 m^3/sec (recorded max) in dry season from April to October.

3. Excavation line for foundation of dams: to be drawn according to the geological profile as shown in DWG.No.D-002 attached to the Main Report.

4. Embankment materials: Borrow area and rock quarry as shown in the attached DWG.No.III.1. Engineering properties of the materials for stability analysis of dams are as follows:

Classification	Specific gravity	Water content	Density, dry	Density, wet	Density saturated	Density submerged	Cohesion consolidated & undrained	Internal friction angle
Notation	G_s	W	γ_d	γ_t	γ_{sat}	γ_{sub}	Ccu	ϕ
Unit		%	t/m^3	t/m^3	t/m^3	t/m^3	t/m^2	o
Impervious material	2.66	21.3	1.61	1.95	2.00	1.00	2.0	17
Filter material	2.62	6.0	1.80	1.91	2.11	1.11	-	30
Rock material	2.70	2.0	1.80	1.84	2.13	1.13	-	40

Further details are referred to ANNEX-II.

5. Stability analysis of dams: In the comparative study stage, section of dams is examined as follows:

   i. Stability of upstream slope of fill dams shall be of the safety factor not less than 1.2 against quick drawdown of reservoir surface and the normal waterlevel plus earthquake movement, and downstream slope of fill dams against the normal waterlevel plus earthquake,

   ii. Section of concrete gravity dam shall be decided in a condition that no tensile stress take place against the normal high water plus earthquake and the flood waterlevel.

Table III.2 Cost Comparison Between Rockfill and Earthfill Types of Second Saddle Dam

Classification	Unit cost	Rockfill type		Earthfill	
		Work quantity	Amount US$1,000	Work quantity	Amount US$1,000
Foundation excavation	US$ 6/m^3	180,900 m^3	1,085	243,200 m^3	1,459
Embankment		471,600 m^3		878,300 m^3	
Earthfill and core	US$ 7/m^3	139,300 m^3	975	783,200 m^3	5,482
Filter zone	US$ 8.5/m^3	50,700 m^3	431	33,400 m^3	284
Rock zone	US$ 12/m^3	281,600 m^3	3,379	61,700 m^3	740
Sod facing	US$ 0.4/m^2	-	-	18,500 m^2	7
Total amount		US$5,870,000		US$7,972,000	

Conditions:

1. Dam axis: Line B, Crest elevation: 199, Crest width: 10 m
2. Dam section:

   Rockfill: Slope 1:1.8 upstream, 1:1.6 downstream

   Earthfill: Slope 1:4.0 upstream, 1:2.7 downstream
3. Crest length: 490 m
4. Dam height: 41 m in rockfill, 42 m in earthfill
5. Cost for consolidation and curtain grouting omitted since the cost may be almost equal.
6. Work quantity of riprapping on upstream slope of earthfill not counted.

Table III.3 Work Quantities of Main Items of 2nd Saddle Dam Along Alternative Axes, "A", "B" & "C"

Classification		Alternative A	Alternative B	Alternative C
Dam height	(m)	42.0	41.0	29.0
Crest length of dam	(m)	320	490	630
Foundation excavation	(m^3)	185,400	180,900	248,500
Embankment	(m^3)	546,200	471,600	581,000
Rock zone	(m^3)	335,600	281,600	343,400
Filter zone	(m^3)	55,200	50,700	79,000
Impervious zone	(m^3)	155,400	139,300	158,600

Conditions: Crest elevation 199 m, crest width 10 m, Rockfill type, Alternative axes shown on Drawing No.III.2.

Table III.4 Cost Comparison Among Alternative Layouts

Main Work Items	Unit & price US$	Alternative I Quantity	Alternative I Amount 1,000US$	Alternative II Quantity	Alternative II Amount 1,000US$	Alternative III Quantity	Alternative III Amount 1,000US$	Alternative IV Quantity	Alternative IV Amount 1,000US$	Remarks
1. MAIN DAM										
Foundation excavation	6/m^3	291,300	1,748	405,500	2,433	405,500	2,433	385,200	2,311	In this table, the following items are put out of consideration because of small differences in cost among the alternatives: 1. Powerhouse, generating equipment, intake and penstock, 2. Grouting for foundation treatment, 3. Access and construction roads.
Embankment, Rock zone	12/m^3	-	-	1,203,100	14,437	1,203,100	14,437	1,392,200	16,706	
" , Filter zone	8.5/m^3	-	-	157,300	1,337	157,300	1,337	171,100	1,454	
" , Core zone	7/m^3	-	-	534,400	3,741	534,400	3,741	284,600	4,092	
Dam concrete	67/m^3	628,100	42,083	-	-	-	-			
2. FIRST SADDLE DAM										
Foundation excavation	6/m^3	405,600	2,434	310,800	1,865	405,600	2,434	336,500	2,019	
Embankment, Rock zone	12/m^3	843,200	10,118	-	-	843,200	10,118	901,200	10,814	
" , Filter zone	8.5/m^3	117,200	996	-	-	117,200	996	126,600	1,076	
" , Core zone	7/m^3	382,000	2,674	-	-	382,000	2,674	395,100	2,766	
Dam concrete	69/m^3	-	-	367,000	25,323	-	-	-	-	
3. SECOND SADDLE DAM										
Foundation excavation	6/m^3	180,900	1,085	180,900	1,085	180,900	1,085	180,900	1,085	
Embankment, Rock zone	12/m^3	281,600	3,379	281,600	3,379	281,600	3,379	281,600	3,379	
" , Filter zone	8.5/m^3	50,700	431	50,700	431	50,700	431	50,700	431	
" , Core zone	7/m^3	139,300	975	139,300	975	139,300	975	139,300	975	
4. COFFERING										
Foundation excavation	6/m^3	-	-	303,200	1,819	303,200	1,819	270,000	1,620	
Embankment, Rock zone	12/m^3	-	-	225,500	2,706	225,500	2,706	166,100	1,993	
" , Impervious	7/m^3	-	-	253,400	1,774	253,400	1,774	355,200	2,486	
Primary coffer dams	3/m^3	110,000	330	85,500	257	85,800	257	85,500	257	
Steel sheet piling	L.S.	1,630^{t}	1,114	320^{t}	202	320^{t}	202	320^{t}	202	
5. RIVER DIVERSION										
Open excavation	5/m^3	359,000	1,795	635,900	3,180	-	-	-	-	
Tunnel works *	12,000/m					1,300	15,600	1,030	12,360	* ø 12m, 1.0 m lining thickness
6. SPILLWAY										
Open excavation	6/m^3	87,000	522	*		860,000	5,160	313,300	1,880	*: Included in excavation of diversion canal
Concrete (massive)	70/m^3	-	-	-	-	-	-	19,600	1,372	
" (structural)	110/m^3	17,000	1,870	20,200	2,222	133,600	14,696	73,500	8,085	
7. SURGE TANK										
Excavation	12/m^3	-	-	-	-	20,400	245	20,400	245	
Concrete	120/m^3	-	-	-	-	5,200	624	5,200	624	
TOTAL			71,554		67,166		87,123		78,232	

Table III.5 Power Schemes Taken for Optimal Scale Study

SCHEME NO.	2	3	4	5	6
H.W.L. Elevation (m)	188	195		200	
H.W.L. Elevation (m)	154	170		175	
Effective capacity (million m^3)	606	686		802	
Dam crest elevation (m)					
First saddle dam	190.7	197.5		202.5	
Main & 2nd saddle	192.2	199.0		204.0	
Power installation capacity (MW) x unit	22.5x1	26x1	20x2	28.5x1	33x2

Notes:

Scheme No.2: To harness potential obtained by the irrigation dam, Power generation will be made with irrigation release of water with waterlevel above El.165 m. No firm output is expected.

Scheme No.3: Maximum discharge of turbine is so limited to 56.6 m^3/sec that afterbay is not required.

Scheme No.4: Peak power station to be operated for about 4 hours (Maximum scale of installation)

Scheme No.5: Maximum discharge is so limited to 56.6 m^3 that afterbay is not necessary.

Scheme No.6: Peak power station designed to be operated for about four hours (maximum scale)

Table III.6 Approximate Cost of Dam and Power Station
(on 1978 December basis, unit in million Rupees)

Description	H.W.L.188		H.W.L.195		H.W.L.200	
	Scheme No.1 NO POWER	No.2 22.5 MW	No.3 26.0 MW	No.4 40.0 MW	No.5 28.5 MW	No.6 66.0 MW
LAND & RIGHT OF WAY	6.0	6.0	10.7	10.7	12.0	12.0
HIGHWAY RELOCATION	24.1	24.1	24.1	24.1	24.1	24.1
ADMINISTRATOR'S QUARTER	5.6	5.6	5.6	5.6	5.6	5.6
TOTAL	35.7	35.7	40.4	40.4	41.7	41.7
CONSTRUCTION WORKS						
Preparatory works	30.1	30.1	30.1	30.1	30.1	30.1
Care of river	60.9	60.9	60.9	60.9	60.9	60.9
Main dam	388.6	388.6	450.6	450.6	506.9	506.9
First saddle dam	309.7	309.7	425.6	425.6	495.8	495.8
Second saddle dam	88.7	88.7	134.1	134.1	166.5	166.5
Spillway & basin	97.6	97.6	100.2	100.2	101.9	101.9
Irrigation intake	12.0	12.0	-	-	-	-
Power intake	-	11.3	11.3	18.9	15.0	25.9
Powerhouse	-	56.2	56.2	62.4	58.2	68.6
Miscellaneous	6.9	6.9	6.8	6.8	6.8	6.8
SUB-TOTAL	994.5	1,062.0	1,275.8	1,289.6	1,442.1	1,463.4
CONTINGENCY	99.4	106.2	127.6	129.0	144.2	146.3
GENERATING EQUIPMENT	-	125.6	124.2	183.0	122.3	257.0
ADMINISTRATION & ENGINEERING	87.5	103.5	122.2	128.1	136.7	149.3
TOTAL	1,217.1	1,433.0	1,690.2	1,770.1	1,887.0	2,057.7
AFTERBAY WEIR	-	-	-	218.8	-	256.7
GRAND TOTAL	1,217.1	1,433.0	1,690.2	1,988.9	1,887.0	2,225.7
MILLION US$ EQUIVALENT OF TOTAL COST	81.14	95.54	112.69	132.59	125.80	154.29

NOTES: 1. No taxes and duties levied in Sri Lanka included.
2. No price escalation contingency included.
3. Exchange rate applied: one US dollar = 15 Rupees = ¥195.

Table III.7 Financial Cost and Benefit Stream

No.	Year	Scheme No.2, 22.5 MW: Cost stream: Increm. cost for power	Cost stream: O & M	Benefit stream: Cost for thermal plant	Benefit stream: O & M	Benefit stream: Fuel cost
0	1980					
1	81	0.22				
2	82	0.14				
3	83	0.15				
4	84	0.15				
5	85	0.15				
6	86	0.09				
7	87					
8	88					
9	89	4.86				
10	1990	4.85				
11	1	2.43				
12	2	1.36	0.223			2.611
⋮	⋮		⋮			⋮
32	2012					
⋮	⋮		⋮			⋮
42	2022					
⋮	⋮		⋮			⋮
47	2027	9.04				
⋮	⋮		⋮			⋮
50	2030		0.223			2.611
Present worth at 1980		6.58	0.84	–	–	8.93
Total cost & benefit		7.42		8.93		
Net benefit		1.51				
B/C ratio		1.20				

No.	Year	Scheme No.3, 26 MW: Cost stream: Increm. cost for power	Cost stream: O & M	Benefit stream: Cost for thermal plant	Benefit stream: O & M	Benefit stream: Fuel cost
0	1980					
1	81	5.65				
2	82	3.67				
3	83	3.68		1.11		
4	84	6.89		3.33		
5	85	6.90		4.43		
6	86	3.87		2.22		
7	87	0.89	0.308	1.24	0.450	1.713
8	88		⋮		⋮	⋮
9	89		⋮		⋮	⋮
10	1990		⋮		⋮	⋮
11	1		⋮		⋮	⋮
12	2		⋮		⋮	3.867
⋮	⋮		⋮		⋮	⋮
32	2012		⋮	12.32	⋮	⋮
⋮	⋮		⋮		⋮	⋮
42	2022	8.94	⋮		⋮	⋮
⋮	⋮		⋮		⋮	⋮
47	2027		⋮		⋮	⋮
⋮	⋮		⋮		⋮	⋮
50	2030		0.308		0.450	3.867
Present worth at 1980		22.72	1.71	8.32	2.50	16.89
Total cost & benefit		24.43		27.71		
Net benefit		3.28				
B/C ratio		1.13				

No.	Year	Scheme No.4, 40 MW: Cost stream: Increm. cost for power	Cost stream: O & M	Benefit stream: Cost for thermal plant	Benefit stream: O & M	Benefit stream: Fuel cost
0	1980					
1	81	5.92				
2	82	3.85				
3	83	3.85		1.93		
4	84	12.97		5.80		
5	85	14.42		7.74		
6	86	7.66		3.87		
7	87	2.77	0.463	2.15	0.784	1.713
8	88		⋮		⋮	⋮
9	89		⋮		⋮	⋮
10	1990		⋮		⋮	⋮
11	1		⋮		⋮	⋮
12	2		⋮		⋮	4.113
⋮	⋮		⋮		⋮	⋮
32	2012		⋮	21.49	⋮	⋮
⋮	⋮		⋮		⋮	⋮
42	2022	13.18	⋮		⋮	⋮
⋮	⋮		⋮		⋮	⋮
47	2027		⋮		⋮	⋮
⋮	⋮		⋮		⋮	⋮
50	2030		0.463		0.784	4.113
Present worth at 1980		35.24	2.57	14.52	4.36	17.73
Total cost & benefit		37.81		36.61		
Net benefit		-1.20				
B/C ratio		0.97				

No.	Year	Scheme No.5, 28.5 MW: Cost stream: Increm. cost for power	Cost stream: O & M	Benefit stream: Cost for thermal plant	Benefit stream: O & M	Benefit stream: Fuel cost
0	1980					
1	81	8.96				
2	82	5.83				
3	83	5.82		1.19		
4	84	9.00		3.57		
5	85	8.99		4.77		
6	86	5.17		2.39		
7	87	0.88	0.377	1.33	0.484	2.398
8	88		⋮		⋮	⋮
9	89		⋮		⋮	⋮
10	1990		⋮		⋮	⋮
11	1		⋮		⋮	⋮
12	2		⋮		⋮	4.334
⋮	⋮		⋮		⋮	⋮
32	2012		⋮	13.25	⋮	⋮
⋮	⋮		⋮		⋮	⋮
42	2022	8.81	⋮		⋮	⋮
⋮	⋮		⋮		⋮	⋮
47	2027		⋮		⋮	⋮
⋮	⋮		⋮		⋮	⋮
50	2030		0.377		0.484	4.334
Present worth at 1980		32.60	2.10	8.95	2.69	19.95
Total cost & benefit		34.70		31.59		
Net benefit		-3.11				
B/C ratio		0.91				

No.	Year	Scheme No.6, 66 MW: Cost stream: Increm. cost for power	Cost stream: O & M	Benefit stream: Cost for thermal plant	Benefit stream: O & M	Benefit stream: Fuel cost
0	1980					
1	81	9.39				
2	82	6.10				
3	83	6.10		3.27		
4	84	17.89		9.81		
5	85	19.60		13.07		
6	86	10.51		6.54		
7	87	3.56	0.639	3.64	1.326	2.398
8	88		⋮		⋮	⋮
9	89		⋮		⋮	⋮
10	1990		⋮		⋮	⋮
11	1		⋮		⋮	⋮
12	2		⋮		⋮	4,706
⋮	⋮		⋮		⋮	⋮
32	2012		⋮	36.33	⋮	⋮
⋮	⋮		⋮		⋮	⋮
42	2022	18.50	⋮		⋮	⋮
⋮	⋮		⋮		⋮	⋮
47	2027		⋮		⋮	⋮
⋮	⋮		⋮		⋮	⋮
50	2030		0.639		1.326	4.706
Present worth at 1980		50.65	3.55	24.56	7.37	21.23
Total cost & benefit		54.20		53.16		
Net benefit		-1.04				
B/C ratio		0.98				

Table III.8 Cost and Benefit Stream for Future Development

		Original 26 MW - 1 unit					Stage-develop. 26 MW + 26 MW					26 MW without future unit				
		Cost stream		Benefit stream			Cost stream		Benefit stream			Cost stream		Benefit stream		
		Incremenal cost	O&M cost	Install. cost	O&M cost	Running	Increment. cost	O&M cost	Install. cost	O&M cost	Running	Increment. cost	O&M cost	Install. cost	O&M cost	Running
0	1980			16.1 x 660 x 1118												
1	81	6.15					6.54					6.54				
2	82	5.60					5.97					5.97				
3	83	5.41		1.78			5.77		1.78			5.77		1.78		
4	84	7.61		7.72			8.13		7.72			8.13		7.72		
5	85	6.35		2.38			6.79		2.38			6.79		2.38		
6	86		0.304		0.434	1.715		0.337		0.434	1.715		0.337		0.434	1.715
7	87															
8	88								1.78							
9	89						5.13		7.72							
10	1990						7.69		2.38							
11	91					3.734		0.475		0.868	4.248					3.734
	⋮															
29	2009			11.88					11.88					11.88		
30	2010															
	⋮															
34	2014								11.88							
35	2015															
	⋮															
39	2019	8.94					8.94					8.94				
40	2020															
	⋮															
44	2024						6.84									
45	2025															
	⋮															
50	2030															
Present worth at 1980		23.64	1.86	8.84	2.66	18.12	30.45	2.58	14.32	4.29	20.05	25.21	2.06	8.84	2.66	18.12
Total cost & benefit		25.5		29.62			[illegible].03		38.66			27.27		29.62		
Net benefit		4.12					5.63					2.35				
B/C ratio		1.16					1.17					1.09				

Table III.9 Required Major Plant and Equipment

Main equipment	Capacity	Quantity
Concrete plant	1.5 m^3 x 3	1 set
Potable concrete plant	0.5 m^3 x 1	1 set
Crushing plant	200 t/h	1 set
Bulldozer	32 t	9 nos.
Bulldozer	21 t	15 nos.
Power shovel	1.2 m^3	8 nos.
Wheel loader	2 m^3	5 nos.
Dump truck	20 t	40 nos.
Ordinary truck	8 t	50 nos.
Crawler drill	15 m^3/m	24 nos.
Air compressor	34 m^3/m	12 nos.
Jib crane	14.5 t	2 nos.
Concrete pump	60 - 85 m^3/hr	1 no.
Agitator truck	3 m^3	4 nos.
Tamping roller	15 t	4 nos.
Vibrating roller	8 t	4 nos.
Pump dredger	600 ps	2 nos.
Fuel tanker	5,000 ℓ	18 nos.
Grout pump	7.5 kW	3 nos.
Grout pump	3.7 kW	8 nos.
Grout mixer	5.5 kW	11 nos.
Boring machine	5.5 kW	18 nos.
Diesel generator	750 kW	3 nos.
Water pump for water supply	ϕ 200, 37 kW	6 nos.

Table III.10 Main Construction Materials

Cement	100,000 tons
Reinforcement bars	1,500 tons
Structural steel	2,200 tons
Explosives	700 tons
Diesel (high speed diesel)	28,000 $k\ell$
Timber	8,200 m^3
Fine aggregate for concrete	150,000 m^3
Coarse aggregate for concrete	400,000 m^3

Table III.11 Unit Costs of Basic Items of Materials and Labour Employed in Cost Analysis

Item	Unit	Price (Rp)	Condition
Cement	t	440.41	Bagged, Exfactory at K.K.S.
Reinforcement steel bars	t	5,180	Ex-factory, Colombo
Timber	m^3	1.907	Sawn Ex-sawmill
Light oil	(	1.166	Ex-refinery, Kelaniya
Engine oil	(	7.444	"
Explosive	kg	32.4	At Colombo
Detonators	piece	3	"
Labour (skilled)	M/D	40	At site
" (unskilled)	"	30	"

Table III.12 Summary of Construction Cost of Moragahakanda Dam and Powerstation

(UNIT IN MILLION)

DESCRIPTION	CONSTRUCTION COST		
	YEN PORTION	RUPEE PORTION	TOTAL RUPEES
LAND AND RIGHT OF WAY		10.7	10.7
RELOCATION OF HIGHWAY		24.1	24.1
ADMINISTRATOR'S RESIDENCE & OFFICE		5.6	5.6
Sub-Total		40.4	40.4
CONSTRUCTION WORKS	15,062	262.4	1,421.1
1. Preparatory works	416	7.4	39.4
2. Care of river	549	7.9	50.1
3. Main dam	4,617	66.2	421.4
4. First saddle dam	4,297	97.2	427.7
5. Spillway & stilling basin	434	15.4	48.8
6. Intake structure & anchor blocks	29	1.4	3.6
7. Second saddle dam	1,210	12.1	105.2
8. Powerhouse & switchyard	547	16.2	58.3
9. Miscellaneous	75	0.6	6.4
10. Hydromechanical works	1,474	20.3	133.7
11. Generating equipment & transmission	1,414	17.7	126.5
PHYSICAL CONTINGENCIES	1,365	24.5	129.5
ENGINEERING & ADMINISTRATION	1,314	23.0	124.1
TOTAL	17,741	309.9	1,674.7
GRAND TOTAL	17,741	350.3	1,715.1
	(US$114.34 million)		

Table III.13 Cost Estimate of Project in First Stage Development

Particular	Description	Unit	Q'ty	Foreign Currency		Local Currency	
				Unit Cost Yen	Amount 1,000 Yen	Unit Cost Rupees	Amount 1,000 Rupees
LAND & RIGHT OF WAY							10,660
RELOCATION OF HIGHWAY							24,100
ADMINISTRATOR'S RESIDENCE & OFFICE WITH POWER, WATER SUPPLY SYSTEMS AND TELEPHONE							5,600
CONSTRUCTION WORKS							
1. Preparatory works					416,160		7,395.7
Permanent access road			2.6 km		13,650		390.0
Construction road & bridges			15 km & 3 bridges		240,518		4,620.0
Construction power distribution system					17,992		145.7
Water supply facilities					144,000		2,240.0
2. Care of river					549,112		7,903.6
Diversion canal, excavation							
	Soil	m^3	161,800	505	81,709	5.4	873.7
	Weathered rock	m^3	337,700	650	219,505	6.4	2,161.3
	Rock	m^3	104,300	1,186	123,700	34.7	3,619.2
Primary coffering including dewatering		L.S.			98,050		873.0
Miscellaneous					26,148		376.4
3. Main dam					4,617,254		66,233.7
Excavation	Soil	m^3	103,100	505	52,066	5.4	556.7
	Weathered rock	m^3	201,100	650	130,715	6.4	1,287.0
	Rock	m^3	98,700	1,180	116,466	34.7	3,424.9
	River bed material	m^3	175,200	505	88,476	5.4	946.1
Embankment	Core	m^3	714,200	1,102	787,048	11.7	8,356.1
	Filter	m^3	181,700	1,349	245,113	12.1	2,198.6
	Rockfill	m^3	1,533,200	1,574	2,413,257	27.0	41,396.4
Grouting	Consolidation & blanket	m	3,465	19,742	68,406	197.9	685.7
	Curtain	m	17,160	28,895	495,838	246.4	4,228.2
Miscellaneous	5 %				219,869		3,154.0

Table III.13 - Continue -

Particular	Description	Unit	Q'ty	Foreign Currency Unit Cost Yen	Foreign Currency Amount 1,000 Yen	Local Currency Unit Cost Rupees	Local Currency Amount 1,000 Rupees
4. First Saddle dam					4,296,565		97,171.1
Excavation	Soil	m^3	37,100	505	18,736	5.4	200.3
	W. Rock	m^3	80,700	650	52,455	6.4	516.5
	Rock	m^3	130,500	1,180	153,990	34.7	4,528.4
Concreting	Concrete	m^3	375,910	9,048	3,401,234	218.9	82,286.7
Reinforcing steel bars		t	176	18,300	3,221	5,600	985.6
Grouting	Consolidation	m	2,840	19,742	56,067	197.9	562.0
	Curtain	m	14,060	28,895	406,264	246.4	3,464.4
Miscellaneous	5 %				204,598		4,627.2
5. Spillway & Stilling basin					434,447		15,409.4
Excavation	Soil	m^3	4,900	505	2,475	5.4	26.5
	W. Rock	m^3	17,300	650	11,245	6.4	110.7
	Rock	m^3	36,300	1,180	42,834	34.7	1,259.6
Concreting	Structural concrete	m^3	25,570	10,400	265,928	393.4	10,059.2
Reinforcing	Steel reinf.	t	384	18,300	7,027	5,600	2,150.4
Spillway bridge		L.S.			84,250		1,069.2
Miscellaneous	5 %				20,688		733.8
6. Power intake					29,050		1,392.6
Concreting intake be anchor blocks		m^3	2,560	10,400	26,624	393.4	1,007.1
Reinforcing	Steel bars	t	57	18,300	1,043	5,600	319.2
Miscellaneous	5 %				1,383		66.3
7. Second Saddle dam					1,210,226		12,148.2
Excavation	Soil	m^3	43,600	505	22,018	5.4	235.4
	W.rock	m^3	92,600	650	60,190	6.4	592.6
	Rock	m^3	40,900	1,186	48,507	34.7	1,419.2
Embankment	Core	m^3	139,300	1,013	141,111	10.7	1,490.5
	Filter	m^3	50,700	1,349	68,394	12.1	613.5
	Rock-fill	m^3	240,600	896	215,578	8.4	2,021.0
Grouting	Consolidation & blanket	m	3,665	19,742	72,354	197.9	725.3
	Curtain	m	18,150	28,895	524,444	246.4	4,472.2
Miscellaneous	5 %				57,630		578.5

Table III.13 - Continue -

Particular	Description	Unit	Q'ty	Foreign Currency Unit Cost Yen	Foreign Currency Amount 1,000 Yen	Local Currency Unit Cost Rupees	Local Currency Amount 1,000 Rupees
8. Powerhouse & outdoor switchyard					546,563		16,220.5
Excavation	Soil	m^3	23,300	505	11,767	5.4	125.8
	W. rock	m^3	52,100	650	33,865	6.4	333.4
	Rock	m^3	43,400	1,186	51,472	34.7	1,506.0
Concreting	Substruct.	m^3	11,710	10,400	121,784	393.4	4,606.7
Reinforcing	Steel bars	t	586	18,300	10,724	5,600	3,281.6
Superstructure		L.S.			290,924		5,594.6
Miscellaneous	5 %				26,027		772.4
9. Other items					75,263		617.7
Jungle clearing		ha	44.6	680,000	30,328	9,770	435.7
Embedded instrument & laboratory apparatus		L.S.			44,935		182.0
10. Hydromechanical works					1473,800		20,255.5
Spillway gates & hoists		L.S.	4 Nos. 560 t		682,000		10,846.2
Gate, hoist & screen of diversion conduit		L.S.	49 t		77,500		576.9
Closing gate of diversion conduit		L.S.	55 t		96,300		415.4
River outlet (screens, ring follower valves, jet flow values & steel pipes)		L.S.	268 t		325,800		2,815.4
Intake gate & hoist and screens		L.S.	66 t		69,300		1,138.5
Steel penstock	ø3.9 m	L.S.	255 t		177,300		3,892.3
Tailrace gates & hoists		L.S.	37 t		45,600		570.8
11. Generating equipment & transmission line					1,414,140		17,720.0
Hydro-turbine, generator and first auxiliary equipment		L.S.	26 MW		1,339,780		15,630.0
Transmission line 132 kV,			16 km		74,360		2,090.0

Table III.14 Disbursement Schedule of Investment Cost to Dam and Powerstation

(UNIT IN MILLION RUPEES)

CLASSIFICATION	1981	1982	1983	1984	1985
Civil, Metal and G/E cost including Physical Contingencies	110.1	320.6	308.8	443.3	367.7
Engineering Cost	38.8/1	22.4	22.3	22.3	22.4
Sub-Total	114.9	343.0	331.1	465.6	390.1
Land compensation & others	40.4	-	-	-	-
Total	185.3	343.0	331.1	465.6	390.1

Note: /1: Including disbursement in earlier years

Remarks:

1. No conditions such as advance payment to the contractors, detention money and premium of performance bond are considered herein.

2. Total of 1,715.1 million Rupees corresponds to estimated cost on 1978 price basis.

Table III.15 Tentative Disbursement Schedule of Incremental Cost for Power Sector including Future Stage

(Unit in US$ million)

Classification	Dam & /1 Powerstation	Future Unit 26 MW	Kongetta Oya Afterbay	Total
1981	6.54	-	-	6.54
82	5.97	-	-	5.97
83	5.77	-	-	5.77
84	8.13	-	-	8.13
85	6.79	-	-	6.79
86	-	-	-	-
87	-	-	-	-
88	-	-	-	-
89	-	2.81	2.32	5.13
1990	-	4.21	3.48	7.69
Total	33.20	7.02	5.80	46.02

/1: Worked out proportional to the disbursement schedule given in Table III.14, in a condition that an advance payment at 10 % of the cost is paid.

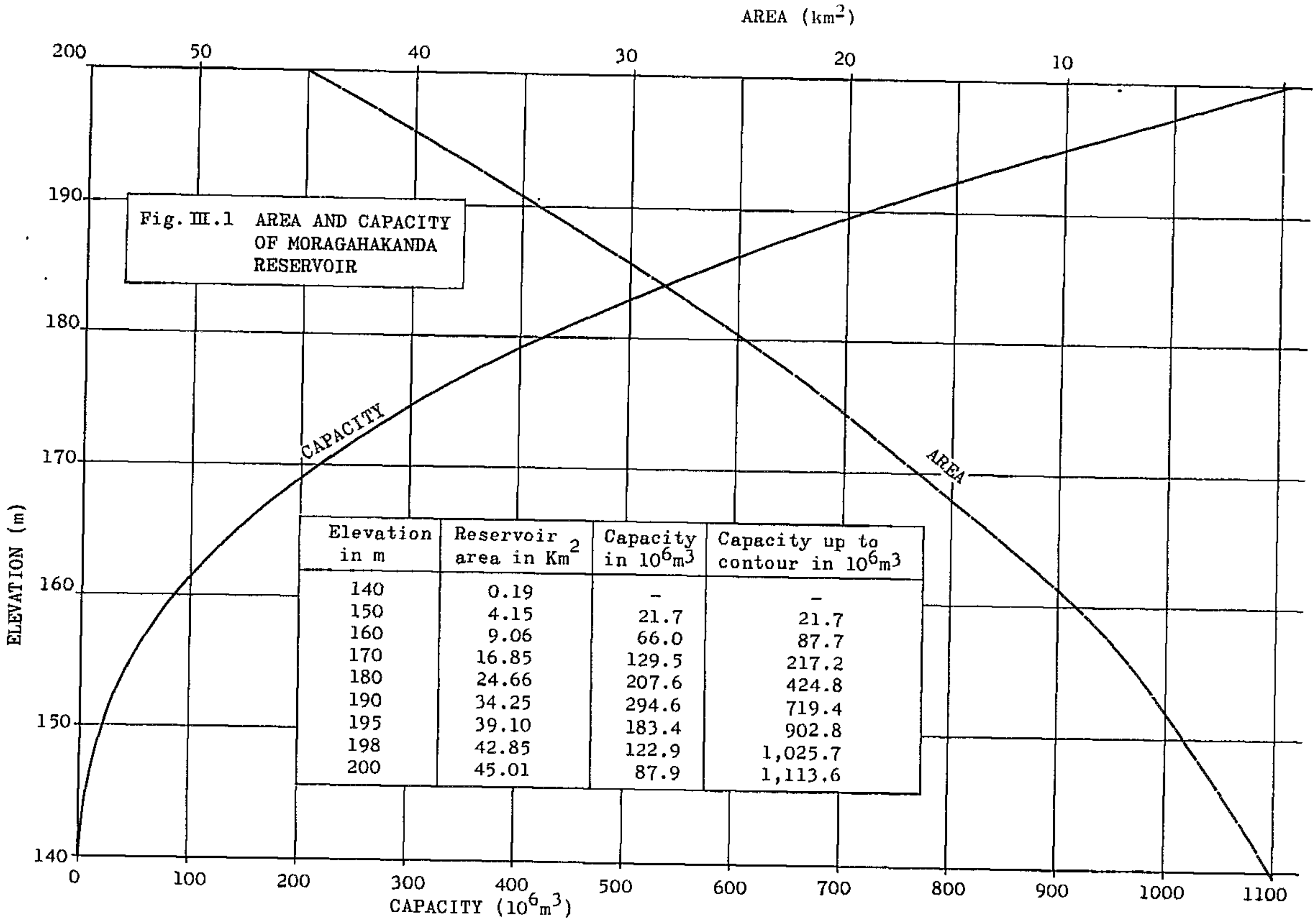


Fig. III.1 AREA AND CAPACITY OF MORAGAHAKANDA RESERVOIR

Elevation in m	Reservoir area in Km^2	Capacity in $10^6 m^3$	Capacity up to contour in $10^6 m^3$
140	0.19	-	-
150	4.15	21.7	21.7
160	9.06	66.0	87.7
170	16.85	129.5	217.2
180	24.66	207.6	424.8
190	34.25	294.6	719.4
195	39.10	183.4	902.8
198	42.85	122.9	1,025.7
200	45.01	87.9	1,113.6

Fig.III.2 ELAHERA AFTERBAY

(No. consideration to NCP canal)

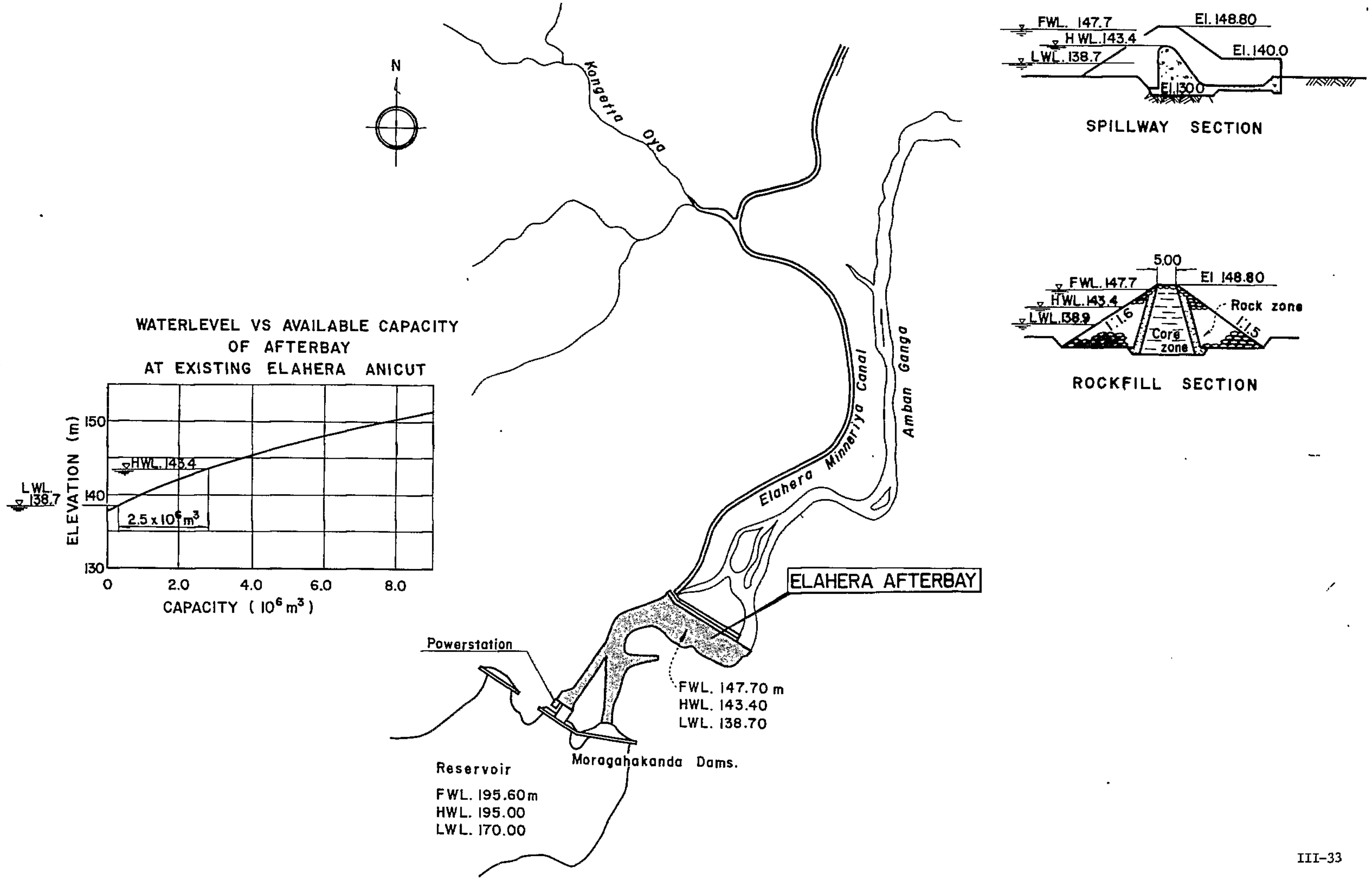


Fig. III.3 KONGETTA OYA AFTERBAY
(Consideration to NCP canal)

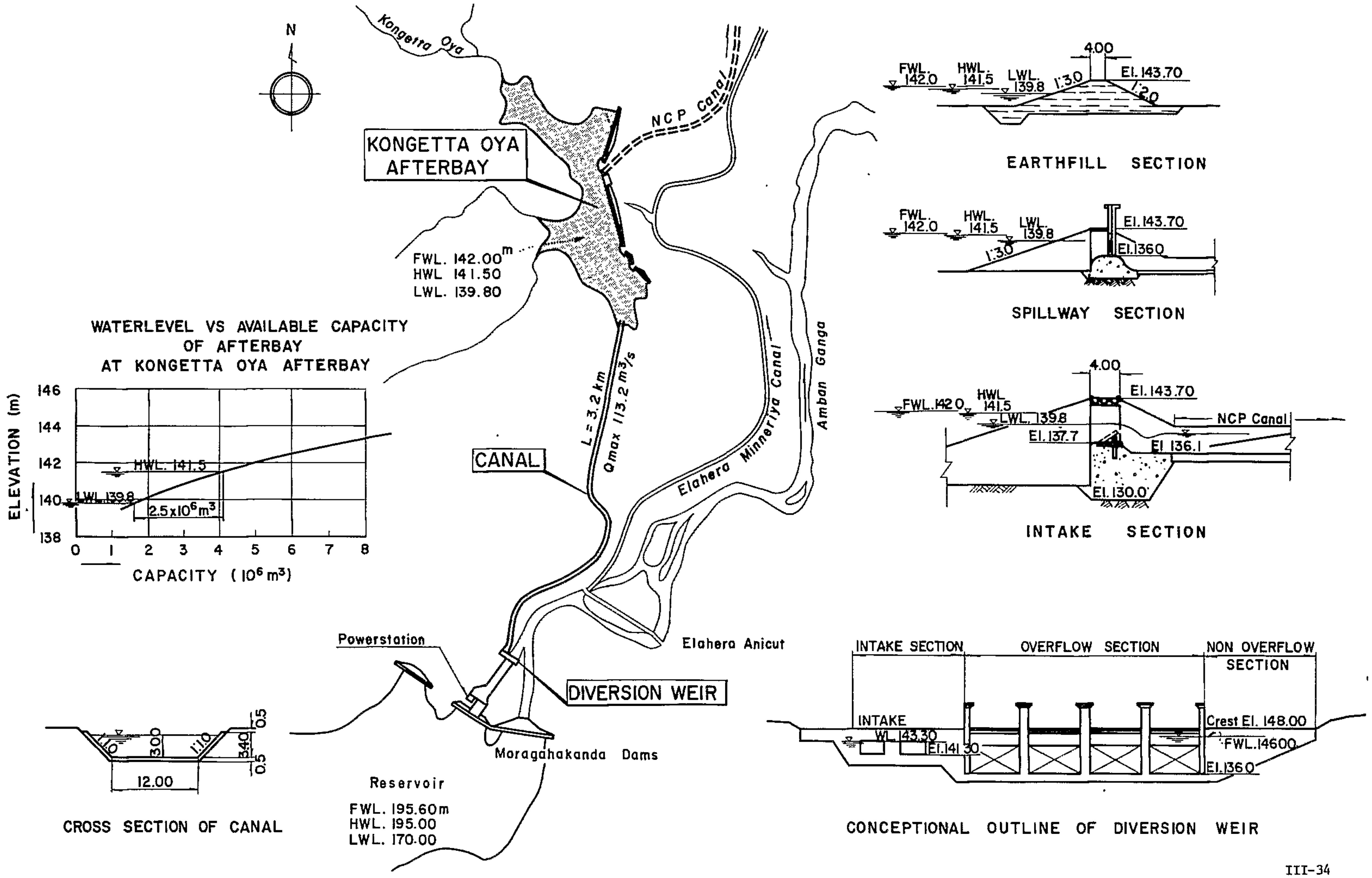
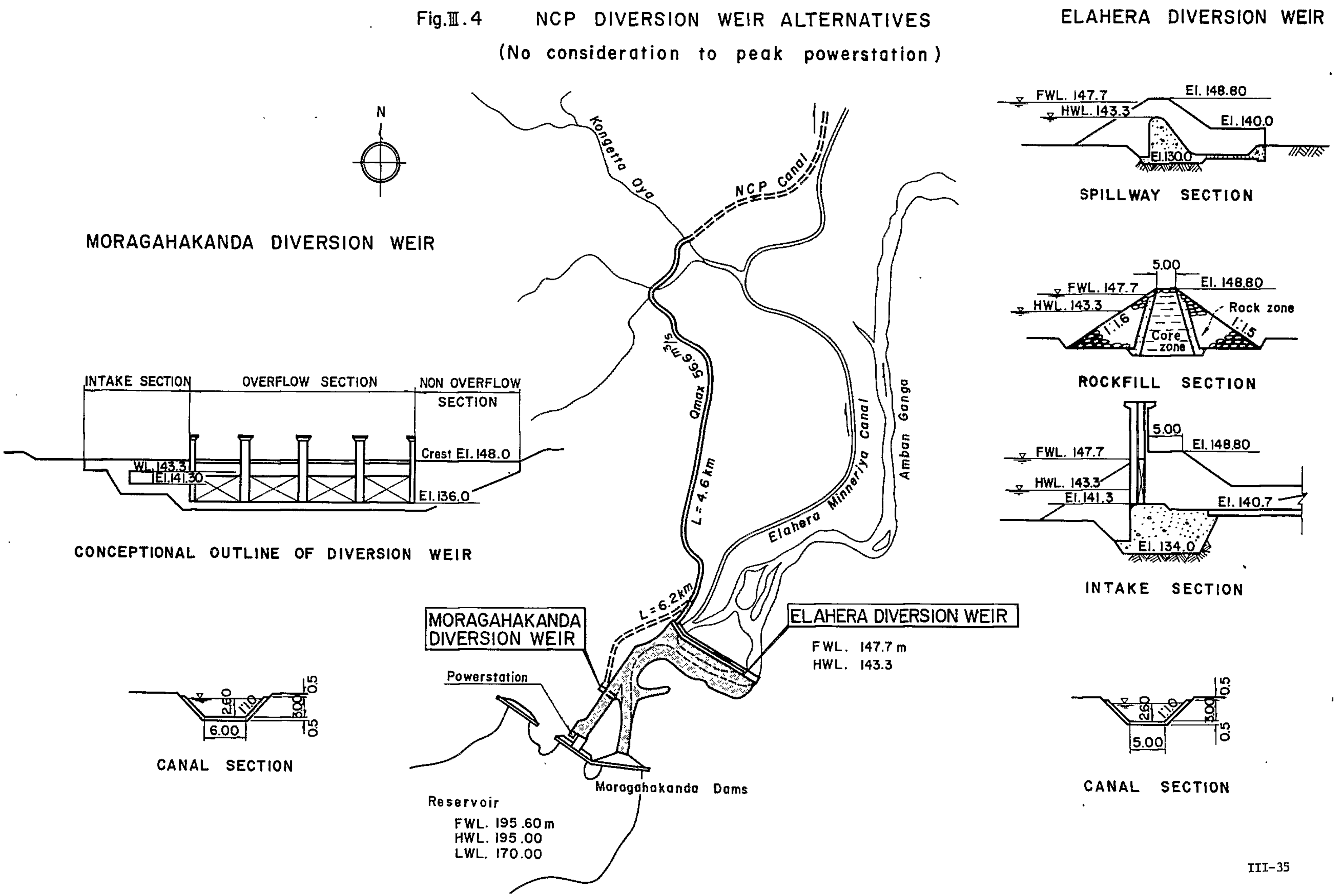
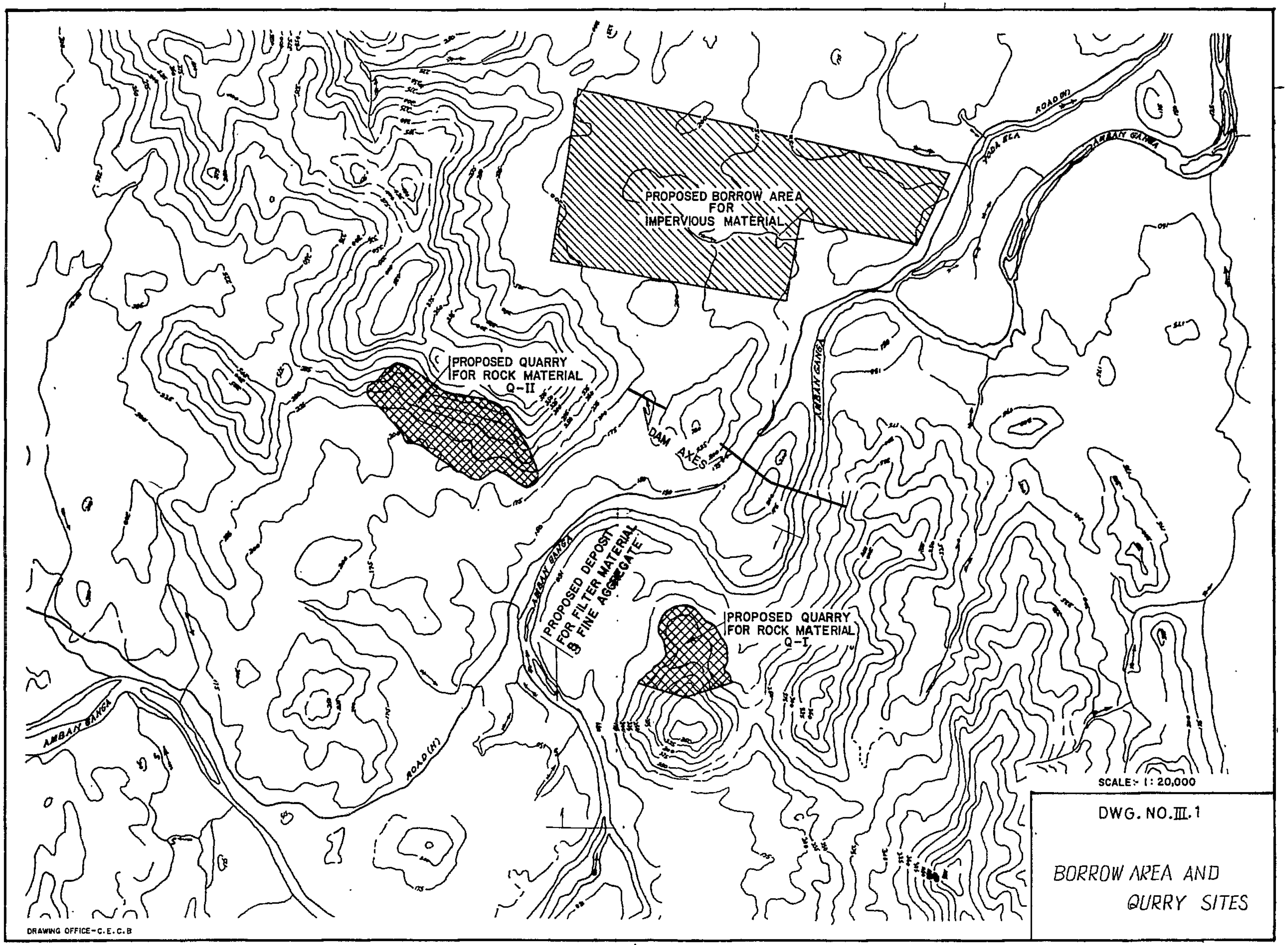
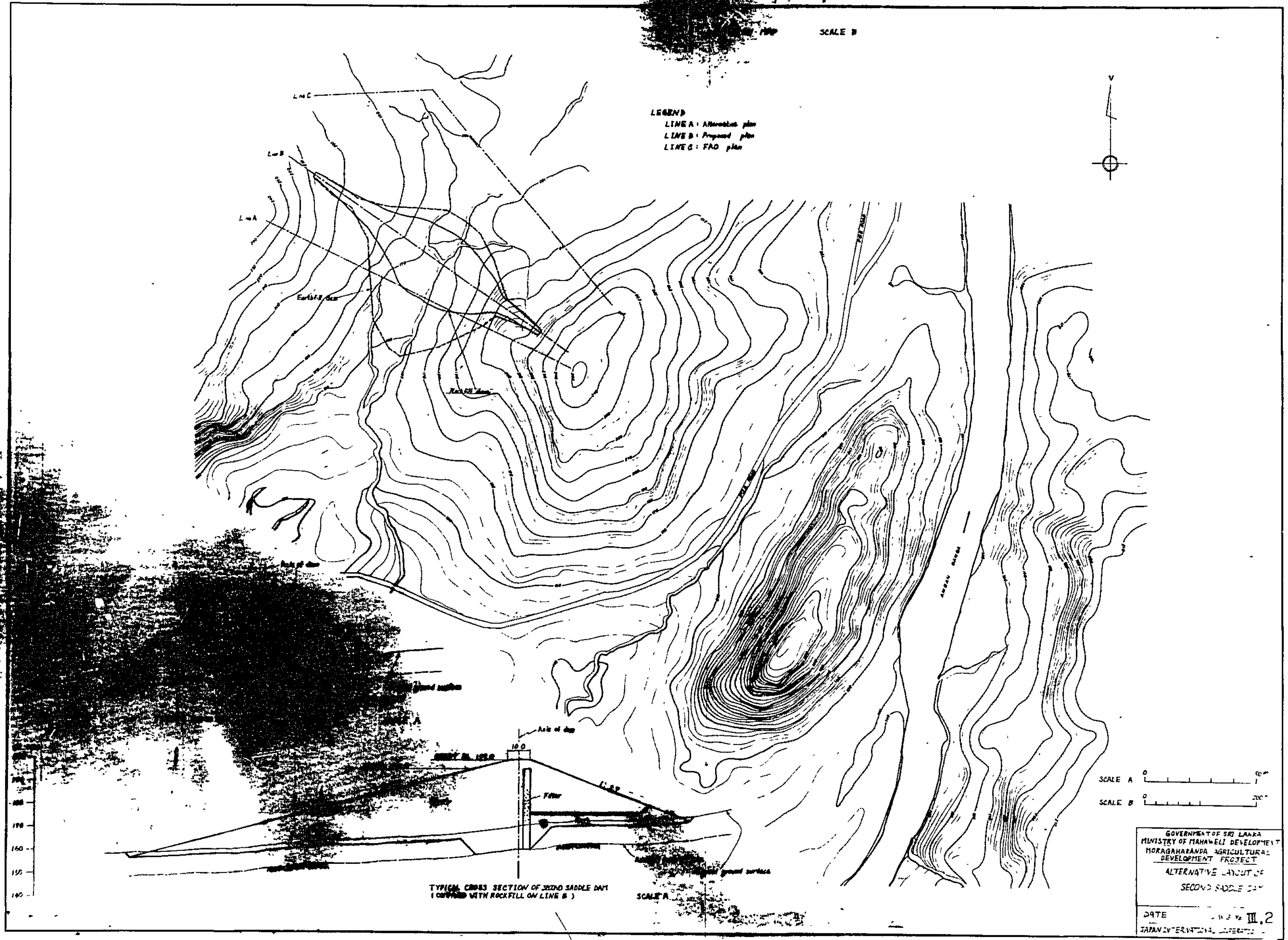


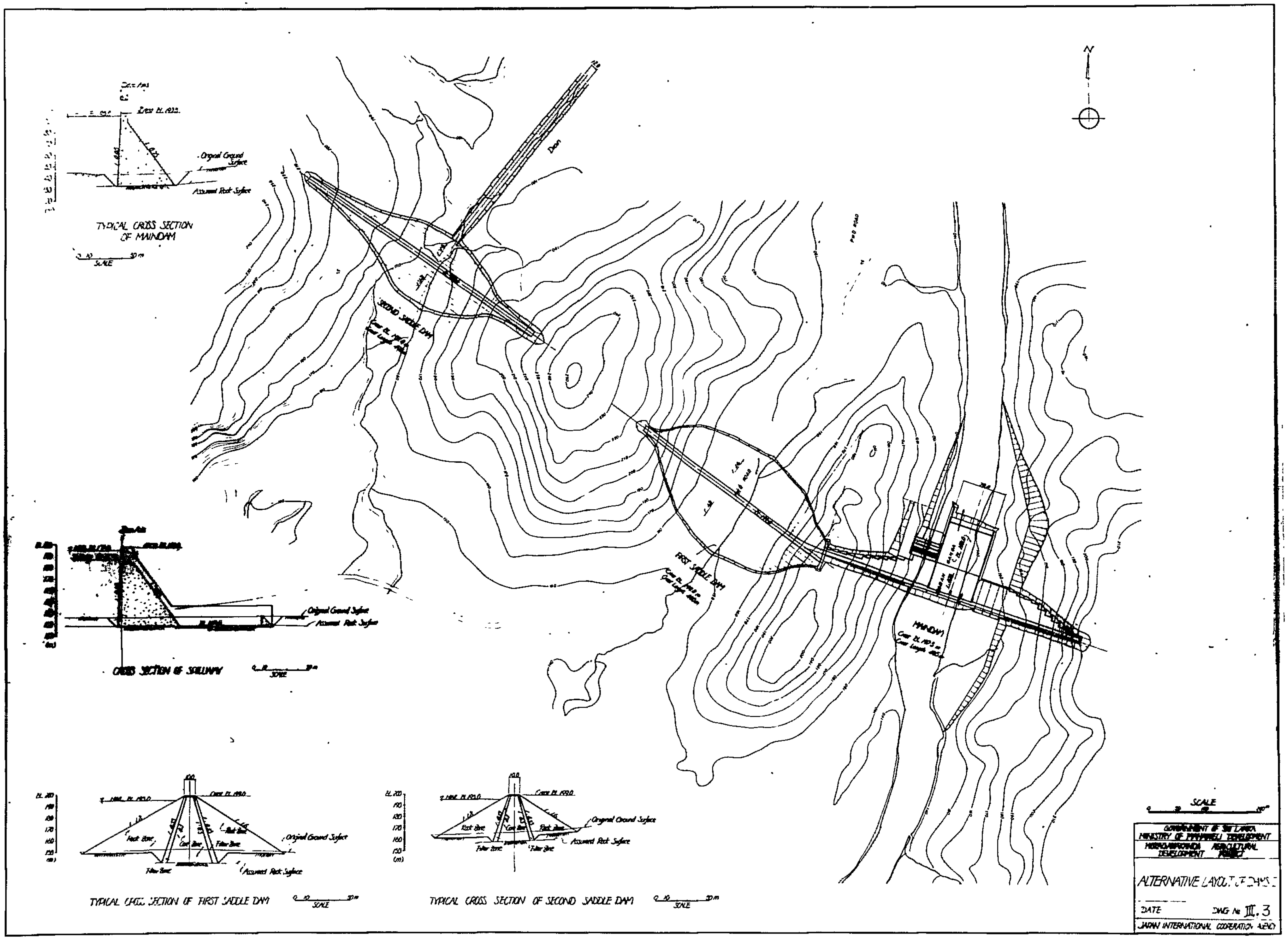
Fig.III.4 NCP DIVERSION WEIR ALTERNATIVES

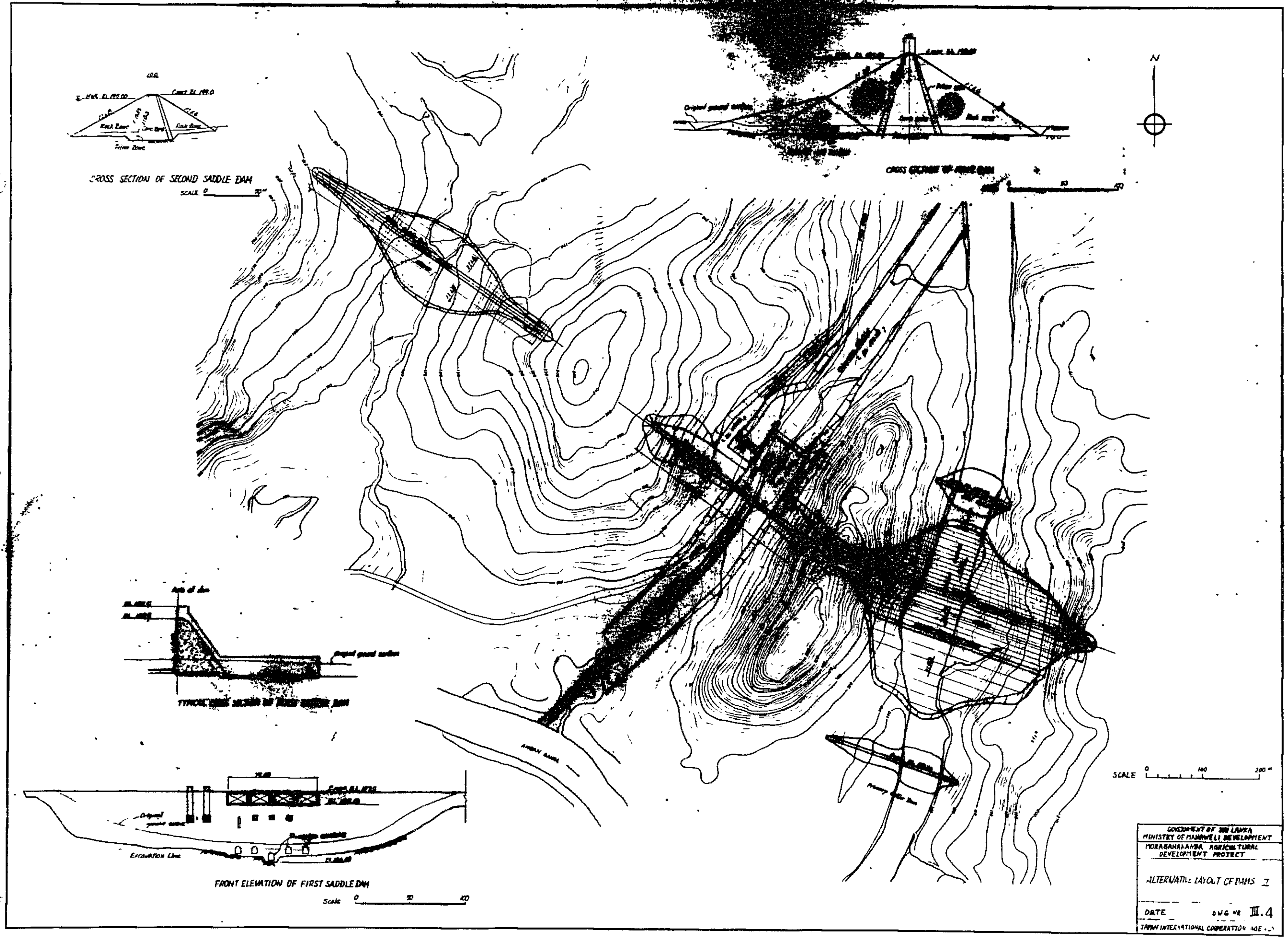
(No consideration to peak powerstation)

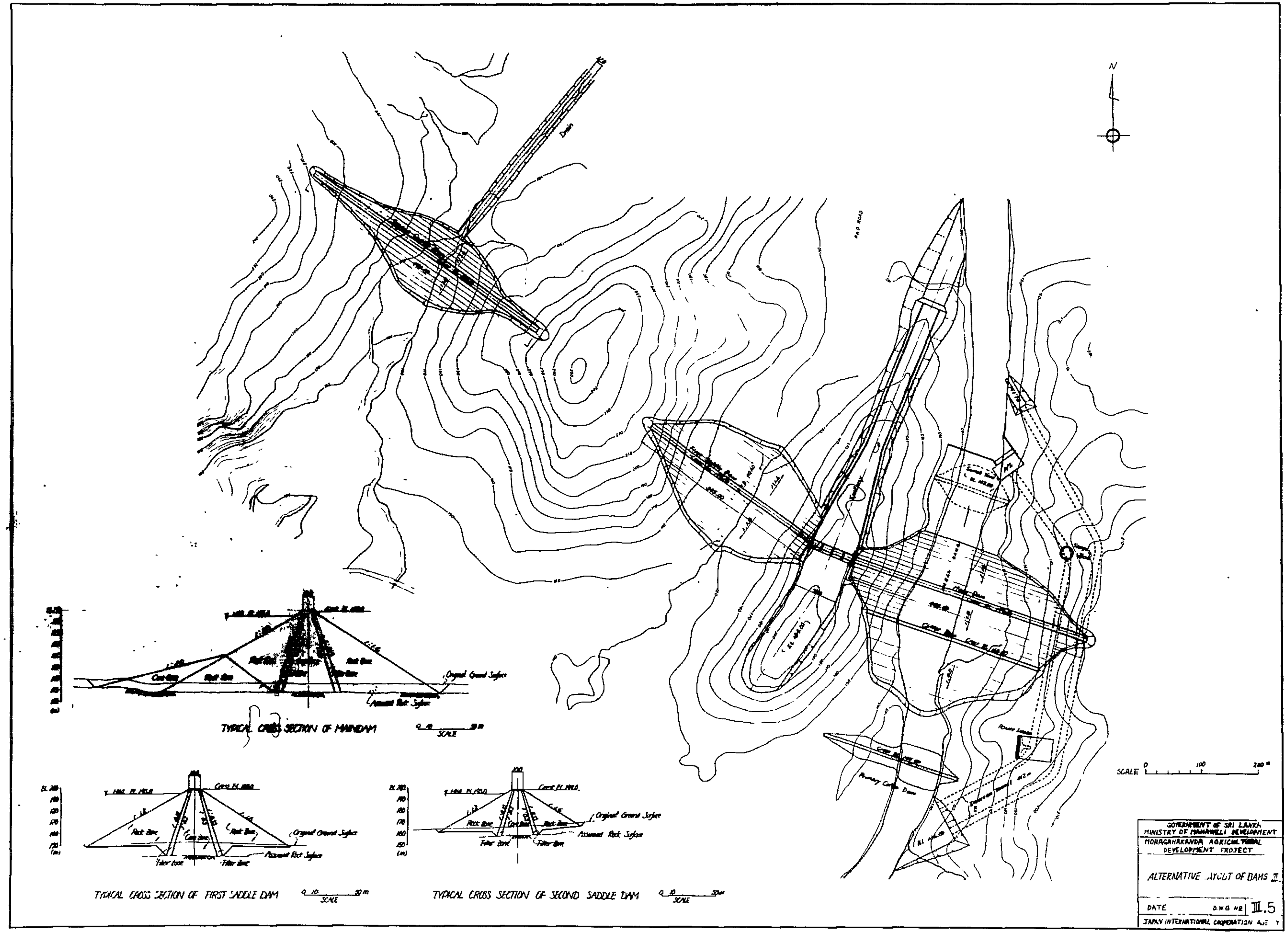


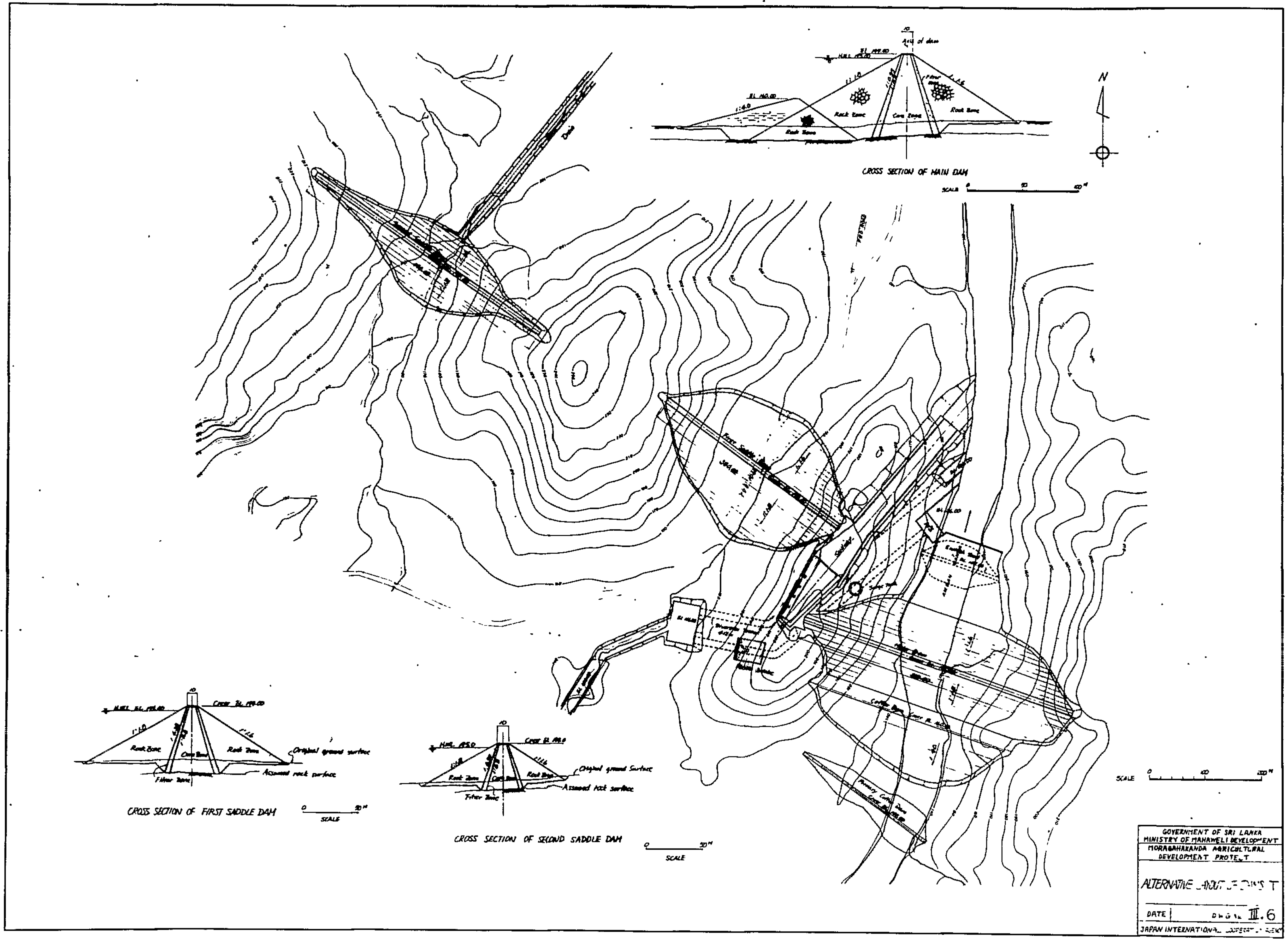

PROPOSED BORROW AREA
FOR
IMPERVIOUS MATERIAL
PROPOSED QUARRY
FOR ROCK MATERIAL
Q-II
DAM AXES
PROPOSED DEPOSIT
FOR FILTER MATERIAL
& FINE AGGREGATE
PROPOSED QUARRY
FOR ROCK MATERIAL
Q-I
AMBAN GANGA
AMBAN GANGA
AMBAN GANGA
AMBAN GANGA
YODA ELA
ROAD (H)
ROAD (H)
SCALE:- 1:20,000
DWG. NO. III.1
BORROW AREA AND
QURRY SITES
DRAWING OFFICE-C.E.C.B

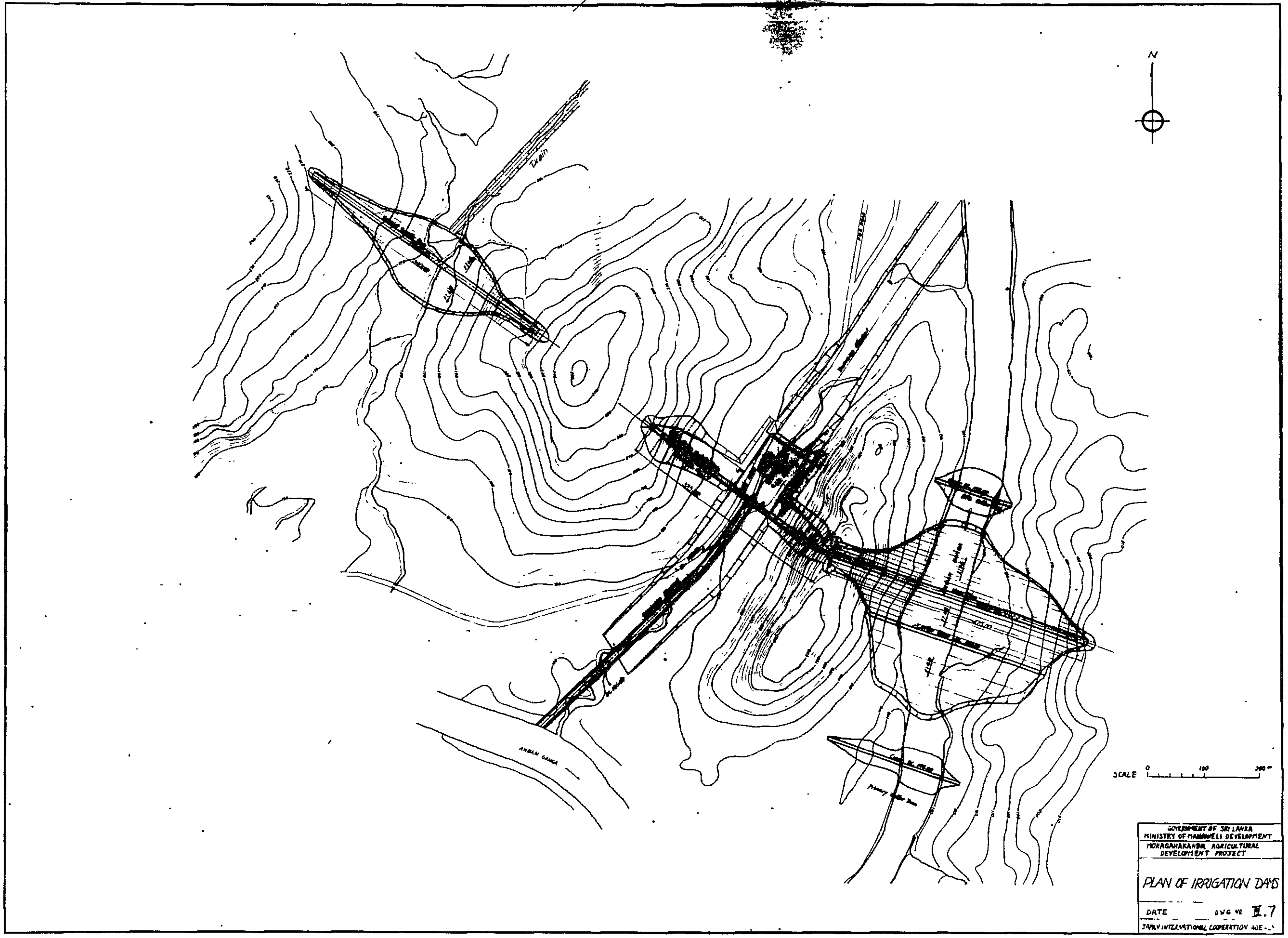

SCALE B
LEGEND
LINE A : Alternative plan
LINE B : Proposed plan
LINE C : FAO plan
Line C
Line B
Line A
Earthfill dam
Rockfill dam
Axis of dam
10.0
Filter
TYPICAL CROSS SECTION OF SECOND SADDLE DAM
(COMBINED WITH ROCKFILL ON LINE B)
SCALE A
SCALE A
SCALE B
GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT
MORAGAHAKANDA AGRICULTURAL
DEVELOPMENT PROJECT
ALTERNATIVE LAYOUT OF
DATE
III.2


TYPICAL CROSS SECTION OF MAINDAM
Original Ground Surface
Assumed Rock Surface
SCALE
CROSS SECTION OF SPILLWAY
SECOND SADDLE DAM
FIRST SADDLE DAM
MAINDAM
TYPICAL CROSS SECTION OF FIRST SADDLE DAM
TYPICAL CROSS SECTION OF SECOND SADDLE DAM
Rock Zone
Core Zone
Filter Zone
MINISTRY OF MAHAWELI DEVELOPMENT
DEVELOPMENT
ALTERNATIVE LAYOUT
DATE
DWG No III. 3
JAPAN INTERNATIONAL COOPERATION AGENCY

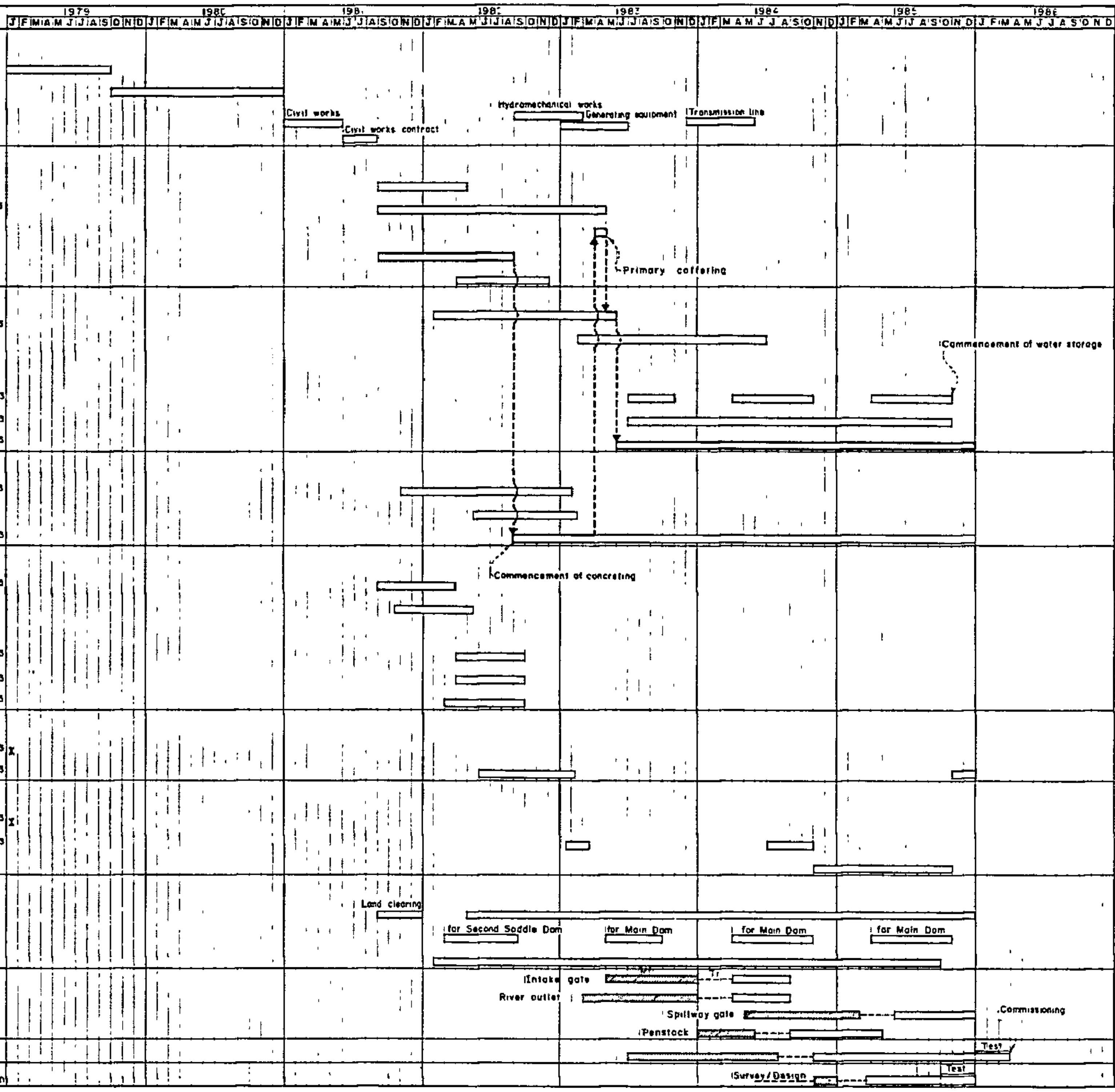

CROSS SECTION OF SECOND SADDLE DAM
N
FRONT ELEVATION OF FIRST SADDLE DAM
Excavation Line
SCALE
MORAGAHAKANDA AGRICULTURAL
DEVELOPMENT PROJECT
ALTERNATIVE LAYOUT OF DAMS I
DATE
DWG No III.4


N
TYPICAL CROSS SECTION OF MAINDAM
SCALE
TYPICAL CROSS SECTION OF FIRST SADDLE DAM
TYPICAL CROSS SECTION OF SECOND SADDLE DAM
Original Ground Surface
Assumed Rock Surface
Rock Zone
Core Zone
Filter Zone
SCALE 0 100 200 m
GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT
MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT
ALTERNATIVE LAYOUT OF DAMS II
DATE
D.W.G NO. III.5
JAPAN INTERNATIONAL COOPERATION AGENCY


CROSS SECTION OF MAIN DAM
Rock Zone
Core Zone
CROSS SECTION OF FIRST SADDLE DAM
Original ground surface
Assumed rock surface
CROSS SECTION OF SECOND SADDLE DAM
SCALE
GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT
MORAGAHAKANDA AGRICULTURAL
DEVELOPMENT PROJECT
DATE
DWG. No. III.6


N
Drain
ANBAN GANGA
SCALE 0 100 200 m
GOVERNMENT OF SRI LANKA
MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT
PLAN OF IRRIGATION DAMS
DATE
DWG NO III.7

Work Item	Quantity
A Tender & Others	
1 Feasibility study	
2 Tender design	
3 Tender & contract	
4 Mobilization	
B. Preparatory Works	
1 Construction road & bridges	
2 Diversion canal	604,000 m³
3 Primary cofferdams	
4 Aggregate & concrete plant	
5 Trestle & crane	
C Main Dam	
1 Excavation	576,000 m³
2 Grouting	20,630 m
3 Embankment	
Core zone	714,000 m³
Filter zone	182,000 m³
Rock zone	1,533,000 m³
D First Saddle Dam	
1. Excavation	248,000 m³
2 Grouting	16,900 m
3. Concreting	376,000 m³
E. Second Saddle Dam	
1 Excavation	177,000 m³
2 Grouting	21,820 m
3 Embankment	
Core zone	139,000 m³
Filter zone	51,000 m³
Rock zone	241,000 m³
F Stilling Basin	
1. Excavation	58,500 m³ I
2 Concreting	25,600 m³
G Powerhouse	
1 Excavation	119,000 m³ I
2 Substructure	12,000 m³
3 Superstructure	L.S
H. Quarry Operation	
1 Quarry site	L.S
2 Borrow area	
3 River sand	
I Hydro-mechanical Equipment	L.S
J Electro-mechanical Equipment	L.S
K Transmission Line	16 km



Remarks

1 Months with hatch are rainy seasons and the rest without hatch are dry seasons

2. Asterisk "I" shows excavation to be made together with diversion canal work

3. Mfr Manufacturing; Tr Transportation

4 The flow of thick lined is a critical path

GOVERNMENT OF SRI LANKA
MINISTRY OF MAHAWELI DEVELOPMENT

MORAGAHAKANDA AGRICULTURAL DEVELOPMENT PROJECT

MORAGAHAKANDA DAM

CONSTRUCTION TIME SCHEDULE

DATE | DWG. NO. III. 8

JAPAN INTERNATIONAL COOPERATION AGENCY

ANNEX IV: POWER GENERATION

ANNEX IV POWER GENERATION

ANNEX IV POWER GENERATION

4.1 Power Demand Forcast

Table IV.1.1 shows the annual records of the energy consumption and generation for ten years from 1968 to 1977. Fig. IV.1.1 is a graphical display of the above records.

The graph shows that the energy consumption, except industries, increased gradually year by year for the past ten years, but the increasing rate of energy consumption for industries rapidly slowed down after 1973 and reached nearly zero after 1975.

This means that the effect of the so-called oil shock was very severe for industries.

This tendency can be clearly expressed by the growth rate for each item for ten year period of 1968-1977, the first five year period and the last five year period.

	1968-1972	1973-1977	1968-1977
Industries	12.5 %	3.4 %	7.35 %
Total except industries	7.12 %	7.2 %	7.17 %
Grand total	9.87 %	5.2 %	7.26 %

The above table shows that the growth rate of the total energy consumption other than the industries was not influenced by the oil shock and actually it became rather larger after the oil shock.

As for the industries, their growth rate seems to be almost stopped by the oil shock, but it will be possible not only to recover the growth rate before the oil shock but also to become larger, if a good policy for industries is well applied throughout the industrial world.

For the power projection, two regression analysis are applied. One is the regression equation between the total electricity consumption and GDP and the other is that between the total electricity consumption and the value added in manufacturing and mining.

The mean value of the above two methods is taken as the most probable value.

Table IV.1.2 shows the annual records of GDP, value added in manufacturing and mining and total electricity consumption.

These records were obtained from NEDECO's report.

By these records, two regression equations, (A) and (B), are derived as follows:

$$Y = 0.1521\ X - 765.4 \qquad (R^2 = 0.96) \qquad \text{(A)}$$

Y : Total electricity consumption (GWH)

X : GDP (million Rs)

R : Coefficient of correlation

$$Y = 0.757\ X_1 - 360.4 \qquad (R^2 = 0.982) \qquad \text{(B)}$$

X_1: Value added in manufacturing and mining (million Rs)

The annual growth rate of GDP was as follows:

1962 - 1977	3.89 %
1962 - 1973	4.05 %
1973 - 1977	3.44 %

The above data show that it might be easy to obtain a 4 % or more growth rate but without the effects of the oil shock.

An important question is, how much growth rate of GDP can be expected in the future?

To estimate this value, the maximum growth rate for five years and for three years are obtained from Table IV.1.2 as listed below.

1966 - 1969	6.06 %
1963 - 1968	6.28 %

Both values are from the period before 1973.

The government is very eager to develop the country and to promote policies such as the Accelerated Mahaweli Ganga Development Program, the establishment of a free-trade zone which is going on quite well, promotion of rural electrification and so on.

Therefore, the growth rate of GDP in the future may be a little higher than that of the past record of 6.28 % if a world-wide economic upheaval such as was caused by the oil shock does not occur in the future.

The growth rate of 6.9 % is adopted as that of GDP for power projection.

The annual growth rate of the value added in manufacturing and mining was as follows.

1962 - 1977	5.35 %
1962 - 1973	6.65 %
1973 - 1977	1.85 %

The above data show that industries suffered a great set back due to the oil shock.

The maximum growth rate for five years and three years are listed as follows:

1965 - 1970	7.55 %
1967 - 1970	8.66 %

The growth rate of 8.5 % is adopted as that of value added in manufacturing and mining for power projection using similar reasons as in the case of GDP.

The mean annual load factor is calculated at 55 % from Table IV.1.1 Of course, this value will be improved by the expansion of industries but the value 55 % is adopted for future maximum demand forcast because it is on the safe side.

The mean transmission and distribution efficiency for a ten-year period was 86.7 %, however the efficiency in 1970 was very low compared with the values of the other nine years, so there might be some error in statistics.

Excluding the value in 1970, the mean efficiency becomes 87.1 %.

The mean efficiency for the recent five years was 88 % but the value in 1977 was 85.9 %.

Thus in order to forcast electricity generation, 87.5 %, which is the mean value of 87.1 % and 88 %, has been adopted.

Table IV.1.3 shows the forcast of electricity consumption, generation and peak power demand calculated by Equation (A) and (B) under the following conditions:

1.	Annual growth rate of GDP	6.9 %
2.	" " of Value added	8.5 %
3.	Annual load factor	55 %
4.	Transmission and distribution efficiency	87.5 %

4.2 Firm Peak Output of Hydropower Stations

The firm peak output of each hydropower station is necessary to study the balance of the peak power demand. To find the firm peak output other than the Moragahakanda power station, the head variation of the water turbine is used; that is, the power of the turbine varies according to the square root of the third power of the turbine head.

To find simply the head variation, the following formula is used:

$$\text{Head variation} = \frac{A - B}{2} / H$$

where, A = maximum reservoir water level
B = minimum " "
H = turbine head

The head variation, thus obtained is as follows:

Power Station	Reservoir Level (feet) Max.	Mini.	Turbine Head (feet)	Head variation (%)
Old Laxapana	2,844	2,834	1,528	0.33
Winalasurendra	3,590	3,531.5	746	3.92
Polpitiya	1,247	1,228	850	1.11
New Laxapana	3,157	3,128	1,704	0.85
Canyon	3,830	3,758	670	5.37
Bowatenna	826	800	160	8.13
Samanalawesa	1,509.2	1,390.7	1,080	5.49
Kotmale	2,391.3	2,180	700	15.1
Randenigala	750	672	244	16
Victoria	1,410	1,215	609	16

It is assumed that the firm peak output is to be the same as the installed capacity when the head variation is less than 5 %. The Ukuwela power station is the only exceptional case, because it is operated as a run-of-river type power station, and its firm peak output is equal to its firm power.

The results obtained are as follows:

	Installed (MW)	Firm Peak (MW)
Old Laxapana	50	50
Wimalasurendra	50	50
Polpitiya	75	75
New Laxapana	100	100
Ukuwela	40	20
Canyon	30	28
Bowatenna	40	36
Samanalawewa	120	111
Kotmale	150	117
Randenigala	75	58
Victoria	120	92

4.3 kW and kWH Benefit

It is common to use the kW and kWH benefit for justifying development of a hydroelectric power station.

The kW benefit and the kWH benefit are the annual expense per kW and per kWH of the thermal power station which is equivalent to the planned hydroelectric power station.

Of course, the site of a thermal power station is not always the same as for a hydropower station and therefore the compensation factor must be used for line losses. Also, the annual utilization factor of a thermal power station is not the same as for a hydropower station, so a compensation factor must again be used.

As the electric energy produced by the Moragahakanda power station will be mainly consumed in Colombo, the line loss factor is estimated at the 132 kV bus of Kolonawa substation under the rough assumption as mentioned below.

(1) All power stations produce their maximum output at the same time, listed as follows:

Moragahakanda	26 MW
Bowatenna	40 MW
Ukuwella	40 MW
Total	106 MW

(2) Out of 106 MW, two-thirds of it is sent to Polpitiya and one-third of it is sent to the northern district.

(3) From Polpitiya, 300 MW is sent to Kolonawa through 4 circuits of a 132 kV line.

(4) The power factors of each line are equal and 90 % lagging.

As a result, the line loss factor becomes 11.6 %.

Thus, if the main transformer loss at Moragahakanda is 0.8 %, then the total loss from Moragahakanda to Kolonawa is 12.4 %.

By applying the Buller-Woodrowo's formula, the loss factor for the mean power is determined to be about 9 % including the Moragahakanda main transformer, having a 60 % load factor.

kW value adjustment factor

	Hydro	Thermal
Transmission loss	12.4 %	0.8 %
Forced outage	-	2 %
Outage for overhauls and inspection	9 %	21.4 %
Station service	0.3 %	7 %

kW value ratio $\left(\frac{\text{Hydro}}{\text{Thermal}}\right) = \frac{(1-0.124)(1-0.09)(1-0.003)}{(1-0.008)(1-0.02)(1-0.214)(1-0.07)} = 1.118$

kWH value adjustment factor

	Hydro	Thermal
Transmission line loss	9 %	0.6 %
Station service	0.3 %	7 %

kWH value ratio $\left(\frac{\text{Hydro}}{\text{Thermal}}\right) = \frac{(1-0.09)(1-0.003)}{(1-0.006)(1-0.07)} = 0.9814$

Annual Fixed Charges of Thermal Power Station

(1) Annual capital and interest repayment at 10 % discount rate amortized over 25 years	11.02 %
(2) Major overhaul and renewals	2 %
(3) Operation and maintenance, administration and general costs	1.2 %
(4) Insurance and taxes	0.05 %
(5) Cost of electricity for general use	0.4 %
Total	14.67 %

The construction cost of the Thermal power station of 50 MW capacity is around 660 US$ per kW, then the annual fixed charge is

660 x 0.1467 = 96.82 US$/kW

Annual Running Charge of Thermal Power Station

(1) Lubricant and consumables 1.0 %

(assumption: annual energy generation is 6,000 kWH per kW)

660 x 0.01/6,000 = 0.0011 US$/kWH

(2) Fuel cost

Unit price : 0.073 US$/ℓ = 0.0811 US$/kg (Specific gravity = 0.9)
= 0.03679 US$/lb.

Calorific value: 18,500 BTU/lb.

Assuming the overall thermal efficiency is 27 % the fuel cost per kWH is as follows:

$$\frac{3,412.7 \times 0.03679}{0.27 \times 18,500} = 0.02514 \text{ US\$/kWH}$$

Running charge per kWH = 0.0011 + 0.02514
= 0.02624 US$/kWH

kW benefit = 96.82 x 1.118
= 108 US$/kW

kWH benefit = 0.02674 x 0.9814
= 0.02575 US$/kWH

Annual Charge for Hydropower Station

(1) Annual capital and interest repayment at 10 % discount rate

for civil works (amortized over 50 years) 10.08 %

for electro-mechanical equipment (amortized over 35 years). 10.369 %

(2) Major overhauls and renewals 0.5 %

(3)	Operation and maintenance, administration and general costs	1.0 %
(4)	Insurance and taxes	0.05 %

Annual Charge for Transmission line

(1)	Annual capital and interest repayment at 10 % interest amortized over 35 years	10.369 %
(2)	Maintenance and renewals	1.5 %

4.4 Schemes of the Power Station

The storage capacity of 606 MCM (million cubic meters) is enough for the irrigation requirements only and high water level of the Reservoir is EL. 188 m.

Thus, the Reservoir scale of H.W.L. at EL. 188 m is the minimum scale of the Reservoir.

Two Reservoir scales of H.W.L. at EL. 195 m and EL. 200 m are also picked up for a comparative study.

The high water level at more than EL. 200 m has not been considered because the tailrace level of the Bowatenna power station is around EL. 200 m.

In the case of a Reservoir scale of H.W.L. at EL. 188 m the firm power cannot be expected because the priority of water release is given to the irrigation requirements.

In the case of a Reservoir scale of H.W.L. at EL. 195 m and 200 m, the water is released to produce the firm power as high as possible when the Reservoir water level is less than the operation level. As such, the firm power obtained is 6 MW at H.W.L. = 195 m and 10 MW at H.W.L. = 200 m.

The operation level is the level where the storage capacity of 606 MCM is obtained between this level and the high water level.

The operation level is EL. 174.4 m in the case when the H.W.L. = 195 m, and 184.77 m in the case when the H.W.L. = 200 m.

The water level duration curves are shown in the Fig. IV.4.1.

There are two different concepts which can be used to determine the generating capacity.

One concept is to limit the maximum discharge capacity of the turbine at 56.6 m^3/s in order to eliminated the construction cost of the afterbay. The water quantity of 56.6 m^3/s is the maximum intake capacity of the Elahera diversion weir, and this capacity is enough for irrigation requirements.

The other concept is to install a larger capacity than the above, with the afterbay construction to meet the daily peak demand.

The peak hours per day are around 3 or 4 hours as shown in the Fig. IV.4.2 and Fig. IV.4.3.

Then, 40 MW and 66 MW capacities are applied for the firm output of 6 MW and 10 MW, respectively.

Six schemes have been selected and studied.

Scheme No.1 is a scheme which has no generating equipment and provides only agricultural benefits.

The other five schemes are shown in the Table IV.4.1.

In the case of Schemes No.2, No.3 and No.5, the rated effective head in Table IV.4.1 is such a head as where the turbine can discharge water amounting to 56.6 m^3/s at this head with full gate opening.

In the case of Schemes No.4 and No.6, the rated effective head is such a head as the turbine can produce the maximum output at this head with a full gate opening.

The annual effective energy output is obtained as described hereinunder.

By the simulation calculation of the monthly power output for 28 years from 1950 to 1977, 28 values of monthly output for each month have been obtained.

The value of the third order from the lowest value is assumed as the effective power output of the due month. The total of the effective power output of each month from January to December is the effective energy output. Accordingly, the probability of this energy output is about 92.8 %; ie (28-2)/28 = 0.9286.

The effective peak output is obtained as described below.

As discussed above, by using simulation calculations there are 28 values of the Reservoir water level for each month of the 28 year period from 1950 to 1977.

The maximum output at the water level of the third order from the lowest for each month is assumed as the effective peak output of the due month.

The mean value of the effective peak output of 12 months from January to December is the effective output.

Figs.IV.4.4 & IV.4.5 show the results of the dependable peak power and energy yield at the first stage unit of 26 MW recalculated on the basis of the waterlevel of the Reservoir and available discharge obtained from the reservoir operation study as referred to Section 7.2, and loss of head in the waterway and estimated efficiency of generating unit.

The construction cost of the above five schemes are as follows:

	Foreign Currency	Local Currency	Total (10^6Rs)
Scheme No.2	102.8	15	117.8
Scheme No.3	101.6	14.8	116.4
Scheme No.4	153.7	21.5	175.2
Scheme No.5	99.9	14.6	114.5
Scheme No.6	218.5	30.6	249.1

Table IV.1.1 Annual Energy Generation and Consumption (GWH)

Description	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Consumption										
Industries	272	302	329.2	373.2	436.2	466.4	477.2	519.2	513.6	515
Commercial	81	82	85.6	92.8	96.8	107.6	118.1	122.5	139.6	154
Bulk Supply for Local Authorities	138.5	151	167.1	180.4	193.1	198.4	201.9	226.3	237.3	257
Street Lighting	9.5	10	10.5	11.0	11.5	12.0	12.5	13	13.5	14.7
Domestic	55	59	62.5	64.6	72.5	81.5	82.6	85	93	104
Total	556	604	654.9	722	810.1	865.9	892.3	965	997	1,044.7
Generation	648	695	785.8	845.2	944.3	979.5	1,011.4	1,078.8	1,132.8	1,216.6
Transmission and Distribution Efficiency (%)	85.8	86.9	83.3	85.4	85.8	88.4	88.2	89.5	88.0	85.9
Peak Demand (MW)	134.7	146.7	163.1	173.4	185.3	198.8	215.6	218.9	240.3	261
Annual Load factor (%)	53.1	54.1	55.0	55.6	58.2	56.2	53.6	56.3	53.8	53.2

Table IV.1.2 GDP and Value Added in Manufacturing and Mining

Year	Total Electricity Consumptions (GWH)	Gross Domestic Product at Constant Factor Cost of 1959 (Million Rs)	Value Added in Manufacturing and Mining at Constant Factor Cost of 1959 (Million Rs)
1962	282	6,760	831
63	309	6,591	883
64	333	7,397	933
65	360	7,564	971
66	424	7,854	1,045
67	489	8,255	1,089
68	556	8,937	1,191
69	604	9,369	1,315
70	655	9,771	1,397
71	722	9,792	1,446
72	810	10,098	1,468
73	866	10,462	1,687
74	892	10,840	1,611
75	965	11,142	1,710
76	997	11,480	1,843
77	1,045	11,977	1,816

Table IV.1.3 Power Demand Forcast

Year	Consumption (GWH)			Generation	Peak Power
	(A)	(B)	Mean	(GWH)	(MW)
1978	1,182	1,131.2	1,157	1,322	274
79	1,316.4	1,257.9	1,287	1,471	305
80	1,460	1,395.5	1,428	1,632	339
81	1,613.6	1,544.8	1,579	1,805	375
82	1,777.7	1,706.7	1,742	1,991	413
83	1,953.2	1,882.4	1,918	2,192	455
84	2,140.8	2,073	2,107	2,408	500
85	2,341.3	2,279.9	2,311	2,641	548
86	2,555.7	2,504.3	2,530	2,891	600
87	2,784.8	2,747.8	2,766	3,161	656
88	3,029.8	3,012.0	3,021	3,453	717
89	3,291.6	3,298.7	3,295	3,766	782
90	3,571.6	3,609.7	3,591	4,104	852
91	3,870.8	3,947.1	3,909	4,467	927
92	4,190.7	4,313.3	4,252	4,859	1,009
93	4,532.7	4,710.5	4,622	5,282	1,096
94	4,898.3	5,141.6	5,020	5,737	1,191
95	5,289.1	5,609.2	5,449	6,227	1,293
96	5,706.8	6,116.6	5,912	6,757	1,402
97	6,153.4	6,667.2	6,410	7,326	1,521
98	6,630.8	7,264.5	6,948	7,941	1,648
99	7,141.1	7,912.7	7,572	8,602	1,785
2000	7,686.7	8,615.9	8,151	9,315	1,933

Table IV.4.1 Schemes of the Power Station

Scheme No.		2	3	4	5	6
Reservoir:						
H.W.L.	(m)	188	195	195	200	200
L.W.L.	(m)	165	170	170	175	175
Effective Head:						
Maximum	(m)	48.2	55.2	55.2	60.2	60.2
Minimum	(m)	25.2	30.2	30.2	35.2	35.2
Maximum Discharge :	(m^3/s)	56.6	56.6	114	56.6	165
Output:						
Maximum	(MW)	22.5	26	40	28.5	66
Effective	(MW)	-	16.7	29.1	18.0	49.2
Annual Energy Output:						
Effective	(GWH)	-	66.5	66.5	93.1	93.1
Mean	(GWH)	104.4	150.1	159.6	168.2	183
Turbine:						
No. of Units		1	1	2	1	2
Rated Head	(m)	25.2	34.6	42	43	48
Max. Discharge	(m^3/s)	56.6	56.6	57	56.6	82.5
Speed	(r.p.m.)	214.3	214.3	250	240	214.3
Generator:						
No. of Units		1	1	2	1	2
Capacity	(MVA)	26.5	30.5	23.5	33.5	38.8
Voltage	(kV)	11	11	11	11	11
Speed	(r.p.m.)	214.3	214.3	250	250	214.3
Main Transformer:						
No. of Units		1	1	1	1	1
Capacity	(MVA)	26.5	30.5	47	33.5	77.6
Voltage	(kV)	132/11	132/11	132/11	132/11	132/11

Fig. IV.1.1

ANNUAL ENERGY CONSUMPTION

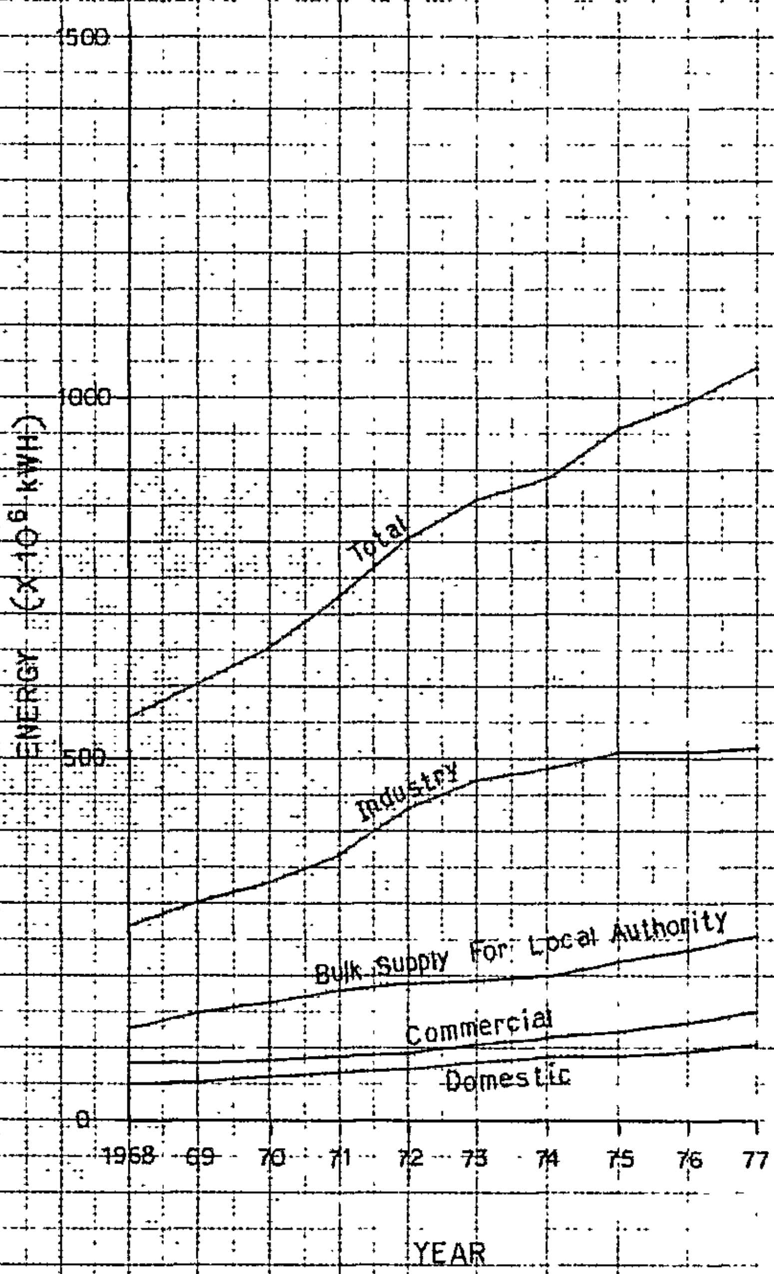


Fig. IV.4.1 WATER LEVEL DURATION CURVES OF RESERVOIR

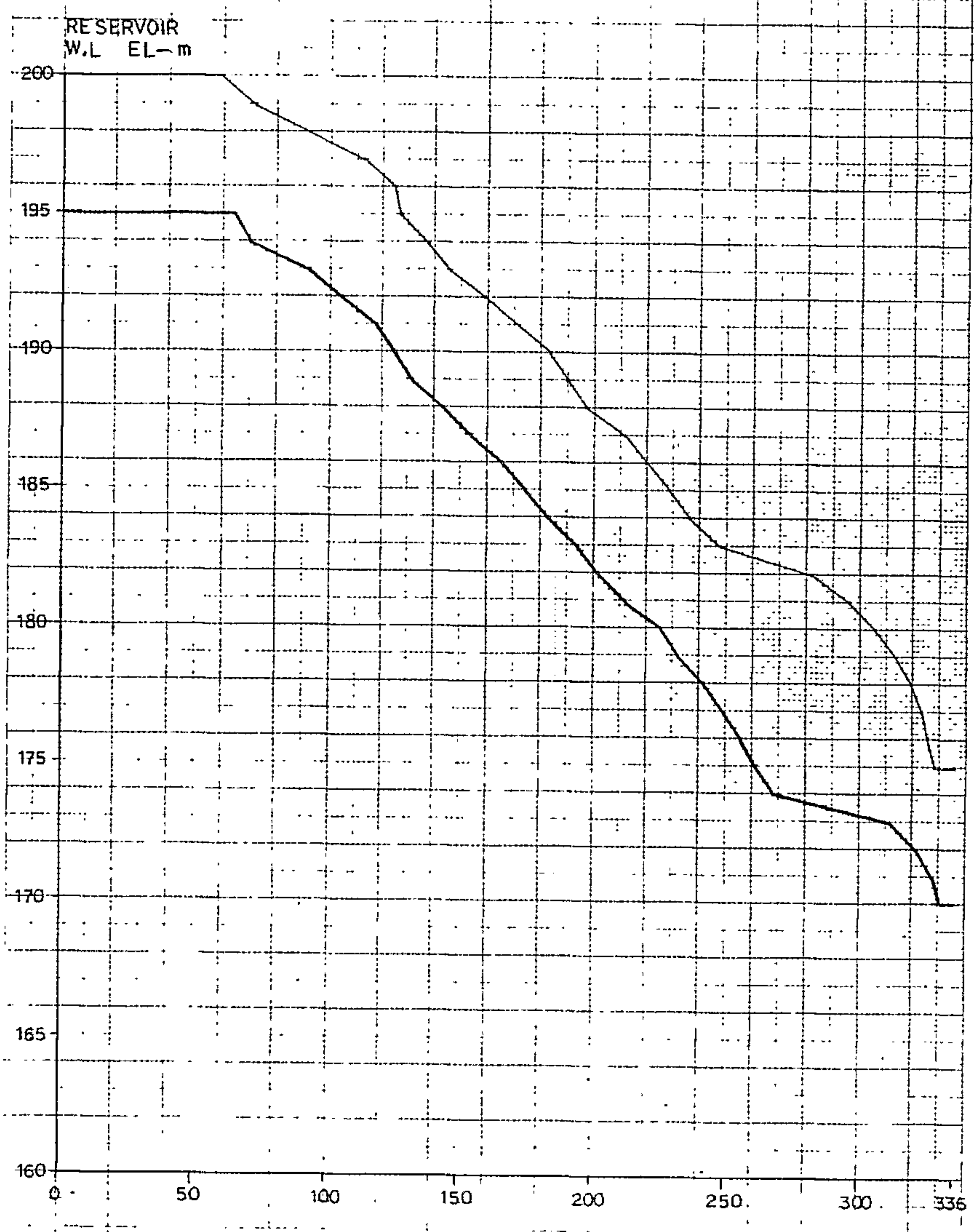
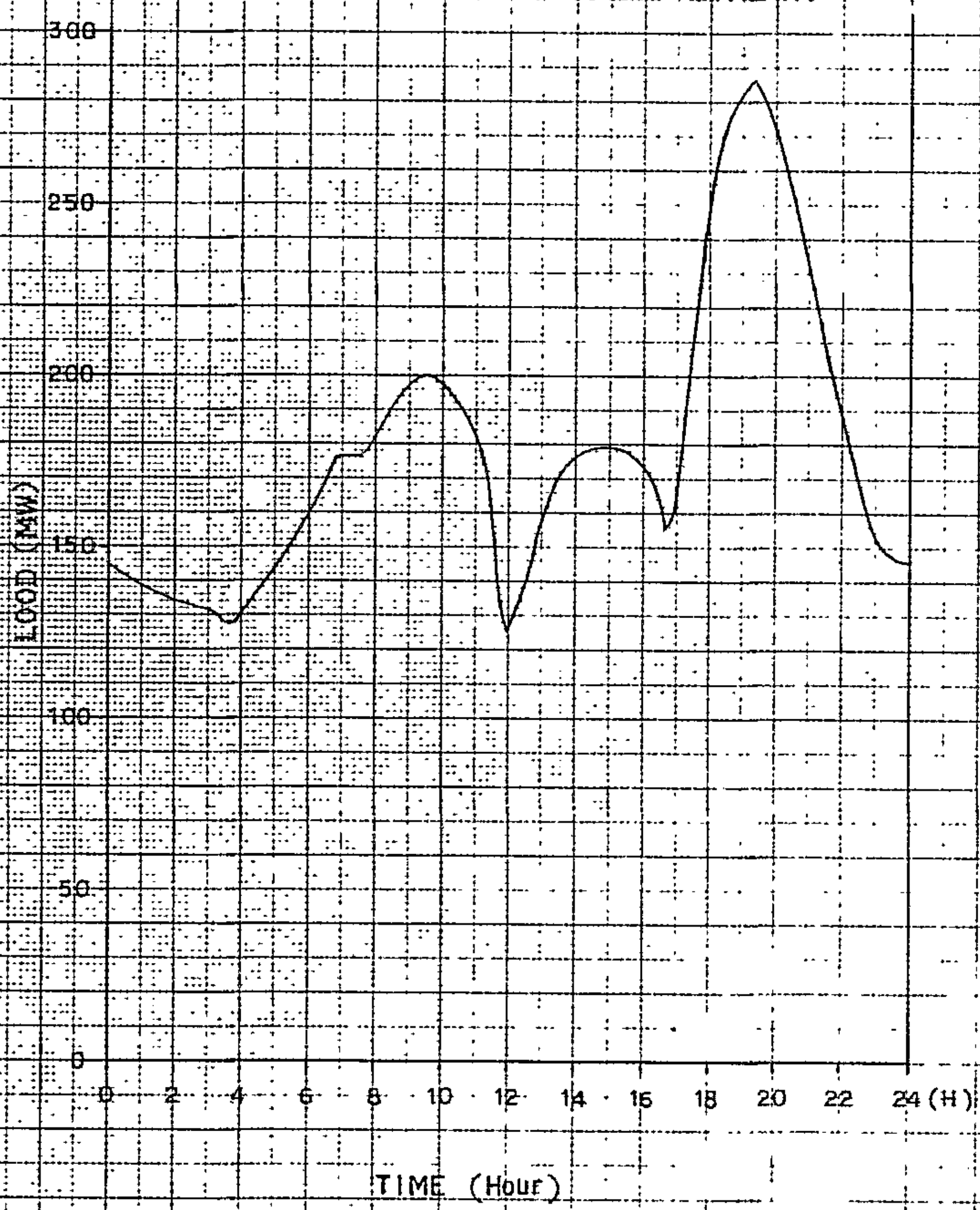


Fig.IV.4.2 DAILY LOOD CARVE FOR THE C.E.B. POWER SYSTEM (1978)



JIS A4 180・250mm

Fig.IV.4.3 DAILY LOOD DURATION CURVE (1978)

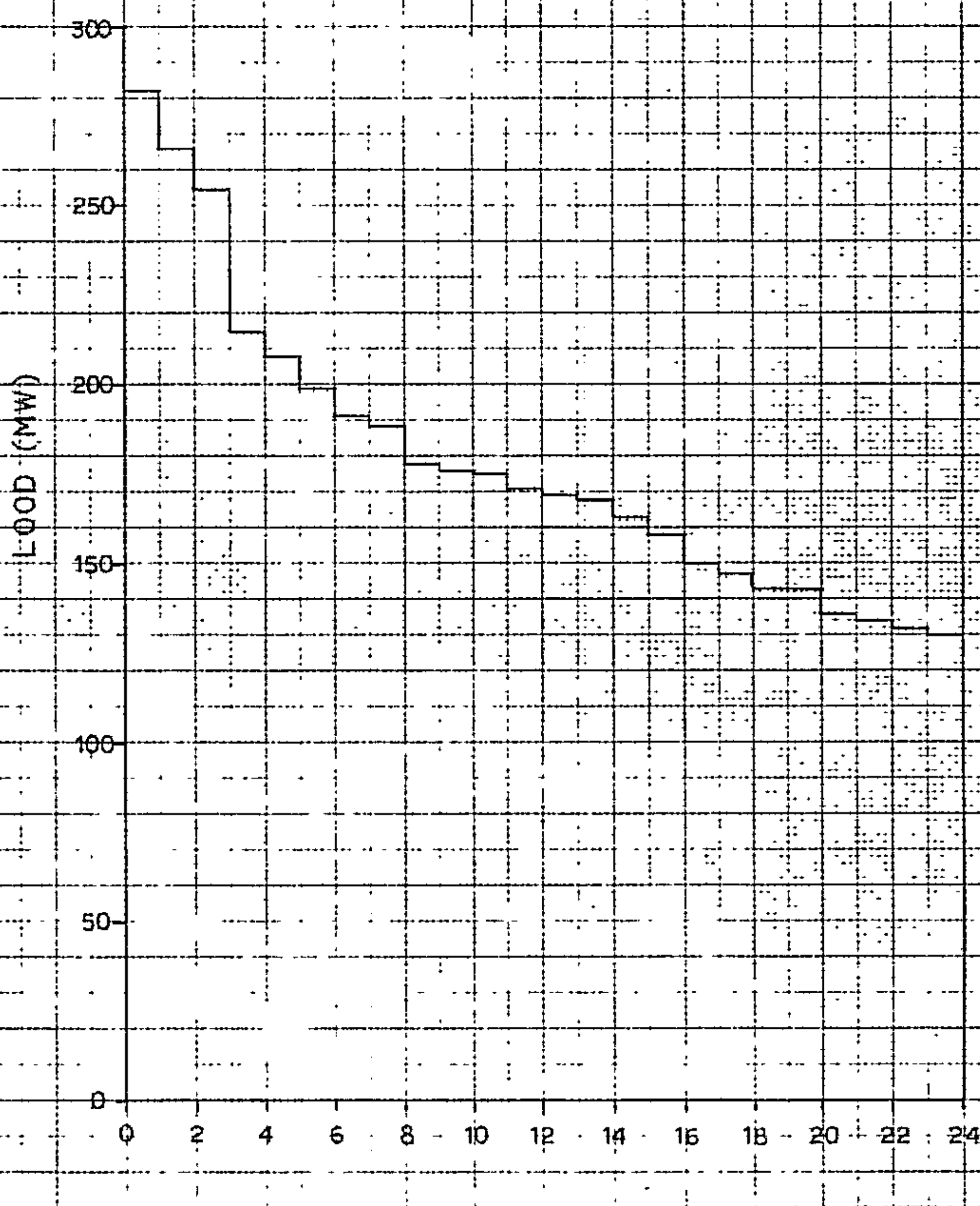


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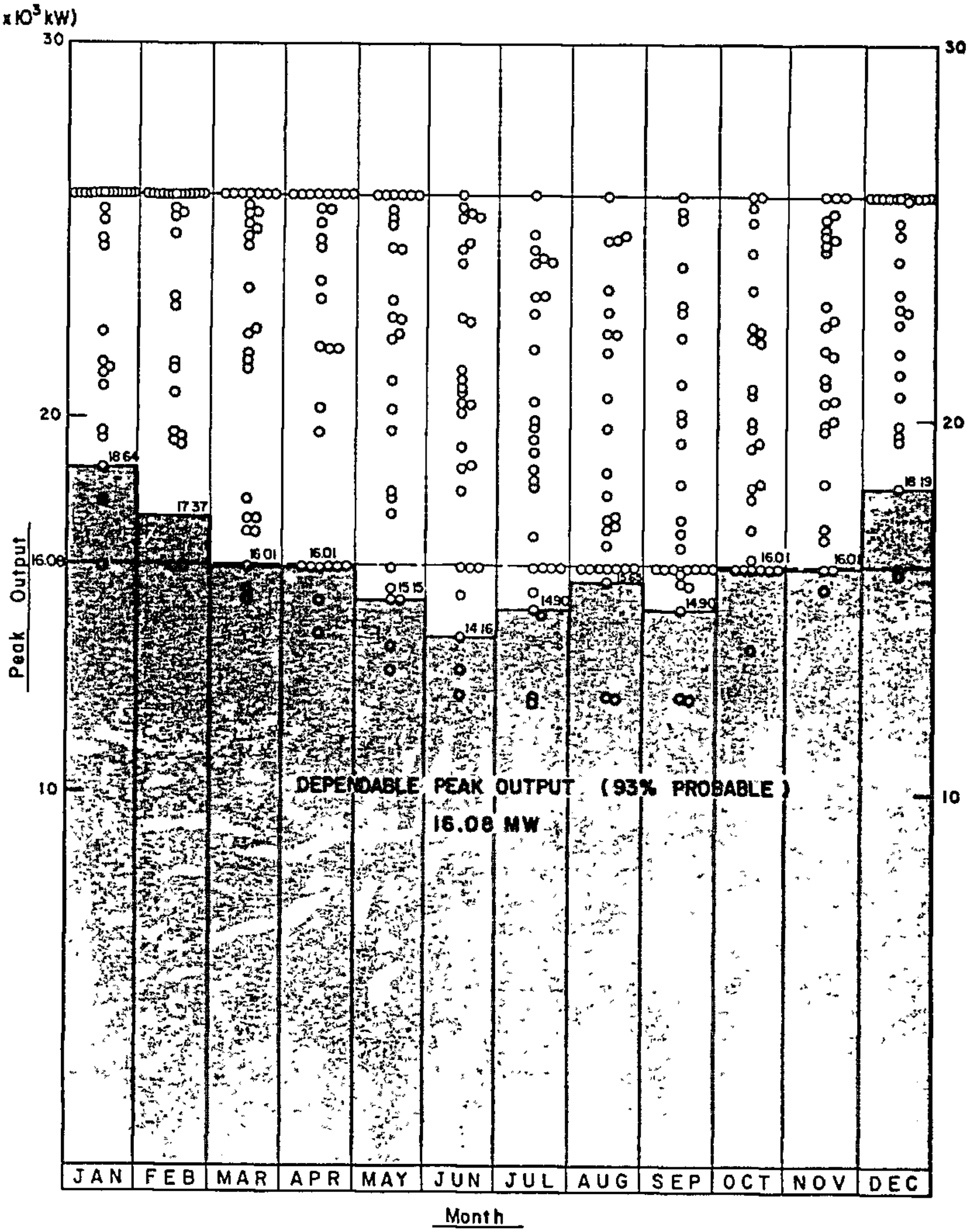
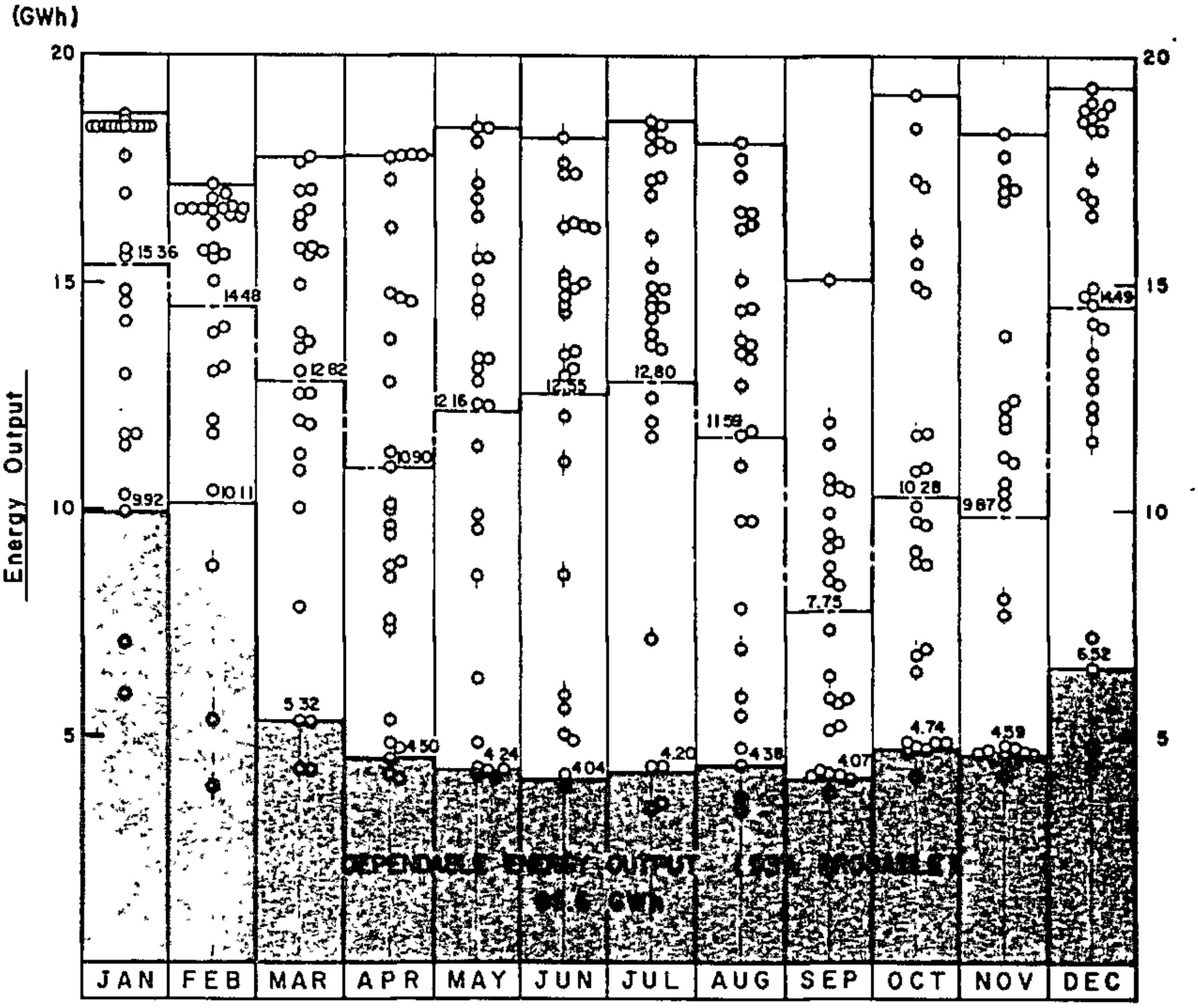
Fig. IV.4.4 ESTIMATED MONTHLY PEAK OUTPUT



Note : Based on the hydrologic data from 1950 to 1977
—·—. Monthly mean peak output

Fig. IV.4.5 ESTIMATED MONTHLY ENERGY OUTPUT



Note : Based on the hydrologic data from 1950 to 1977.

—·—·— : Monthly mean energy output

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