The generated electric power at the Upper Kihansi Power Station is to be transmitted by the connecting transmission line from the switchyard to the 220 kV transmission line constructed from the switchyard of the Lower Kihansi Power Station to Iringa Substation.

(2) The Lower Kihansi Project

The dam site is located about 3 km downstream from the Upper Kihansi Power Station on the Kihansi River and the concrete gravity dam with height 35 m and dam volume 54,000 m^3 is constructed to provide gross regulating reservoir storage capacity of 1.4×10^6 m^3 and the effective of 0.48×10^6 m^3. The inflow into this regulating reservoir is to be daily regulated.

The maximum available discharge of 22.2 m^3/sec is introduced to the intake constructed at the left bank just upstream of the dam and conducted to the powerhouse situated at the left bank through the headrace tunnel and the embedded penstock with total length of 4,181 m and the maximum output of 153 MW with the annual electric firm energy of 551.0 GWh is generated with the effective head of 813.0 m. Generated water is to be outlet to the Kihansi River through the tailrace tunnel with length of 615 m.

The generated electric power at this power station is to be transmitted from the switchyard to Iringa Substation by the newly constructed transmission line.

(3) Transmission Line

The transmission line with 220 kV and 2 circuits is to be newly constructed starting from the switchyard of the Lower Kihansi Power Station via that of the Upper Kihansi Power Station to Iringa Substation with total length of 113 km.

The layouts of the Upper and Lower Kihansi Projects are shown in Fig. 3 - Fig. 12.

Summary of Upper Kihansi Hydroelectric Power Development Project

Item	Unit	Description
Location		Kihansi River
Catchment Area	km^2	583
Annual Inflow	10^6 m^3	494.48
Design Flood	m^3/sec	400
Reservoir		
Normal High Water Level	m	1,360
Low Water Level	m	1,330
Available Drawdown	m	30
Sedimentation Level	m	1,300
Gross Storage Capacity	10^6 m^3	94.90
Effective Storage Capacity	10^6 m^3	75.10
Reservoir Area	km^2	3.86
Sub-diversion Tunnel		
Design flood discharge	m^3/sec	10
Type		Semi-circle
Number		1
Dimension	m	Width 2.00
	m	Height 2.00
Length	m	300.00

Item	Unit	Description
Main Diversion Tunnel		
Design flood discharge	m^3/sec	90
Type		Semi-circle
Number		1
Dimension	m	Width 3.00
	m	Height 3.00
Length	m	425.00
Dam		
Type		Rockfill with center core
Crest elevation	m	1,365.00
Crest length	m	583.00
Crest width	m	10.00
Dam height	m	95.00
Dam volume	m^3	5,350,000
Spillway		
Design flood discharge	m^3/sec	400
Spillway capacity	m^3/sec	400
Type		Free overflow type
Crest elevation	m	1,360.00
Crest length	m	100

Item	Unit	Description
Intake		
Type		Inclined type made of reinforced concrete
Number		1
Maximum discharge	m^3/sec	25.7
Inlet level	m	1,320.00
Dimension	m	Width 6.00
	m	Height 50.00
Headrace Tunnel		
Number		1
Maximum discharge	m^3/sec	25.7
Diameter	m	3.30
Length	m	653.00
Penstock		
Number		1
Maximum discharge	m^3/sec	25.7
Diameter	m	3.30 ~ 1.85
Length	m	510.24

Item	Unit	Description
Powerhouse		
Type		Semi-underground of reinforced concrete
Dimension	m	Width 20.00
	m	Length 22.50
	m	Height 35.00
Turbine center level	m	1,135.00
Installed capacity	MW	47
Tailrace Tunnel		
Type		Horseshoe
Maximum discharge	m^3/sec	25.7
Diameter	m	4.00
Length	m	641.00
Tailrace Outlet		
Type		Box culvert made of reinforced concrete
Maximum discharge	m^3/sec	25.7
Dimension	m	Width 4.00
	m	Length 10.00
	m	Height 7.50
Outlet level	m	1,135.35

Item	Unit	Description
Turbine		
Type		Vertical Shaft Francis Turbine
Number of unit		1
Rated effective head	m	214.50
Water discharge	m^3/sec	25.7
Rated output	MW	48
Revolving speed	rpm	429
Generator		
Type		3-phase, AC, synchronous generator
Number of unit		1
Capacity	MVA	53 (with 0.9 lagging power factor)
Revolving speed	rpm	429
Frequency	Hz	50
Voltage	kV	11.0
Main Transformer		
Type		Outdoor, single-phase transformer
Number of units		4 (including 1 spare transformer)
Capacity	MVA	53
Voltage	kV	11.0

Item	Unit	Description
Switchyard		
Bus type		Single bus
Bus		Aluminum cable
Number of lines		2 circuits
Voltage	kV	220
Conductor type		ACSR, 400 mm^2
Annual Energy Production		
Total Energy	GWh	275.1
Firm Energy	GWh	335.7
Construction Period	years	4.5
Project Cost	10^3 US$	261,000
Unit Construction Cost at Sending End	US$/kWh	0.78
Financial Internal Rate of Return (FIRR)	%	6.49
Economic Internal Rate of Return (EIRR)	%	11.26
Net Present Value (B-C)	10^3 US$	9,221.46
Benefit Cost Ratio (B/C)		1.07

Summary of Lower Kihansi Hydroelectric Power Development Project

Item	Unit	Description
Location		Kihansi River
Catchment Area	km^2	590
Annual Inflow	10^6 m^3	500.48
Design Flood	m^3/sec	400
Regulating Reservoir		
Normal High Water Level	m	1,140
Low Water Level	m	1,137
Available Drawdown	m	3
Sedimentation Level	m	1,125
Gross Storage Capacity	10^6 m^3	1.39
Effective Storage Capacity	10^6 m^3	0.48
Reservoir Area	km^2	0.19
Diversion		
Design flood discharge	m^3/sec	80
Type		Box culvert inside the dam
Number	m	1
Dimension	m	Width 3.00
	m	Height 4.00
Invert level		1,115.00

Item	Unit	Description
Dam		
Type		Concrete gravity
Crest elevation	m	1,143.00
Crest length	m	177.00
Crest width	m	5.00
Dam height	m	35.00
Dam volume	m^3	54,000
Spillway		
Design flood discharge	m^3/sec	400
Spillway capacity	m^3/sec	160
Type		Free overflow type
Crest elevation	m	1,140.00
Crest length	m	13.00 x 4 spans
		= 52.00
Sand Flushing		
Capacity	m^3/sec	240
Type		Controlled type with
		gate inside the dam
Dimension	m	Width 4.00
	m	Height 4.00
Invert level	m	1,123.00

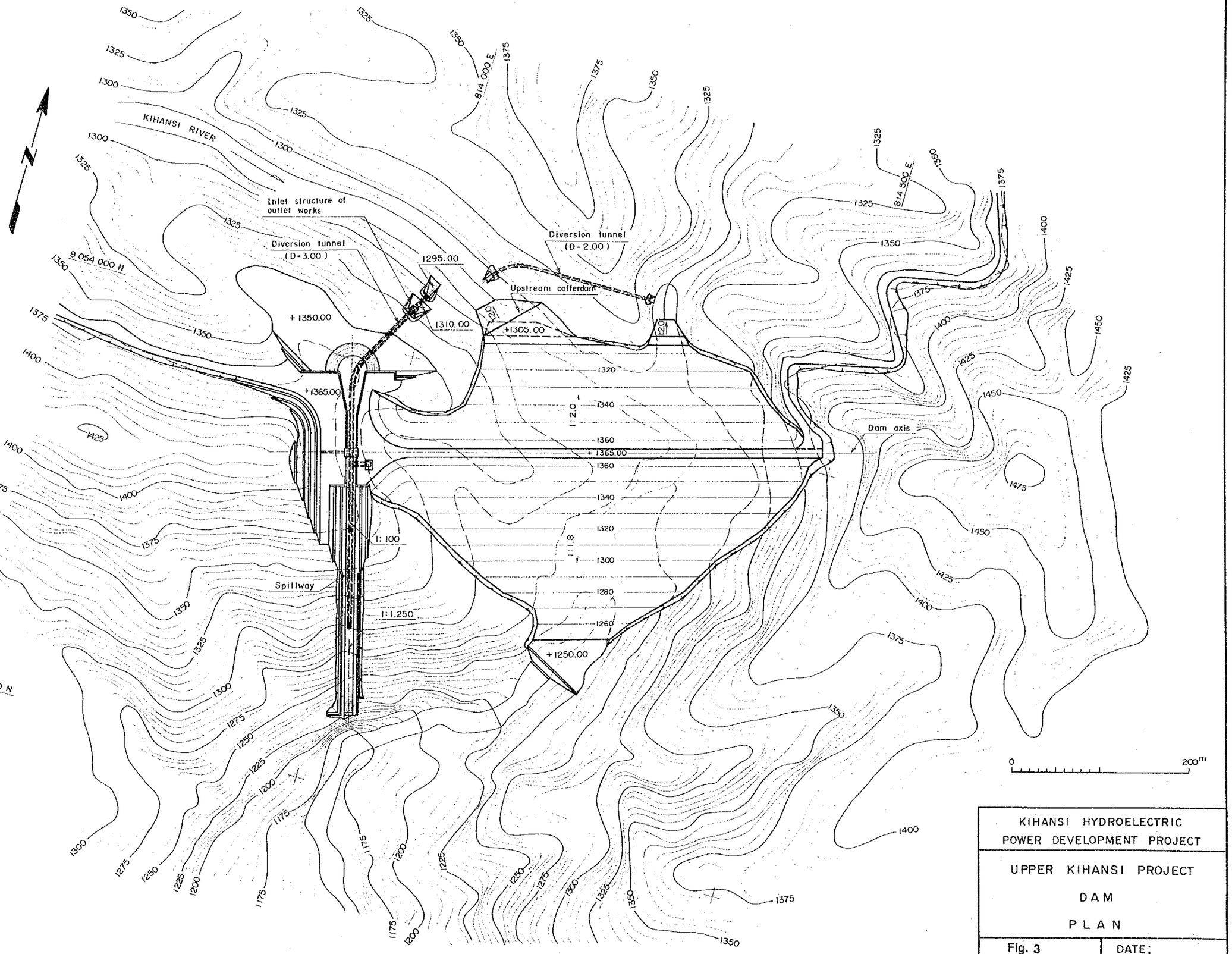
Item	Unit	Description
Intake		
Type		Vertical type made of reinforced concrete
Number		1
Maximum discharge	m^3/sec	22.2
Inlet level	m	1,125.00
Dimension	m	Width 6.00
	m	Height 25.50
Headrace Tunnel		
Number		1
Maximum discharge	m^3/sec	22.2
Diameter	m	3.00
Length	m	1,258.69
Penstock		
Number		Main 1
		Branches 3
Maximum discharge	m^3/sec	Main 22.2
	m^3/sec	Branches 7.4
Diameter	m	Main 3.00 ~ 2.20
	m	Branches 1.80 ~ 0.90
Length	m	Main 2,858.31
	m	Branches No.1 80.00
		No.2 82.05
		No.3 64.00

Item	Unit	Description
Powerhouse		
Type		Semi-underground made of reinforced concrete
Dimension	m	Width 25.50
	m	Length 59.00
	m	Height 34.60
Turbine center level	m	296.50
Installed capacity	MW	153
Tailrace Tunnel		
Type		Main Horseshoe
		Branches Semi-circle
Maximum discharge	m^3/sec	Main 22.2
	m^3/sec	Branches 7.4
Diameter	m	Main 3.50
	m	Branches 3.00
Length	m	Main 580.00
	m	Branches 35.00 x 3 units = 105.00
Tailrace Outlet		
Type		Open channel made of reinforced concrete
Maximum discharge	m^3/sec	22.2
Dimension	m	Width 7.00 ~ 15.00
	m	Length 47.00
	m	Height 9.70
Outlet level	m	293.00

Item	Unit	Description
Turbine		
Type		Vertical Shaft Pelton Turbine (6-nozzle)
Number of unit		3
Rated effective head	m	813.00
Water discharge	m^3/sec	7.4 (22.2 with 3 units)
Rated output	MW	52
Revolving speed	rpm	750
Generator		
Type		3-phase, AC, synchronous generator
Number of units		3
Capacity	MVA	57 (with 0.9 lagging power factor)
Revolving speed	rpm	750
Frequency	Hz	50
Voltage	kV	11.0
Main Transformer		
Type		Outdoor, single-phase transformer
Number of units		10 (including 1 spare transformer)
Capacity	MVA	19
Voltage	kV	11.0

Item	Unit	Description
Switchyard		
Bus type		Double bus
Bus		Aluminum cable
Number of lines		2 circuits
Voltage	kV	220
Conductor type		AAC 400 mm^2
Transmisison Lines		
Number of circuits		2
Voltage	kV	220
Conductor type		ACSR 380 mm^2
Section		Lower switchyard to Iringa Substation
Length	km	113
Annual Energy Production		
Total Energy	GWh	868.9
Firm Energy	GWh	551.0
Construction Period	years	3.5
Project Cost	10^3 US$	206,000
Unit Construction Cost at Sending End	US$/kWh	0.37

Item	Unit	Description
Economic Internal Rate of Return (EIRR)	%	45.94
Financial Internal Rate of Return (FIRR)	%	12.74
Net Present Value (B-C)	10^3 US$	129,236.15
Benefit Cost Ratio (B/C)	-	2.32



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

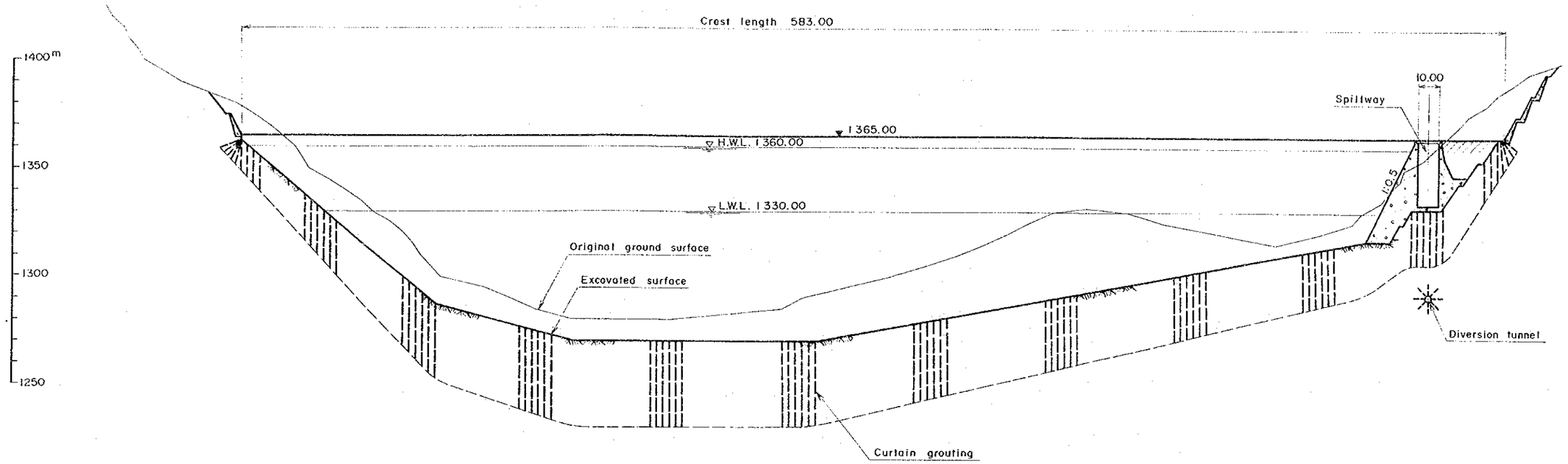
UPPER KIHANSI PROJECT

DAM

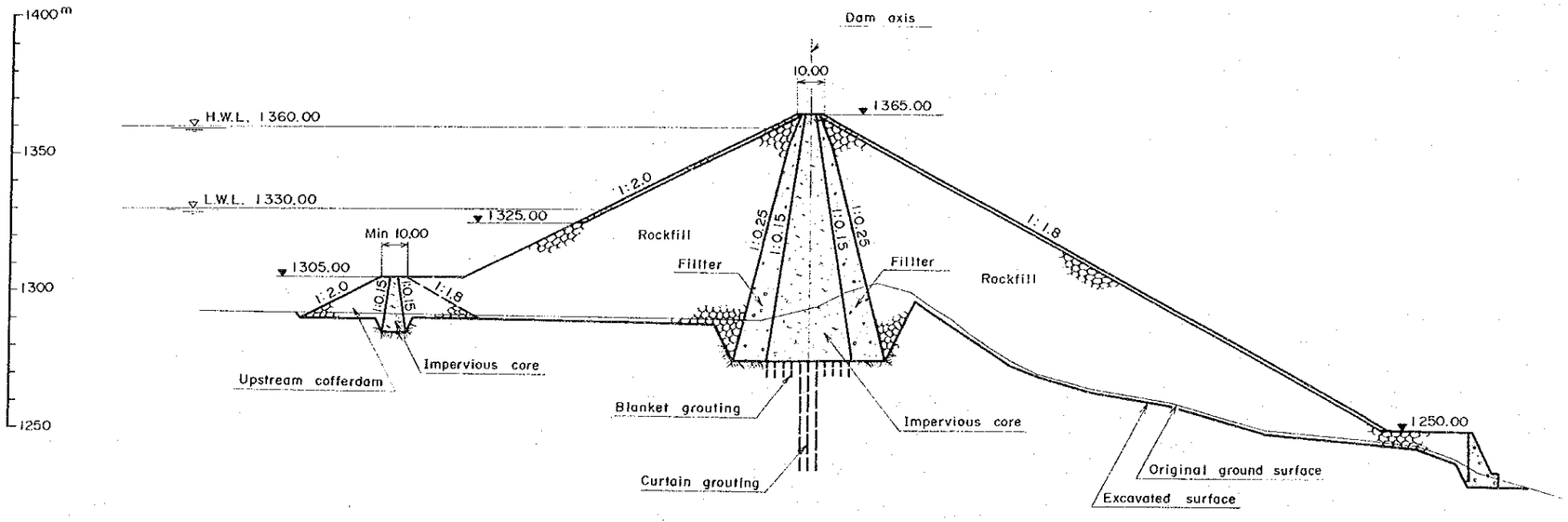
PLAN

Fig. 3 | DATE;

PROFILE OF DAM



TYPICAL SECTION OF DAM



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

UPPER KIHANSI PROJECT

DAM

PROFILE AND TYPICAL SECTION

Fig. 4 | DATE;

N

814 000 E

813 500 E

KIHANSI RIVER

1250
1225
1200
1175
1300
1325
1350
1375
1400
1425
1275

Power house

1163.00

Switchyard

Penstock

292.80

246.00

I.P.Ⓑ

350.00

Tailrace tunnel length 641.00

Penstock L=461.00

150.00

140.00

241.20

I.P.Ⓑ
θ = 34°00'00"
R = 100.00
T.L = 30.57
C.L = 59.34

+1320.00

1370.00

Headrace tunnel

Intake

I.P.Ⓐ

414.43

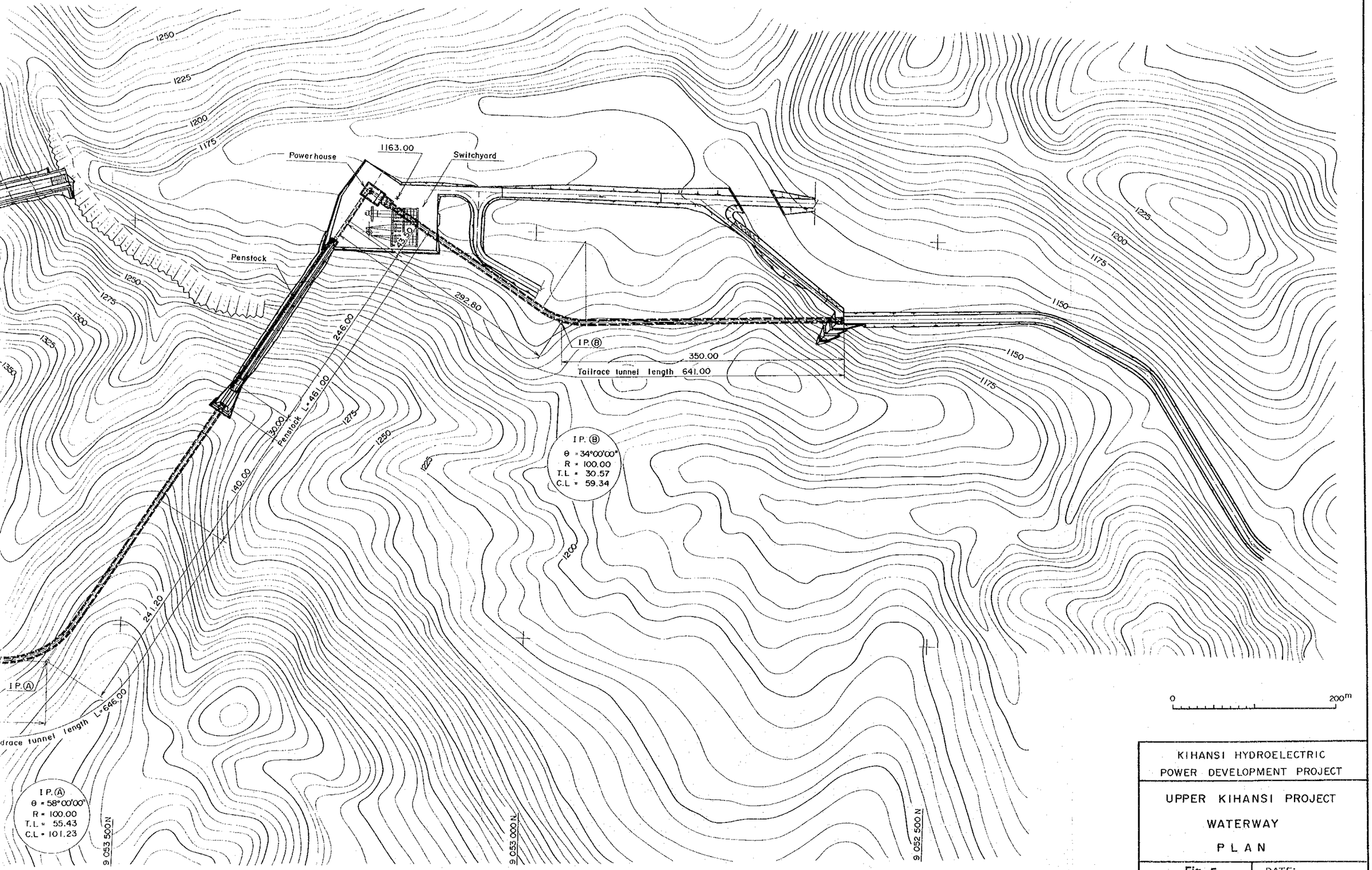
Headrace tunnel length L=646.00

I.P.Ⓐ
θ = 58°00'00"
R = 100.00
T.L = 55.43
C.L = 101.23

9 054 000 N

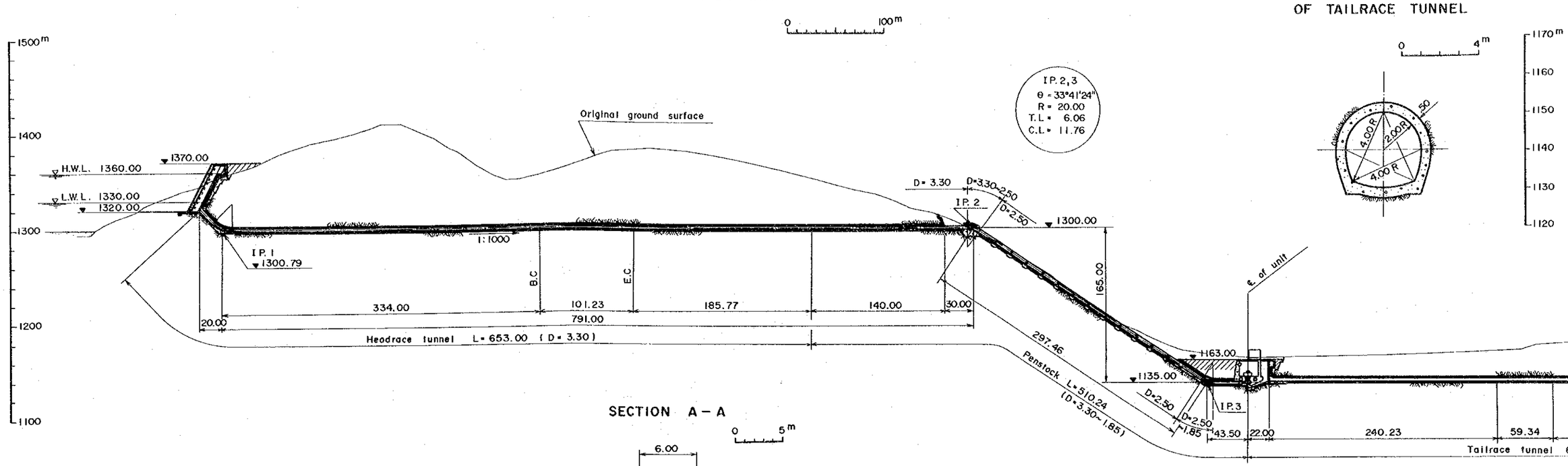
9 053 500 N

9 053 000 N



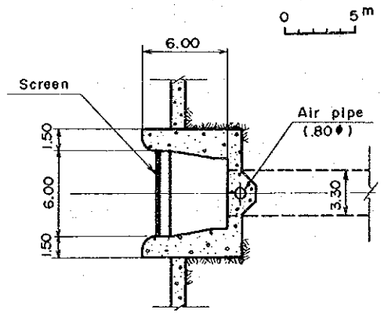
KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT	
UPPER KIHANSI PROJECT WATERWAY P L A N	
Fig. 5	DATE;

PROFILE OF WATER WAY

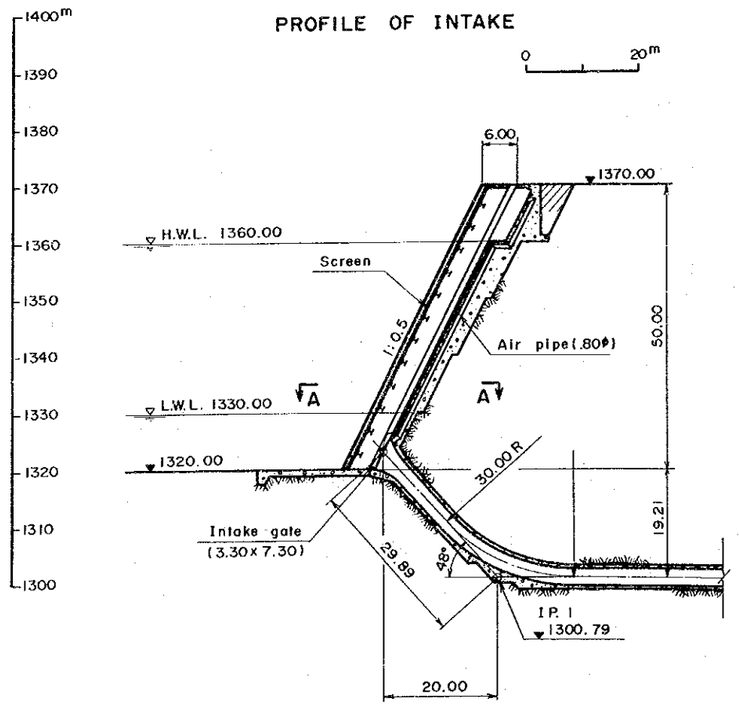


TYPICAL CROSS SECTION OF TAILRACE TUNNEL

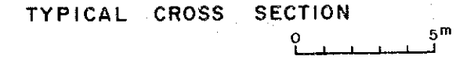
SECTION A – A



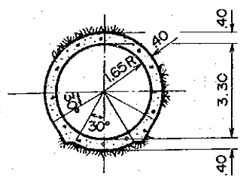
PROFILE OF INTAKE



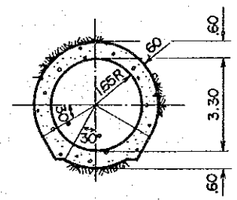
TYPICAL CROSS SECTION



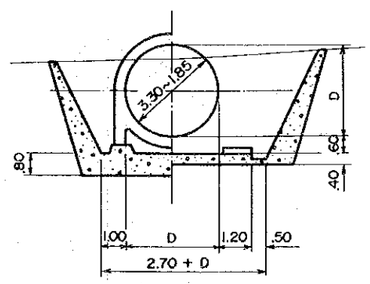
HEADRACE TUNNEL



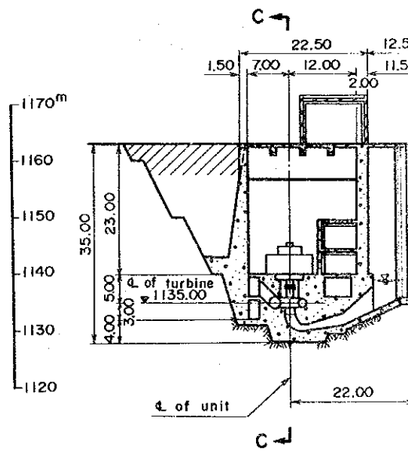
PENSTOCK TUNNEL



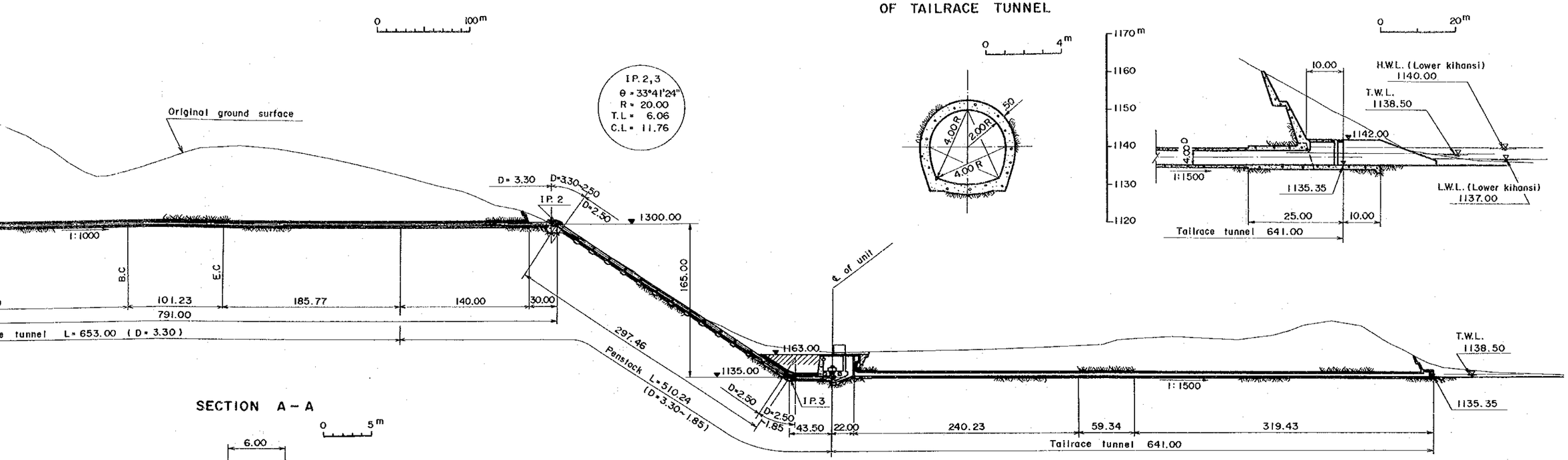
PENSTOCK (OPEN)



SECTION B – B



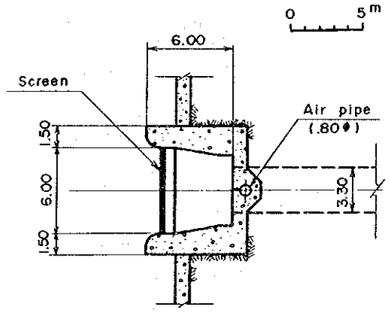
PROFILE OF WATER WAY



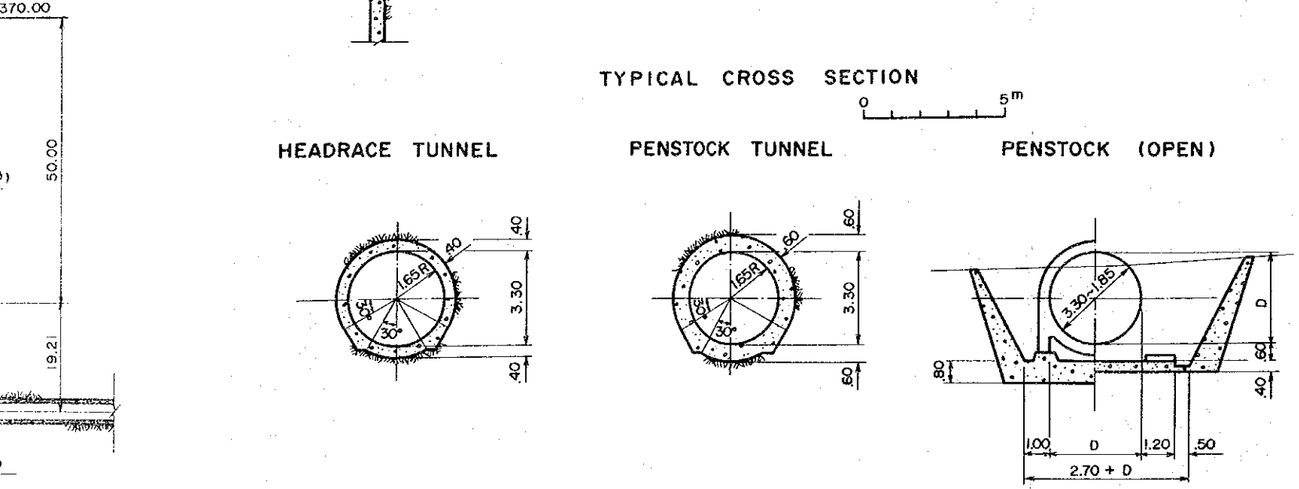
TYPICAL CROSS SECTION OF TAILRACE TUNNEL

PROFILE OF OUTLET

SECTION A – A



TYPICAL CROSS SECTION



SECTION OF POWERHOUSE

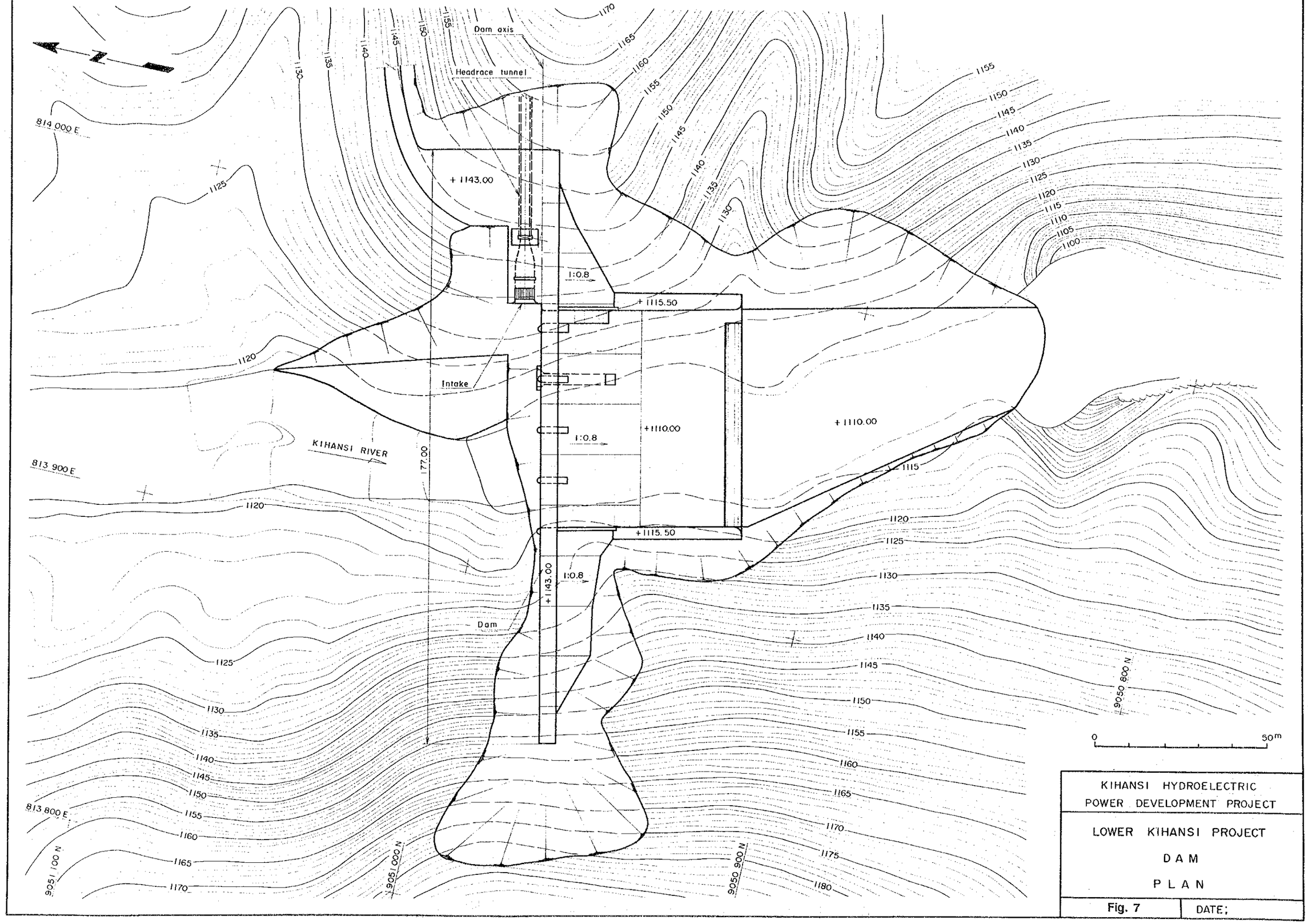
KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

UPPER KIHANSI PROJECT

WATERWAY

PROFILE AND SECTIONS

Fig. 6 | DATE;



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

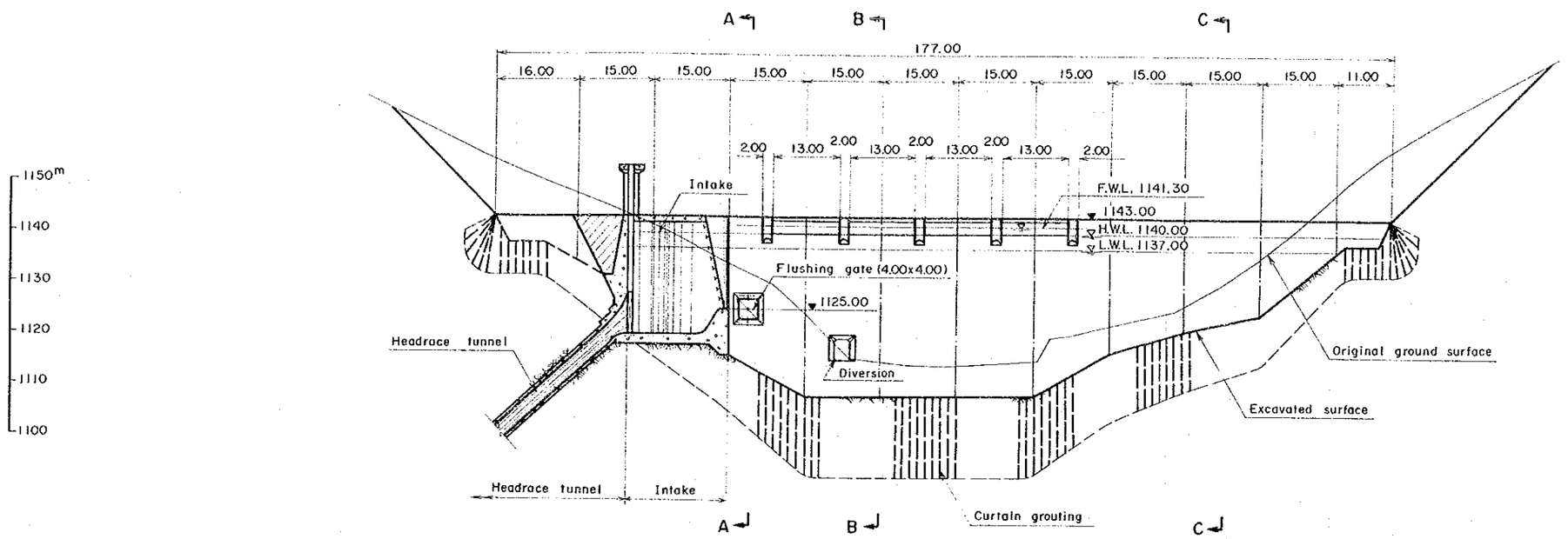
LOWER KIHANSI PROJECT

D A M

P L A N

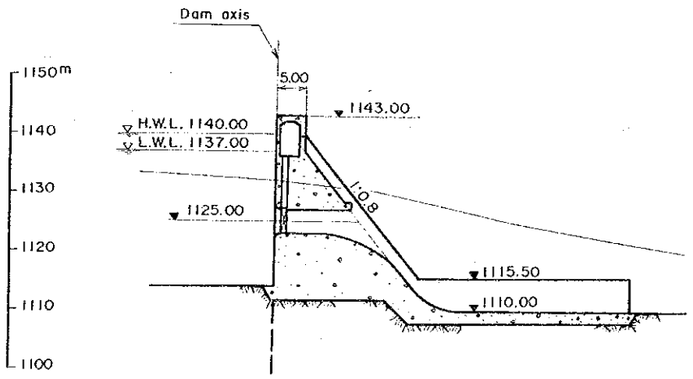
Fig. 7 | DATE;

PROFILE OF DAM

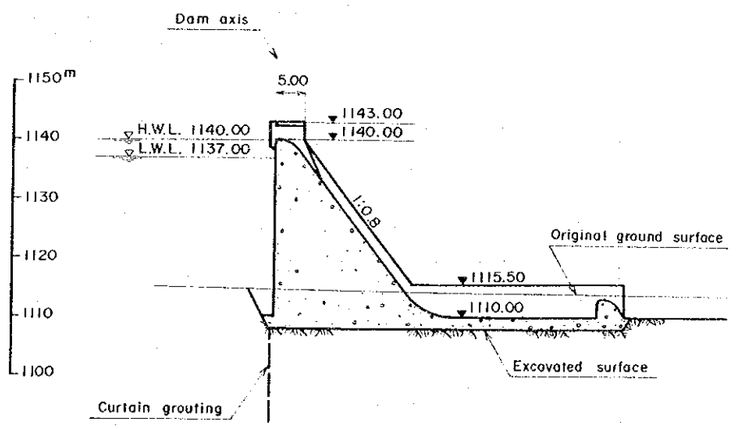


TYPICAL SECTION OF DAM

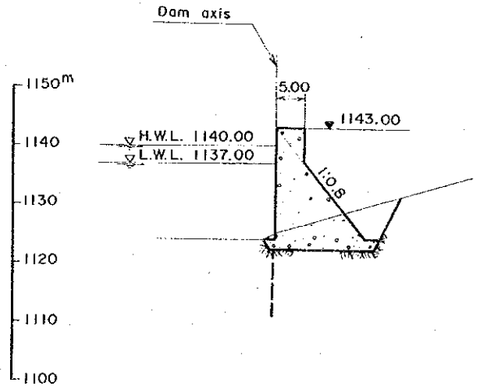
SECTION A – A



SECTION B – B



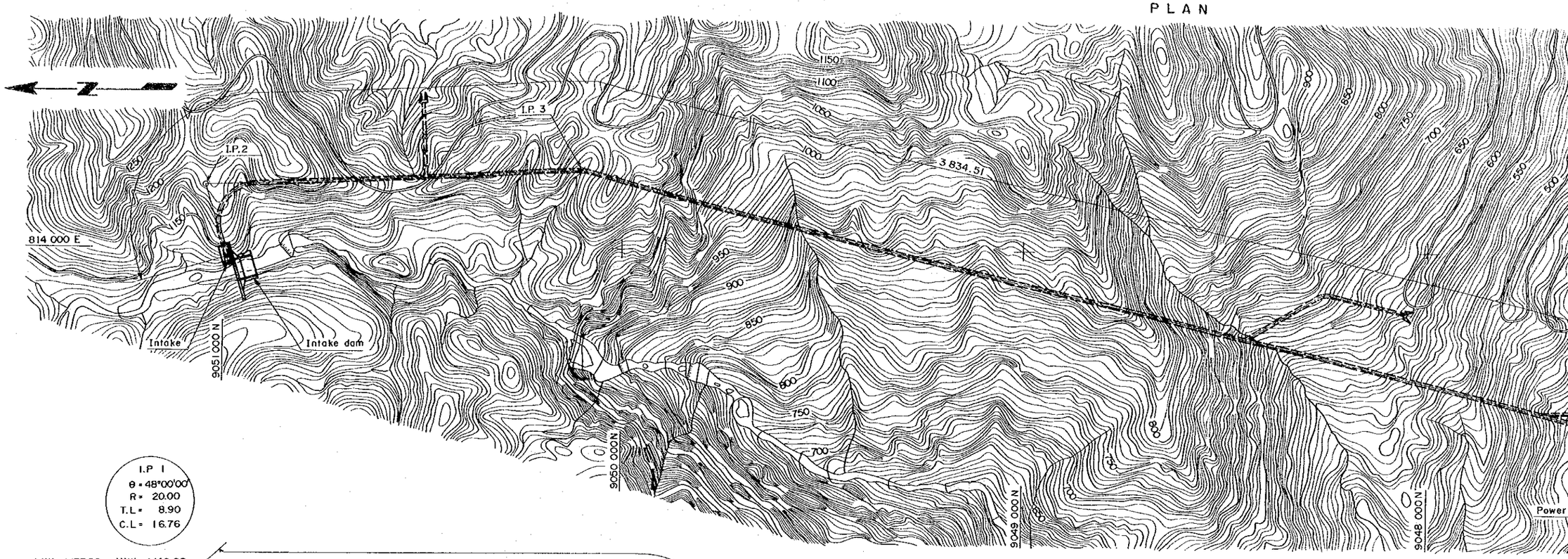
SECTION C – C



0 50m

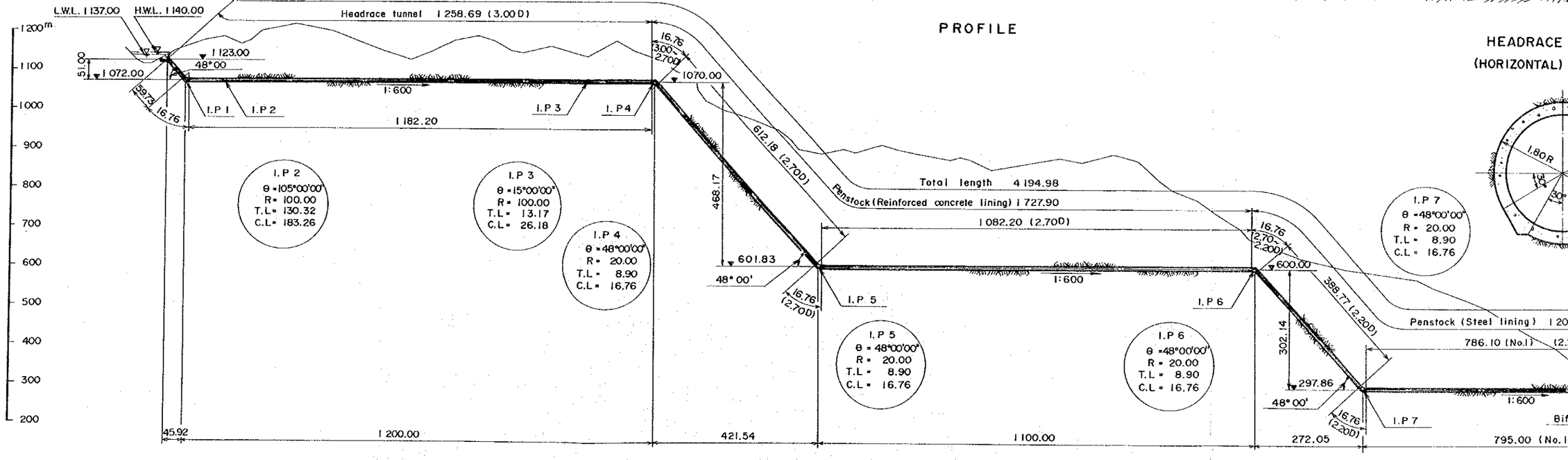
KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT	
LOWER KIHANSI PROJECT DAM PROFILE AND TYPICAL SECTIONS	
Fig. 8	DATE;

PLAN



I.P 1
θ = 48°00'00"
R = 20.00
T.L = 8.90
C.L = 16.76

PROFILE



I.P 2
θ = 105°00'00"
R = 100.00
T.L = 130.32
C.L = 183.26

I.P 3
θ = 15°00'00"
R = 100.00
T.L = 13.17
C.L = 26.18

I.P 4
θ = 48°00'00"
R = 20.00
T.L = 8.90
C.L = 16.76

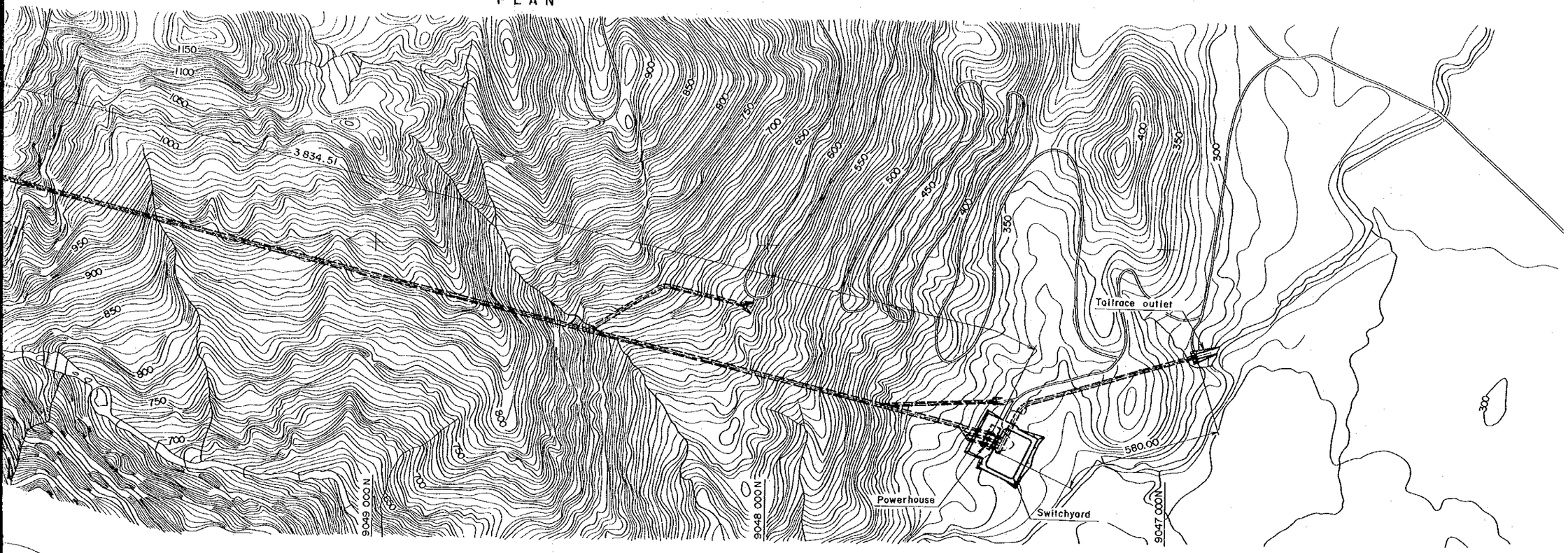
I.P 5
θ = 48°00'00"
R = 20.00
T.L = 8.90
C.L = 16.76

I.P 6
θ = 48°00'00"
R = 20.00
T.L = 8.90
C.L = 16.76

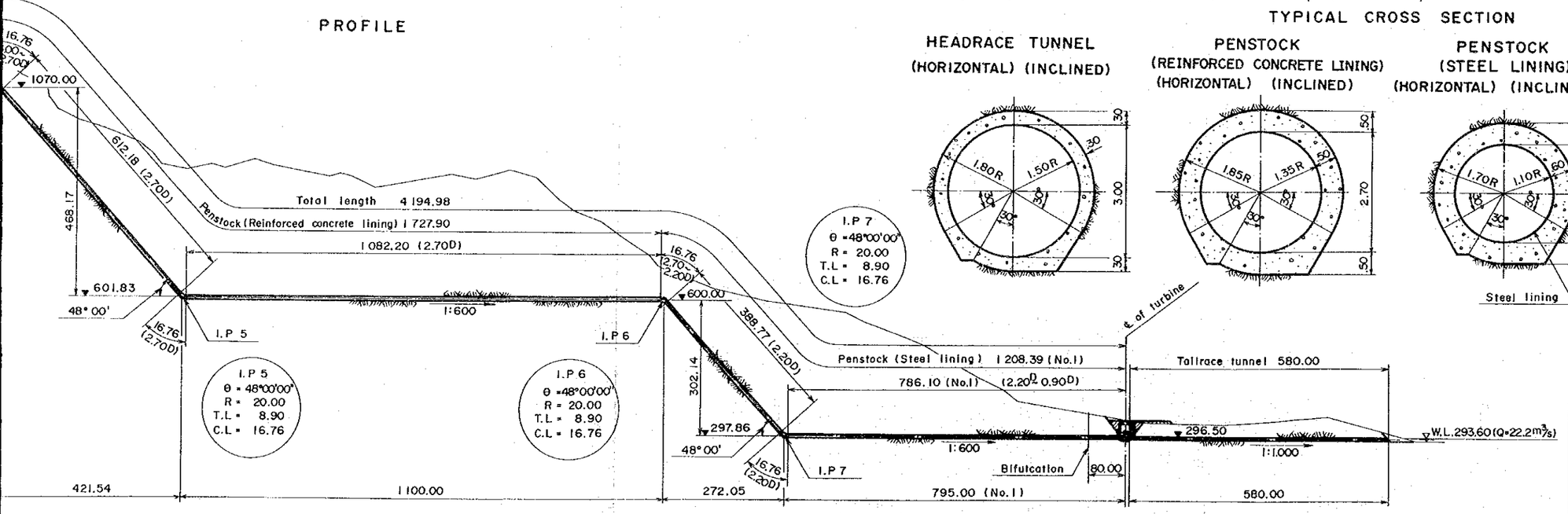
HEADRACE
(HORIZONTAL)

I.P 7
θ = 48°00'00"
R = 20.00
T.L = 8.90
C.L = 16.76

PLAN



PROFILE



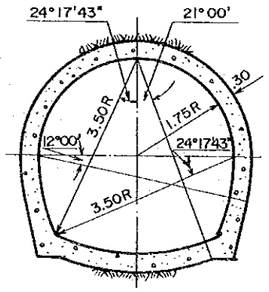
TYPICAL CROSS SECTION

HEADRACE TUNNEL (HORIZONTAL) (INCLINED)

PENSTOCK (REINFORCED CONCRETE LINING) (HORIZONTAL) (INCLINED)

PENSTOCK (STEEL LINING) (HORIZONTAL) (INCLINED)

TAILRACE TUNNEL



0 500m (PLAN AND PROFILE)

0 5m (TYPICAL SECTIONS)

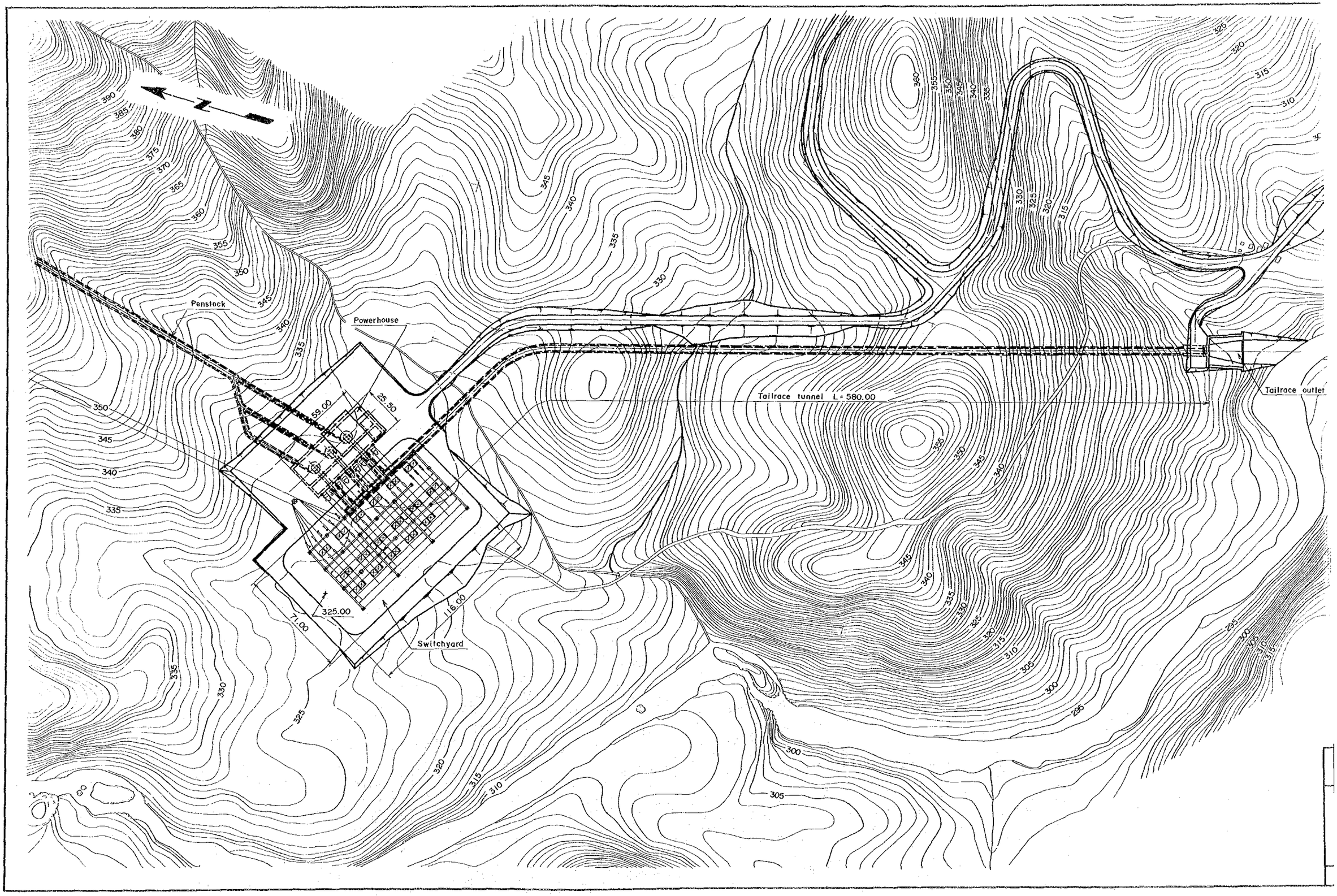
KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

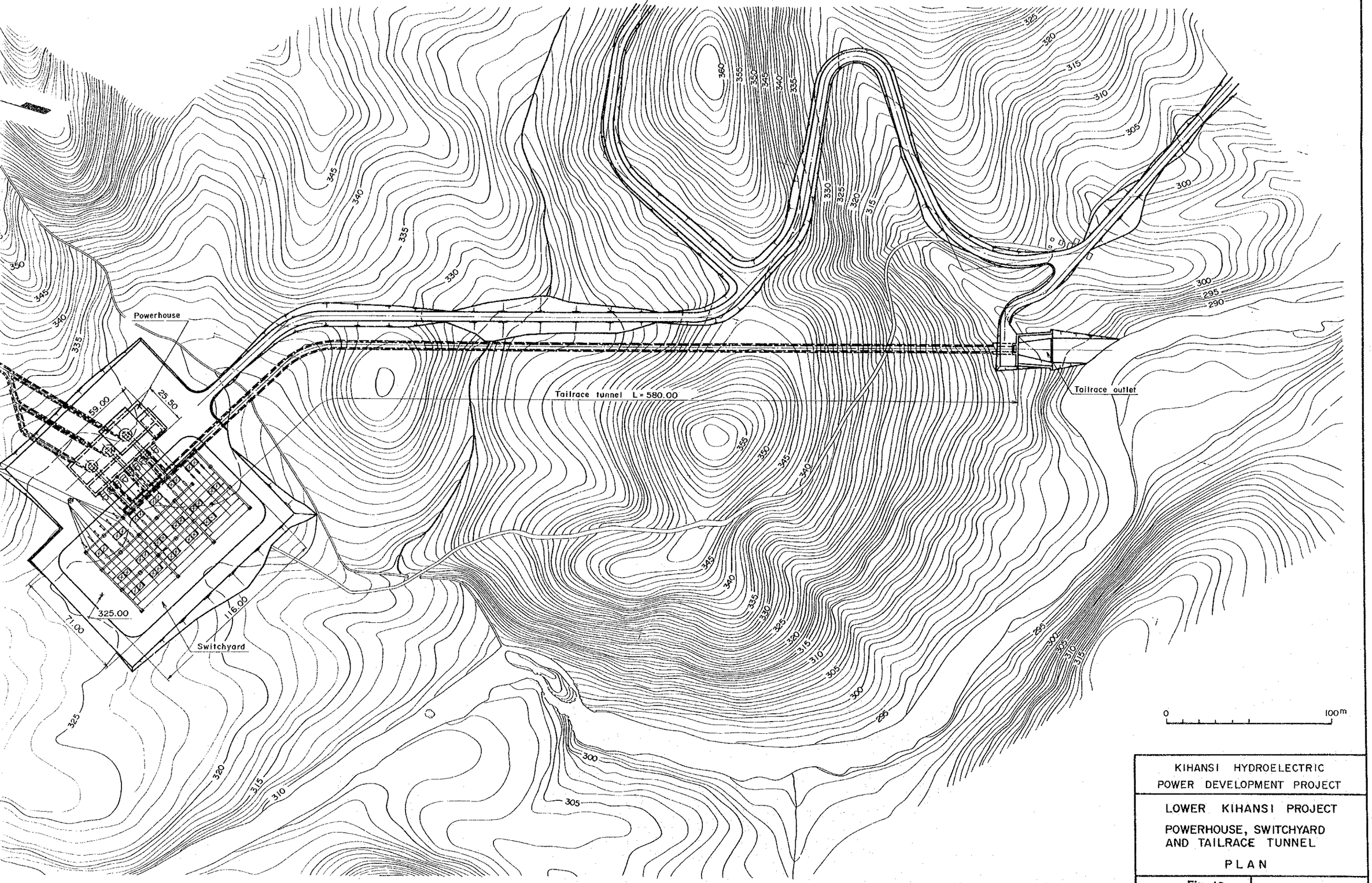
LOWER KIHANSI PROJECT

WATERWAY

PLAN, PROFILE AND TYPICAL SECTIONS

Fig. 9 | DATE:


Penstock
Powerhouse
Tailrace tunnel L = 580.00
Tailrace outlet
59.00
25.50
325.00
71.00
116.00
Switchyard



KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

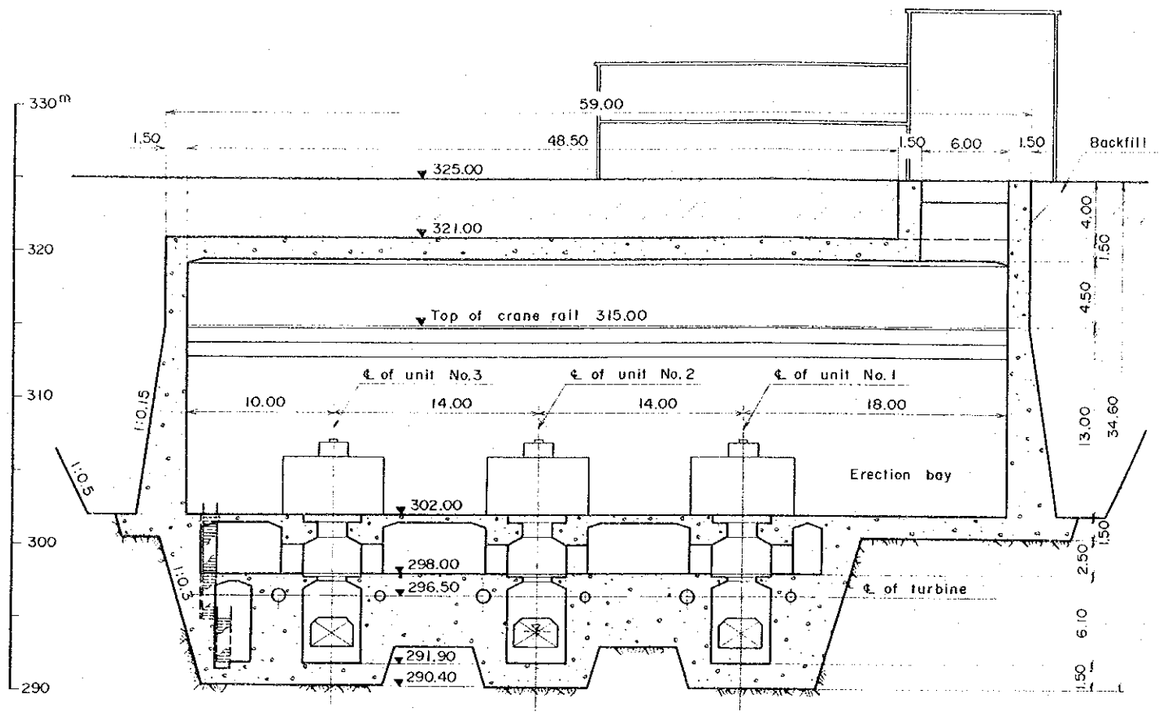
LOWER KIHANSI PROJECT

POWERHOUSE, SWITCHYARD AND TAILRACE TUNNEL

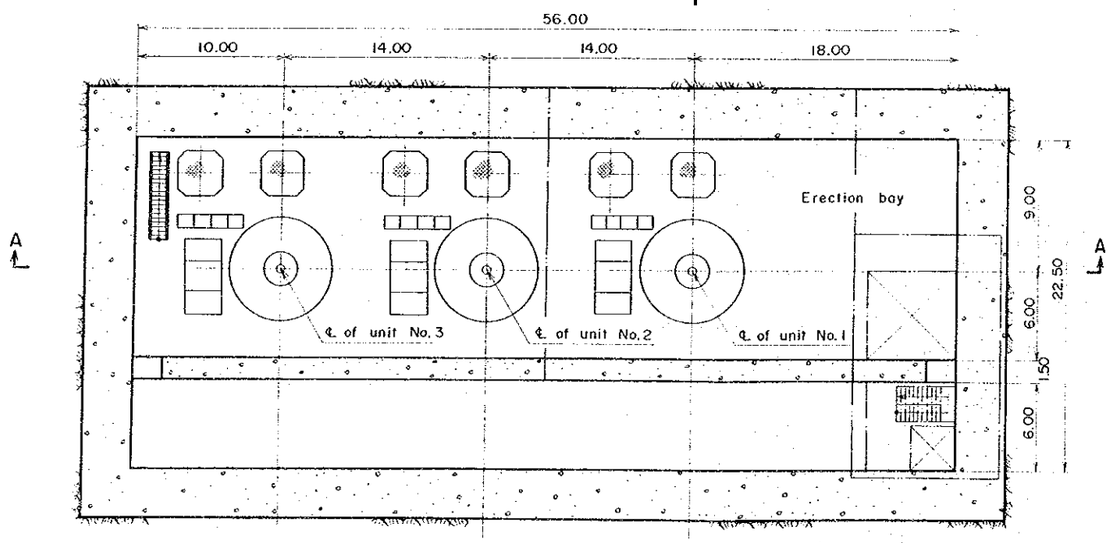
PLAN

Fig. 10 | DATE;

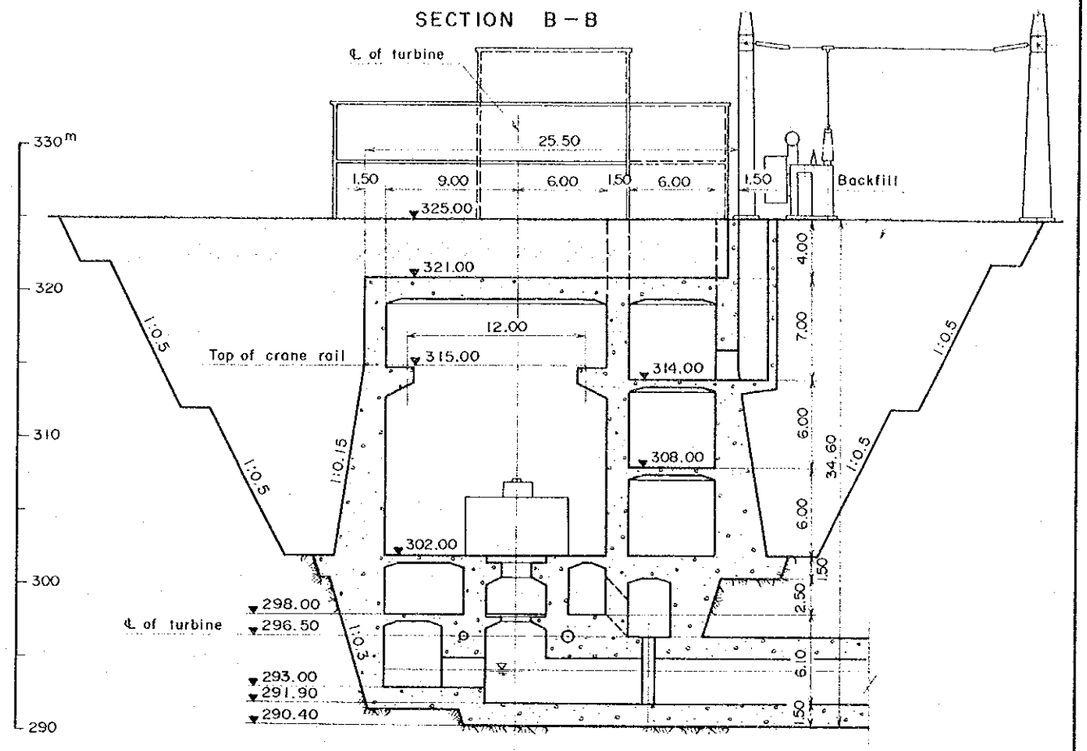
SECTION A – A



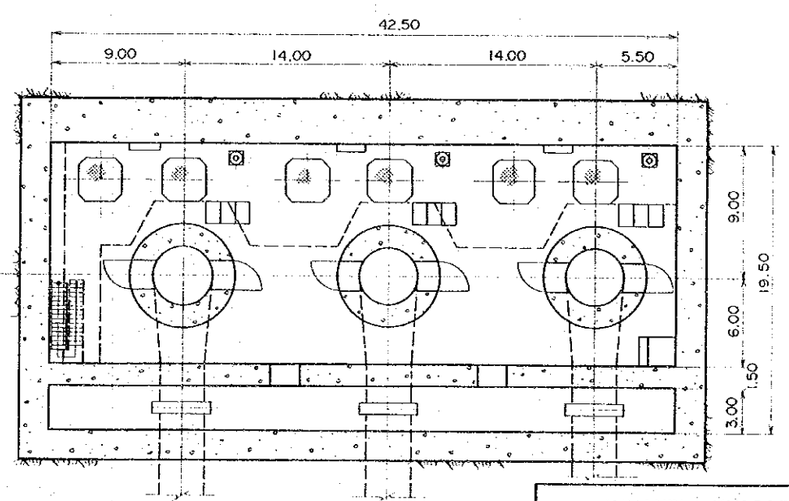
PLAN EL. 302.00



SECTION B – B



PLAN EL. 298.00



0 20m

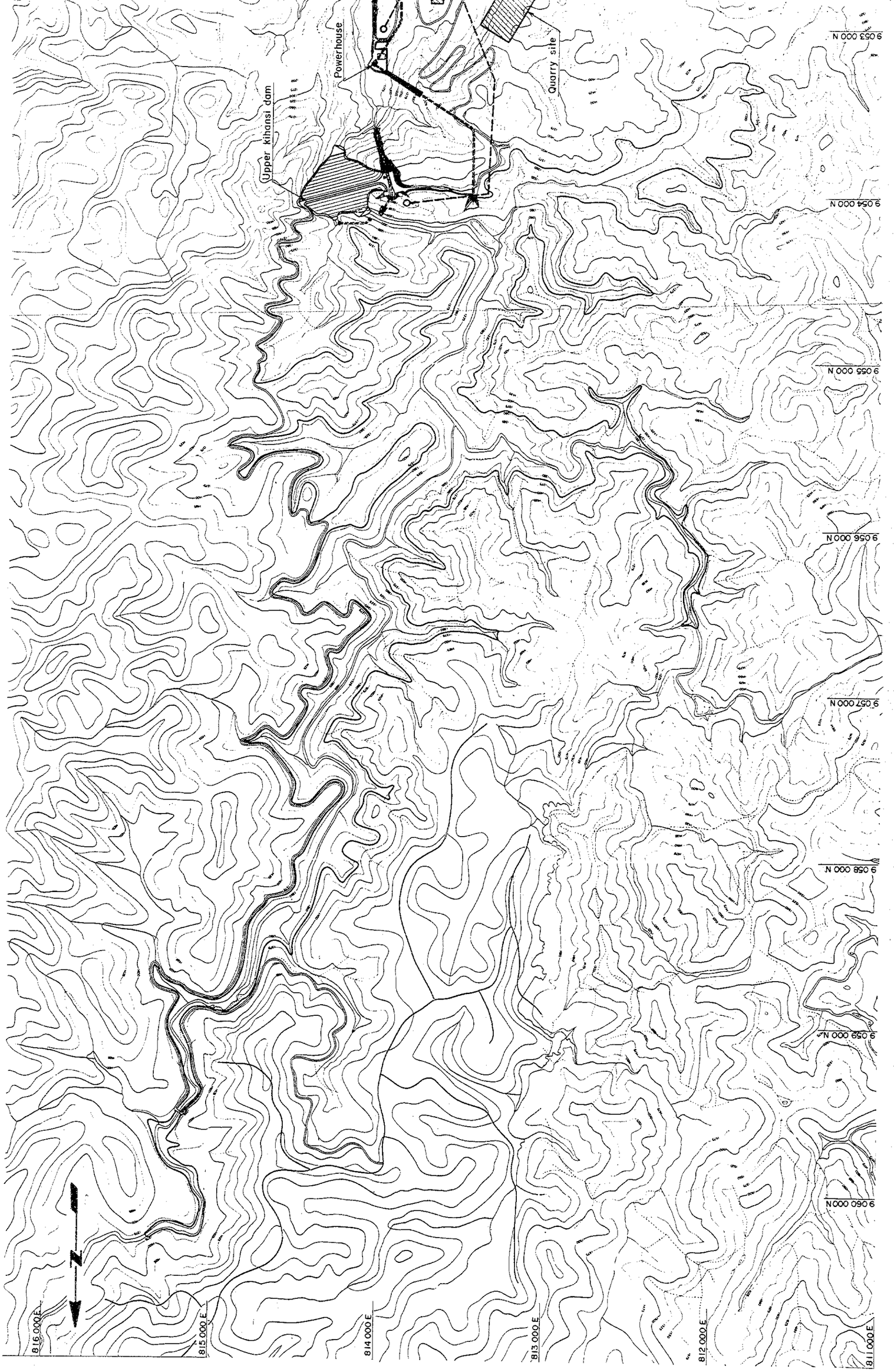
KIHANSI HYDROELECTRIC POWER DEVELOPMENT PROJECT

LOWER KIHANSI PROJECT

POWERHOUSE

PLAN AND SECTIONS

Fig. 11 | DATE;


Upper kihansi dam
Powerhouse
Quarry site
N
816 000 E
815 000 E
814 000 E
813 000 E
812 000 E
811 000 E
9 053 000 N
9 054 000 N
9 055 000 N
9 056 000 N
9 057 000 N
9 058 000 N
9 059 000 N
9 060 000 N

Distribution line (for construction)

Waterway

Access road

No.1 Work adit

Receiving sub station

Lower kihansi dam

Construction office and camp

Aggregate plant

Concrete plant

Powerhouse

Quarry site

Upper kihansi dam

9 049 000 N

9 050 000 N

9 051 000 N

9 052 000 N

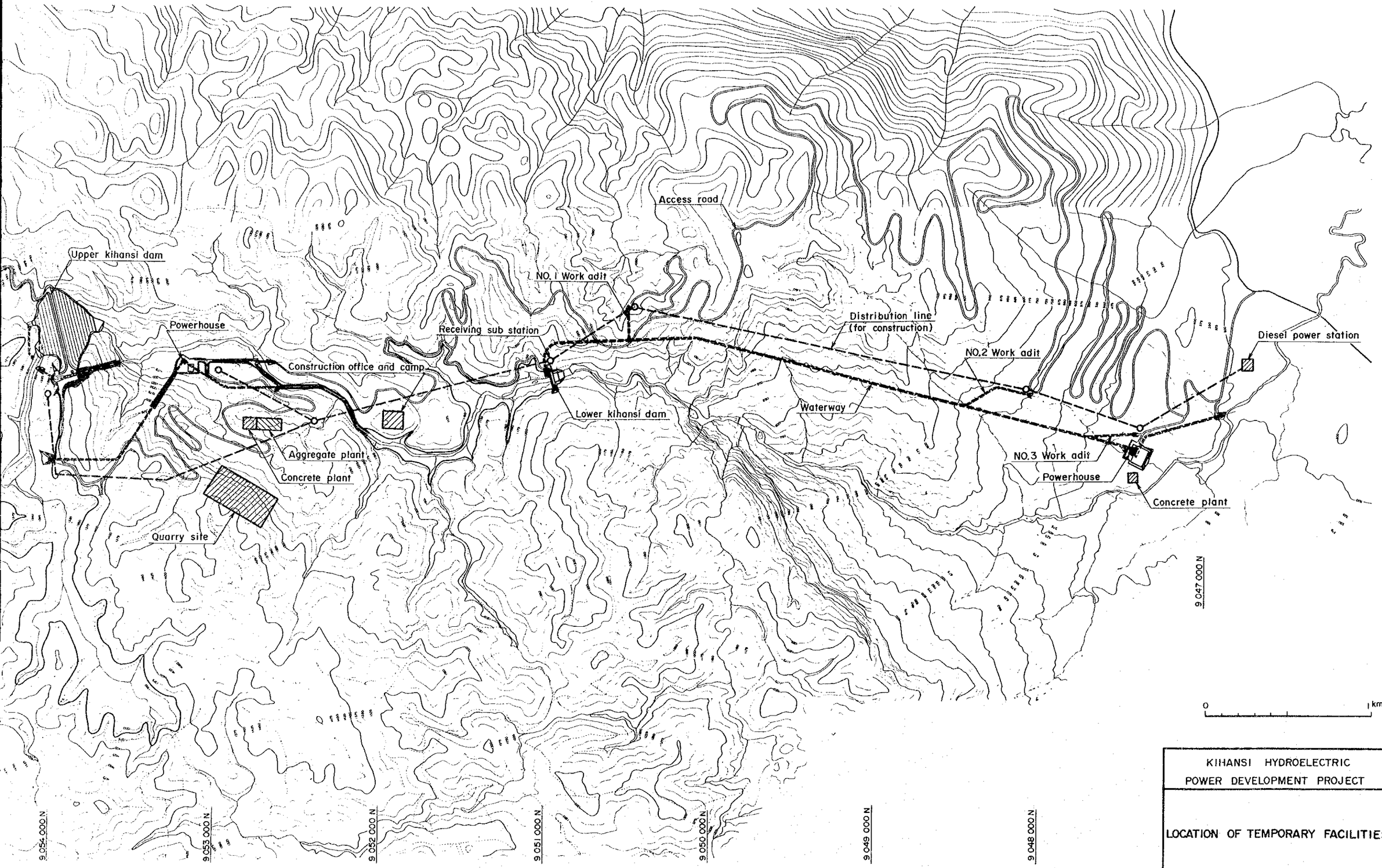
9 053 000 N

9 054 000 N

9 055 000 N

9 056 000 N

9 057 000 N



KIHANSI HYDROELECTRIC
POWER DEVELOPMENT PROJECT

LOCATION OF TEMPORARY FACILITIES

Fig. 12	DATE;

Chapter 4 CONSTRUCTION SCHEDULE AND CONSTRUCTION COST

4.1 Construction Schedule

Considering the commissioning year of the Upper Kihansi Project in 1999, and the Lower Kihansi Project in 1996, preparations for construction should be made roughly according to the following time schedule.

1) Upper Kihansi Project

1989-2 - 1990-12	Prefeasibility Study	(1 year and 9 months)
1991-7 - 1992- 6	Feasibility Study	(1 year)
1992-7 - 1993-12	Definite Design	(1.5 years)
1994-1 - 1995- 6	Finance	(1.5 years)
1995-1 - 1995- 6	Preparation Works	(0.5 year)
1995-7 - 1999-12	Construction	(4.5 years)

2) Lower Kihansi Project

1989-2 - 1990-12	Feasibility Study	(1 year and 9 months)
1991-2 - 1992- 7	Definite Design	(1.5 years)
1991-1 - 1993- 6	Finance	(2.5 years)
1992-1 - 1993- 6	Preparation Works	(1.5 years)
1993-7 - 1996-12	Construction	(3.5 years)

The construction works of the Upper Kihansi Project and the Lower Kihansi Project require periods of approximately 4.5 years and 3.5 years respectively as a result of studying the meteorology and topography of the project area, the scale of construction, construction materials, layout of structures, preparatory works, etc. The work schedules of the projects are given in Figs. 11 and 12.

4.2 Construction Cost

The construction cost of this Project is estimated assuming that design, construction methods, and materials and products according to the technological levels being able to be expected at the present are applied, with the geological and regional conditions of the project sites, construction scales and so on taken into consideration.

The total construction cost of this project is estimated dividing the local and foreign currencies and the costs of access roads, camp facilities, environmental counter-measures, transmission line, substation facilities, engineering fee and administrative expenses and interest during construction are included in the project cost itself, but inflation is not taken into consideration.

The cost estimation time is set in June, 1989 (exchange rate: 140 Tsh/1 US$).

The list of items of construction cost on this project is shown in Table 3.

Table 3 Construction Cost

Unit: 1,000 US$

	Upper Kihansi			Lower Kihansi			Total		
	F.C	L.C	Total	F.C	L.C	Total	F.C	L.C	Total
1. Preparatory Works									
1-1 Access Road			0	15,280	3,820	19,100	15,280	3,820	19,100
1-2 Camp Facility & Others	3,600	1,000	4,600	10,100	3,200	13,300	13,700	4,200	17,900
Sub-total	3,600	1,000	4,600	25,380	7,020	32,400	28,980	8,020	37,000
2. Compensation & Others	1,695	5	1,700	1,698	2	1,700	3,393	7	3,400
3. Civil Works									
3-1 Diversion & Coffer Dam	2,059	641	2,700	160	40	200	2,219	681	2,900
3-2 Dam & Spillway	107,801	33,599	141,400	7,631	2,169	9,800	115,432	35,768	151,200
3-3 Intake	3,621	1,079	4,700	1,087	313	1,400	4,708	1,392	6,100
3-4 Headrace Tunnel	1,733	567	2,300	2,253	747	3,000	3,986	1,314	5,300
3-5 Penstock	1,698	502	2,200	7,364	2,836	10,200	9,062	3,338	12,400
3-6 Powerhouse & Switchyard	4,436	1,264	5,700	9,880	2,720	12,600	14,316	3,984	18,300
3-7 Tailrace Tunnel	1,878	622	2,500	1,203	397	1,600	3,081	1,019	4,100
3-8 Tailrace Outlet	610	190	800	390	110	500	1,000	300	1,300
Sub-total	123,836	38,464	162,300	29,968	9,332	39,300	153,804	47,796	201,600
4. Hydraulic Equipment	2,000	500	2,500	5,760	1,440	7,200	7,760	1,940	9,700
5. Electro-mechanical Equipment	10,700	3,400	14,100	27,700	8,700	36,400	38,400	12,100	50,500
6. Transmission Line	80	40	120	12,700	6,200	18,900	12,780	6,240	19,020
7. Total Cost (1+2+3+4+5+6)	141,911	43,409	185,320	103,206	32,694	135,900	245,117	76,103	321,220
8. Engineering & Administration	11,134	2,783	13,917	8,114	2,029	10,143	19,248	4,812	24,060
9. Physical Contingency	20,648	6,314	26,962	13,173	4,087	17,260	33,821	10,401	44,222
10. Interest during Construction	24,476	10,325	34,801	29,858	12,839	42,697	54,334	23,164	77,498
11. Grand Total (7+8+9+10)	198,169	62,831	261,000	154,351	51,649	206,000	352,520	114,480	467,000

Fig. 13 Construction Schedule (Upper Kihansi)

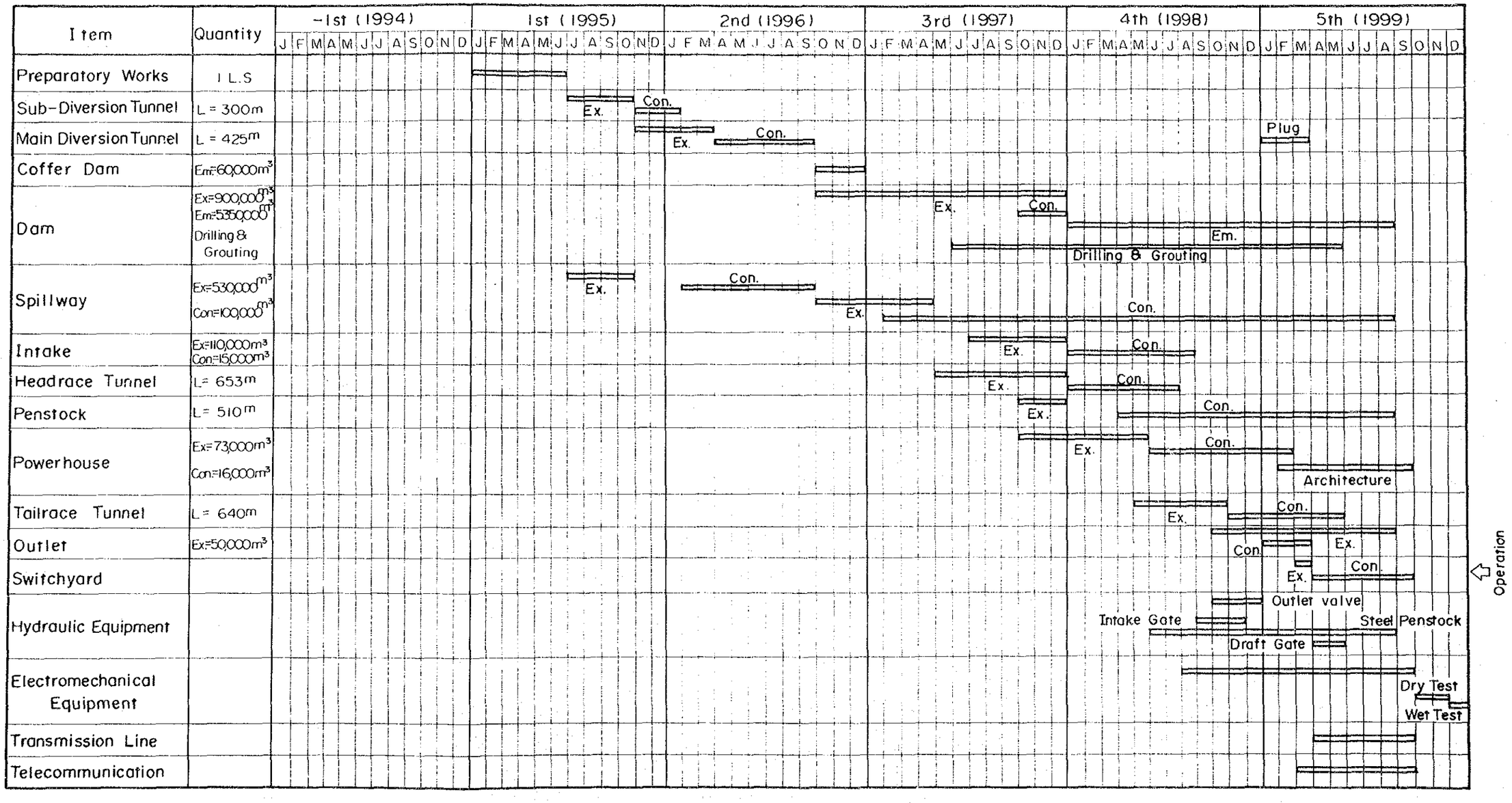
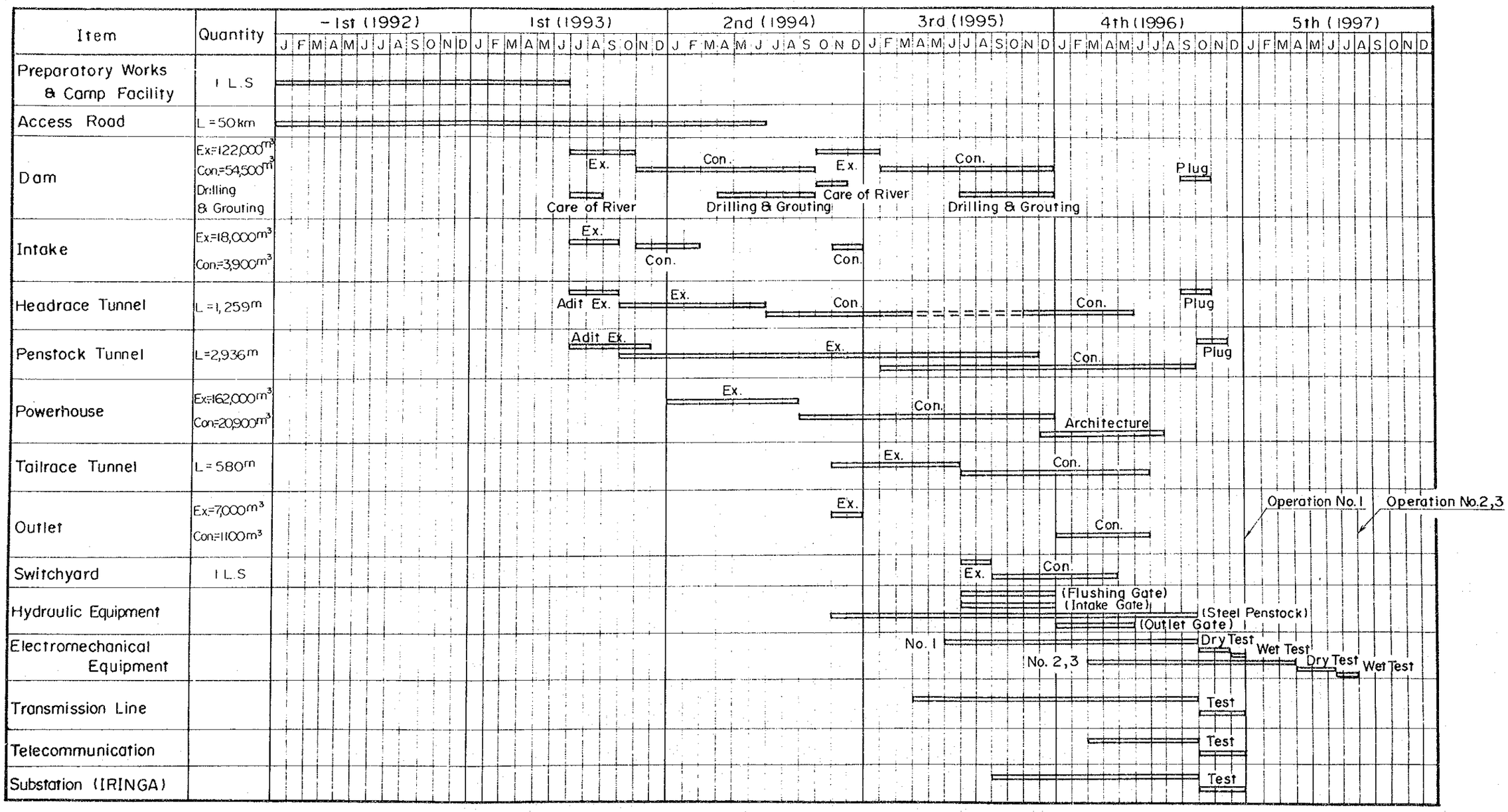


Fig. 14 Construction Schedule (Lower Kihansi)



(1) Economic Evaluation

As the method of the economic evaluation of this project, an alternative plant approach is employed to measure and evaluate economic costs of the proposed project and the alternative project.

The cost and benefit flow of the combined project on the Upper and Lower Kihansi Projects is presented in Table 4 and the results of evaluation of EIRR, B-C and B/C of the Upper and Lower Kihansi Projects and the combined project are as follows:

	EIRR	B - C	B/C
Upper Kihansi Project	11.26%	9,221 x 10^3 US$	1.07
Lower Kihansi Project	45.94%	129,236 x 10^3 US$	2.32
Combined Project	39.31%	146,347 x 10^3 US$	1.76

As indicated by indices of B-C and B/C of the combined project, the costs of construction and operation of the project is much smaller than those of an alternative thermal power plant which can provide equivalent service, and it can be also concluded that the project can continue to maintain its superiority as long as the discount rate which reflects the capital opportunity cost does not exceed 39.31%.

(2) Financial Analysis

For the financial analysis of the project, "Financial Evaluation from Viewpoint of Total Investment-Calculation