CHAPTER VI

PLAN FORMULATION

6.1 Basic Concept

The hydroelectric power capacity in the Greater CNPS will be 111.16 MW, after the completion of the Gandaki, Kulekhani No.1, and Devigat power stations and the Gandaki-Hetauda, Bharatpur-Pokhara power networks. The annual energy output will be 512.2 GWh. The diesel power of 14,650 kW will be reserved as stand-by which will supplement the energy from time to time. A projected supply and demand condition of peak power in the Greater CNPS is presented in Fig.3.4. An additional power station will be required after 1985/86. The Kulekhani No.2 Hydroelectric Project is proposed to meet the power demand after 1985/86.

The Kulekhani No.2 Hydroelectric Project is envisaged to develop the hydroelectric potential resulting from the outflow from the Kulekhani No.1 Power Station and the water head between the No.1 Power Station and the confluence of the Rapti river and the Kani river. By construction of the Kulekhani No.2 Hydroelectric Project, an additional water head of 278 m will be newly available for power generation in the Kulekhani - Rapti cascade.

The power demand in Nepal is high in the dry season. On the other hand, the existing hydroelectric power stations are forced to reduce their output in the same period due to water shortage because they are run-of-river power stations. It has been proposed to generate more output in the dry season than in the wet season at the Kulekhani No.1 Power Station in view of these conditions, taking advantage of a regulating reservoir. The Kulekhani No.1 Power Station is planned to be operated only four hours in a day for peak power generation in the wet season so as to save water for use in the dry season. This operation, complemental to the other power station, will be magnified by inclusion of the Kulekhani No.2 Hydroelectric Project.

There are some streams from which water can be channeled into the waterway for the Kulekhani No.2 Power Project. They will be incorporated in the Project for power generation if economically justifiable.

6.2 Proposed Feature of the Project

The proposed Kulekhani No.2 Hydroelectric Project consists of the Mandu intake and diversion weir across the Mandu river just below the tailrace outlet of the No.1 Power Station, a 5,730 m long headrace tunnel through the right bank hills bordering the Rapti river, a Rani tributary intake at the middle of headrace, a surge tank, a 735 m long penstock line, a power station of 33 MW in installed capacity on the left bank of the Kani river located 600 m upstream of the confluence of the Rapti and Kani rivers, a tailrace, a 132 kV single circuit transmission line of a length of 32 km between Kathmandu and Hetauda via No.2 Power Station along the existing 66 kV line, and additional equipment in the New Teku substation in Kathmandu.

The general layout and preliminary design of the proposed Kulekhani No.2 Hydroelectric Project are compiled in the drawings attached at the end of this report.

6.3 Maximum Discharge and Installed Capacity

There is no storage site for the regulation of outflow from the No.1 Power Station between the proposed intake and power station sites. The maximum discharge for the Kulekhani No.2 Power Station should not be less than 13.1 m^3/sec (which is the same as for the No.1 Power Station), if all water from the No.1 Power Station should be utilized.

Comparative studies described in Paragraph 6.4 justify the utilization of water from the Mandu and the Rani rivers.

The reservoir formed by the Mandu weir will have an active storage capacity of 12,000 m^3. The firm discharge of 0.2 m^3/sec (with the probability exceeding 95 %) at the Mandu weir can be increased to 1.2 m^3/sec by this storage capacity, if a peaking operation of four hours is introduced. On the other hand, the Rani river is not regarded to contribute to the peaking operation, because the firm discharge at the Rani intake site is very low with no storage possibility.

Under these considerations, the maximum discharge of the Kulekhani No.2 Power Station was determined to be 14.3 m^3/sec (13.1 m^3/sec + 1.2 m^3/sec).

The water surface will be at EL.910 m at the Mandu intake and EL.602.5 m at the tailbay of the No.2 Power Station under the normal operating conditions, amounting to a gross water head of 307.5 m. The rated water head is determined to be 278 m, by deducting a loss of head of 29.5 m from the gross water head.

The installed capacity of the Kulekhani No.2 Power Station will be 33 MW assuming a combined efficiency of 85%. This is determined as follows:

$$p = g \times Q \times H \times e = 9.8 \times 14.3 \times 278 \times 0.85 = 33{,}000 \text{ kW}$$

where, p : Installed capacity in kW
g : Acceleration of gravity in m/sec^2
Q : Maximum discharge in m^3/sec
H : Rated water head in m
e : Combined efficiency

6.4 Utilization of Tributaries Flow

The proposed waterway of the Project crosses the Mandu river and the Rani river. The North Rapti river is located near the proposed intake. An economic study was carried out for the utilization of water in these rivers for power generation.

The waterway of the Kulekhani No.2 Hydroelectric Project will be connected with the tailrace tunnel of No.1 Power Station by an inverted siphon and an intake tank at the proposed Mandu diversion weir site, if it be intended to utilize only water coming from the No.1 Power Station. In this case, the installed capacity of the No.2 Power Station will be 30 MW and its annual energy output will be 77.3 GWh. This plan is herein called Alternative 1.

A certain part of the Mandu flow can be utilized, if a weir and a settling basin is added to the siphon and intake tank of Alternative 1 similar to the proposed design of the Mandu intake and diversion weir. The project can then take the Mandu flow at a rate of 1.2 m^3/sec during four hours per day on a firm basis and the installed capacity will be 33 MW as explained in Paragraph 6.3. The annual energy output will be 80.6 GWh. Due to the nature of the peaking power station, two sets of 16.5 MW generating equipment will be installed. This plan is herein called Alternative 2.

Alternative 2 can utilize water from the Mandu river only during the period that the No.1 Power Station is in operation, because the discharge in the Mandu river is too small compared with the minimum discharge required for the turbine in the No.2 Power Station. Water made available in Alternative 2 is estimated to be only 5.0×10^6 m^3 out of the total Mandu runoff of 33.7×10^6 m^3.

Alternative 3 is proposed to utilize the Mandu runoff, even if the No.1 Power Station is not operated. In this plan, the installed capacity is 33 MW, the same as in Alternative 2, but two sets of 15 MW units and one 3 MW unit will be installed. The turbine for the 3 MW unit will be a Pelton type, which is operational over a wide range of discharges. About 55 % of the total Mandu runoff will be utilized in Alternative 3. The annual output is estimated to be 92.1 GWh.

The combination of generation units in Alternative 3 will make it possible to utilize water from other small tributaries. The construction of a weir with settling basin and inclined shaft in the Rani river, like the proposed Rani intake, will further utilize 4.4×10^6 m^3 from the Rani river. The addition of the Rani intake to Alternative 3 constitutes a recommended plan herein called Alternative 4.

Runoff from an area of 11.6 km^2 in the North Rapti river can be collected at the Mandu diversion weir, if a weir in the north Rapti and a 1.0 km long diversion tunnel between the north Rapti and the Mandu is constructed. Alternative 4, including this north Rapti diversion plan to utilize about 3.2×10^6 m^3 of additional water, is herein called Alternative 5.

The above-mentioned five alternatives were compared based on the net benefit maximization criteria. The annual equivalent of benefits was calculated based on the dependable peaking capacity and the energy output. The unit capacity value was assumed to be US$101.8/kW and a unit

Table 6.1 Economic Comparison of Alternatives

Item	Alternative				
	1	2	3	4	5
1. Power generation					
Installed capacity (kW)	30,000	33,000	33,000	33,000	33,000
Annual energy Output (GWh)	77.3	80.6	92.1	95.1	96.9
2. Construction cost (10^3US$)	42,350	46,070	46,970	48,000	49,510
3. Annual benefit (10^3US$)					
Capacity benefit	3,050	3,360	3,360	3,360	3,360
Energy benefit	2,710	2,830	3,230	3,340	3,400
Total	5,760	6,190	6,590	6,700	6,760
4. Annual cost (10^3US$)					
Capital recovery cost	3,460	3,770	3,840	3,920	4,050
O & M cost	310	310	320	320	320
Total	3,770	4,080	4,160	4,240	4,370
5. Annual net benefit (10^3US$)	1,990	2,110	2,430	2,460	2,390

energy value of US mill 35.1/kWh was used. (see APPENDIX III)

The annual equivalent cost was the sum of the capital cost and O & M cost. The capital cost was calculated from the estimated investment cost at the 1978 price level, assuming a discount rate of 8% and an evaluation period of 50 years. The results summarized in Table 6.1 show that Alternative 4 is the best, because the annual net benefit is the highest.

6.5 Operation Method and Output

The installed capacity and annual energy output are listed in Table 6.2 for the hydroelectric power stations existing and under construction which are to be included in the Greater CNPS (hereinafter called the other hydel), except the Kulekhani No.1 Power Station. The energy output in the table was estimated assuming the hydrologic conditions in 1969 which was selected as the standard dry year, being the second driest in twelve years from 1963 to 1974. The energy output of all these power stations in each month was calculated as shown in Table 6.3.

The monthly energy production in Fig.6.1 may be regarded as indicating the monthly variation of potential energy required. The ratio of energy generated in a month to the annual mean energy generated varies somewhat by year. This ratio (averaged for 1969/70 - 1975/76) was, therefore, regarded as the ratio of potential energy required in a month to the annual mean potential energy required. If an annual energy requirement is given, the energy demand for each month can be calculated by this ratio. Tables 6.4 and 6.5 show an estimate of monthly energy required for Case 1 when the Kulekhani No.1 Power Station and the other hydel are in full operation and Case 2 when the Kulekhani No.1 and No.2 Power Stations and the other hydel are in full operation, respectively.

The Tables also show potential energy supply in each month by the other hydel and the Kulekhani No.1 and No.2 Power Stations for both cases. The potential energy supply of these hydropower stations are based on the hydrological conditions in 1969, the standard dry year. In the Tables, the shortage of energy for each month is assumed to be supplemented by diesel power stations. The monthly energy to be supplemented are also shown in Tables 6.4 and 6.5.

The Kulekhani No.1 and No.2 Power Stations will be operated to meet the largely - varying difference between the energy required and energy output of the other hydel to the maximum extent. The annual energy output is 154.7 GWh at the Kulekhani No.1 Power Station for Case 1 and 171.5 GWh at the Kulekhani No.1 Power Station and 95.1 GWh at the Kulekhani No.2 Power Station for Case 2, respectively as shown on page 64. The provable demand and supply of energy shown in Tables 6.4 and 6.5 for Case 1 and 2 are also graphically illustrated in Figs.6.2 and 6.3, respectively.

The list of the diesel power stations, which will be readily available in the Greater CNPS, is shown in Table 3.2. The total installed capacity is 14.65 MW and the largest unit is 1.49 MW.

Assuming a monthly plant utilization factor of 79.2 % for the diesel power, the necessary installed capacity of the diesel power plants is estimated to be 9.7 MW for Case 1 and 12.2 MW for Case 2, i.e., the capacity of existing diesel plants will be enough for Case 1 but will need an additional installation of 2.5 MW for Case 2.

The monthly energy output at Kulekhani No.1 Power Station and discharge from the Kulekhani reservoir corresponding to the said energy output are as shown in Table 6.6. The figures in Table 6.6 shows a large discharge requirement in the dry season. The operation of Kulekhani reservoir according to this requirement was tested as shown in the mass curves in Figs. 6.4 and 6.5. In the operation, supplemental energy supplied by diesel power plants shown in Figs.6.2 and 6.3 is assumed in every year in the study period. The method of operation assumed for the Kulekhani Project was as follows:

(1) Continuous full use of inflow within the limits of plant capacity when the reservoir water surface is at the high water surface elevation.

(2) Operation according to the load when the reservoir water surface is below water surface elevation and above the low water surface elevation.

(3) Operation according to the load when the inflow into the reservoir is larger than required and the reservoir water surface is at the low water surface elevation.

(4) Operation as a run-of-river plant when the inflow into the reservoir is smaller than required and the reservoir water surface is at the low water surface elevation.

The results of the test showed that the Kulekhani Project can supply the required primary energy under the hydrological condition in the years between 1963 and 1974 except for 1970. The secondary energy generated by the project will be 48.4 GWh at the No.1 Power Station in Case 1, and 46.9 GWh at the No.1 Power Station and 23.3 GWh at the No.2 Power Station in Case 2.

Out of the above-mentioned secondary energy in Case 2, some amount can be utilized as primary energy by replacing a part of the supplemental energy supply by the diesel plants. The average annual value of the said secondary energy under the stated hydrologic conditions is calculated to be 17.3 GWh.

It is estimated that the other hydel can generate only 215.6 GWh as primary energy and the remaining 118.6 GWh of output must be regarded as secondary energy, if they are operated with no supplemental power in the dry season under the large demand variation which exists in GNPS. As is indicated in Tables 6.4 and 6.5, the above-mentioned secondary power can totally be utilized as primary power, if the Kulekhani Project is operated with a large output in the dry season and a small output in the wet season. The Kulekhani Project will manifest this advantage further, if hydropower with a small storage reservoir such as the Dev-Gat project would come to operation. In an extreme case, the Kulekhani Project can generate 75 % of the annual output between November and March of heavy demand and small output in the other hydel.

The average annual energy output for each power plant, which is estimated based on the hydrologic conditions in the years between 1963 and 1974, is as follows. These values are used for the economic and financial analysis covered in Chapter IX.

Case 1

(Unit: GWh)

(i)	Primary energy	
	Existing and under-construction hydropower plant	334.2
	Kulekhani No.1 P.S.	154.7
	Diesel plant	23.3
	Total	512.2
(ii)	Secondary energy for Kulekhani No.1 P.S.	48.4

Case 2

(i)	Primary energy	
	Existing and under-construction hydropower plant	334.2
	Kulekhani No.1 P.S.	171.5 /1
	Kulekhani No.2 P.S.	95.1 /2
	Diesel plant	64.7
	Total	665.5
(ii)	Secondary energy	
	Kulekhani No.1 P.S.	30.1 /1
	Kulekhani No.2 P.S.	22.8 /2
	Total	52.9

/1 & /2:

(Unit: GWh)

	No.1 P.S.	No.2 P.S.
Primary energy	154.7	94.6
Primary energy transfered from secondary energy	16.8	0.5
Total	171.5	95.1
Secondary energy	46.9	23.3
Secondary energy transfered to primary energy	16.8	0.5
Total	30.1	22.8

Table 6.2 Installed Capacity and Annual Energy Output of Existing and Under-construction Power Stations

	Installed capacity (kW)	Annual energy output (MWh)
(1) Existing Power Station		
Trisuli	18,000	103,690
Panauti	2,400	5,400
Sunkosi	6,000	56,940
Pharping	500	3,290
Sundarijal	640	5,760
Pokhara (Phewa)	1,024	8,760
Tinau (Butwal)	1,200	10,150
Sub-total	29,764	193,990
(2) Under-construction Power Station		
Gandaki	7,000	48,250
Devighat	14,400	91,980
Sub-total	21,400	140,230
Total	51,164	334,220

Table 6.3 Monthly Energy Output of Existing and Under-construction Power Stations

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual energy (MWh)
Monthly Mean Power Output (kW)													
Trisuli	12,000	11,020	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	10,940	103,690
Panauti	470	340	320	320	570	260	800	1,630	1,240	640	430	340	5,400
Sunkosi	3,930	2,860	3,330	4,960	10,050	6,520	10,050	10,050	10,050	8,250	4,420	3,160	56,940
Pharping	200	200	200	200	500	500	500	500	500	500	500	200	3,290
Sundarijal	600	600	600	600	700	700	700	700	700	700	700	600	5,760
Pokhara (Phewa)	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	8,760
Tinau (Butwal)	1,200	1,100	1,100	1,120	1,000	1,200	1,200	1,200	1,200	1,200	1,200	1,200	10,150
Sub-total	19,400	17,120	18,550	20,200	25,820	22,180	26,250	27,080	26,690	24,290	20,250	17,440	193,990
Gandaki	6,020	4,100	4,130	4,650	5,400	4,260	5,040	6,910	7,000	6,650	5,730	6,050	48,250
Devighet	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	91,980
Sub-total	16,520	14,600	14,630	15,150	15,900	14,760	15,540	17,410	17,500	17,150	16,230	16,550	140,230
Total	35,920	31,720	33,180	35,350	41,720	36,940	41,790	44,490	44,190	41,440	36,480	33,990	
Monthly Energy Output (MWh)	26,720	21,320	24,690	25,450	31,040	26,600	31,090	33,100	31,820	30,830	26,270	25,290	334,220

Table 6.4 Monthly Energy Required for Case 1

(Unit: GWh)

Month	Monthly energy required	Energy to be generated		
		Existing & under-construction	Kulekhani No.1	Diesel
Jan.	52.24	26.72	19.81	5.71
Feb.	46.40	21.32	19.92	5.16
Mar.	46.58	24.69	16.18	5.71
Apr.	40.04	25.45	14.59	-
May	41.37	31.04	10.33	-
June	40.88	26.60	14.28	-
July	39.62	31.09	8.53	-
Aug.	37.01	33.10	3.91	-
Sept.	36.66	31.82	4.84	-
Oct.	39.19	30.83	8.36	-
Nov.	42.14	26.27	14.88	0.99
Dec.	50.07	25.29	19.09	5.71
Total	512.20	334.22	154.70	23.28

Table 6.5 Monthly Energy Required for Case 2

(Unit: GWh)

Month	Monthly energy required	Energy to be generated			
		Existing & under-construction	Kulekhani No.1	Kulekhani No.2	Diesel
Jan.	67.87	26.72	22.40	11.76	7.00
Feb.	60.29	21.32	21.62	11.03	6.32
Mar.	60.53	24.69	19.05	9.79	7.00
Apr.	52.01	25.45	13.01	6.78	6.77
May	53.74	31.04	10.27	5.43	7.00
June	53.11	26.60	12.57	7.17	6.77
July	51.49	31.09	7.14	6.36	6.90
Aug.	48.10	33.10	2.55	5.55	6.90
Sept.	47.64	31.82	3.35	5.81	6.66
Oct.	50.92	30.83	7.44	5.76	6.89
Nov.	54.75	26.27	13.85	7.85	6.77
Dec.	65.05	25.29	21.45	11.32	7.00
Total	665.50	334.22	154.70	94.60	81.98

Table 6.6 Monthly Energy Output and Discharge of Kulekhani No.1 Power Station

Month	Case 1		Case 2	
	Energy (GWh)	Discharge (m^3/sec)	Energy (GWh)	Discharge (m^3/sec)
Jan.	19.81	5.55	22.40	6.27
Feb.	19.92	6.19	21.62	6.70
Mar.	16.18	4.54	19.05	5.33
Apr.	14.59	4.22	13.01	3.76
May	10.33	2.89	10.27	2.87
June	14.28	4.13	12.57	3.63
July	8.53	2.39	7.14	1.99
Aug.	3.91	1.09	2.55	0.71
Sept.	4.84	1.40	3.35	0.96
Oct.	8.36	2.34	7.44	2.07
Nov.	14.88	4.21	13.85	4.00
Dec.	19.09	5.35	21.45	6.01
Mean	12.89	3.69	12.89	3.69

Table 6.7 Calculation of Primary Energy Output of Existing and Under-construction Hydropower Plant

	Ratio to min. monthly mean power	Energy (GWh)
Jan.	1.01	21.53
Feb.	1.00	21.32
Mar.	0.90	19.19
Apr.	0.80	17.06
May	0.80	17.06
June	0.82	17.48
July	0.76	16.20
Aug.	0.71	15.14
Sep.	0.74	15.78
Oct.	0.76	16.20
Nov.	0.84	17.91
Dec.	0.97	20.68
Total		215.55

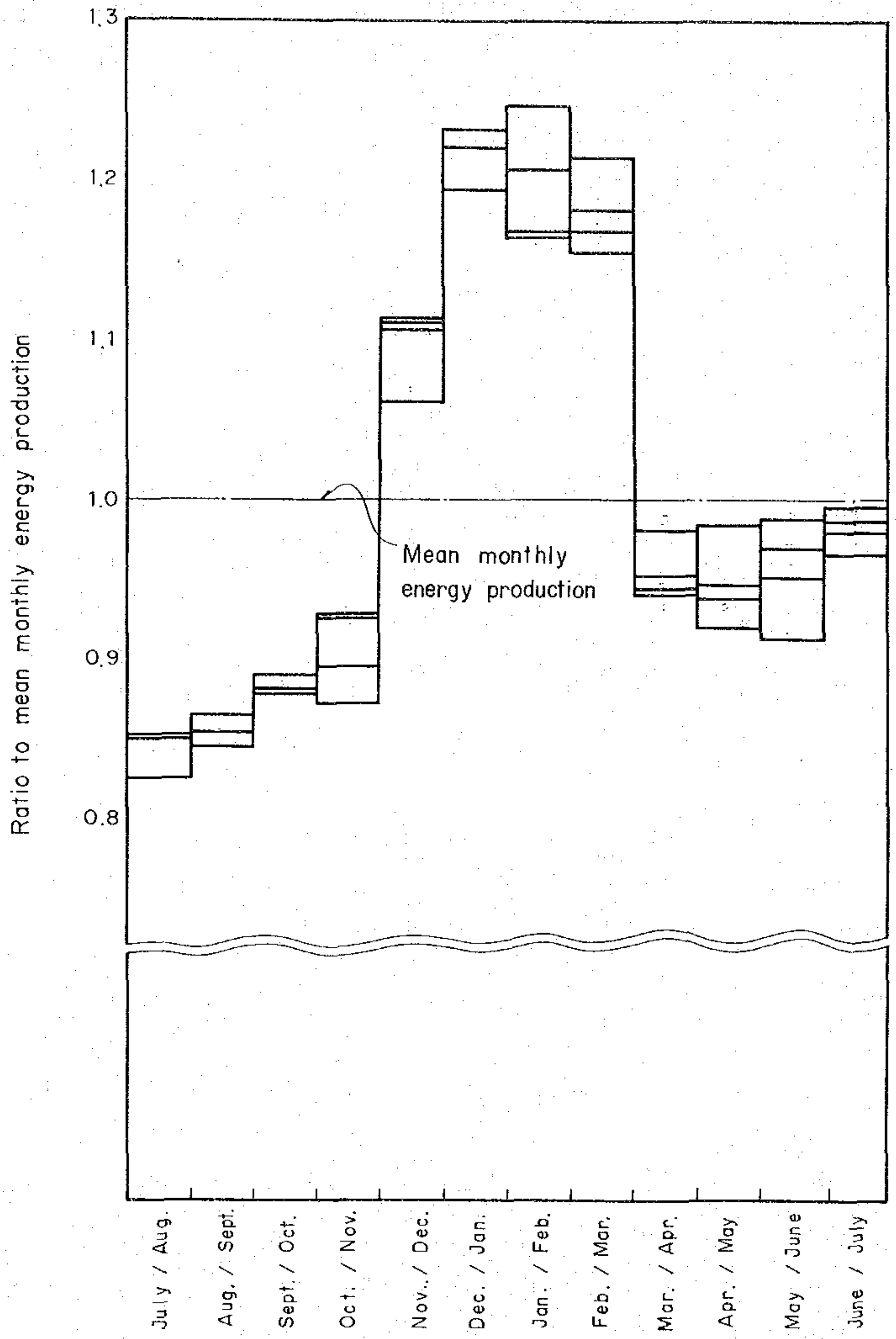


FIG. 6.1 DISTRIBUTION OF MONTHLY ENERGY PRODUCTION

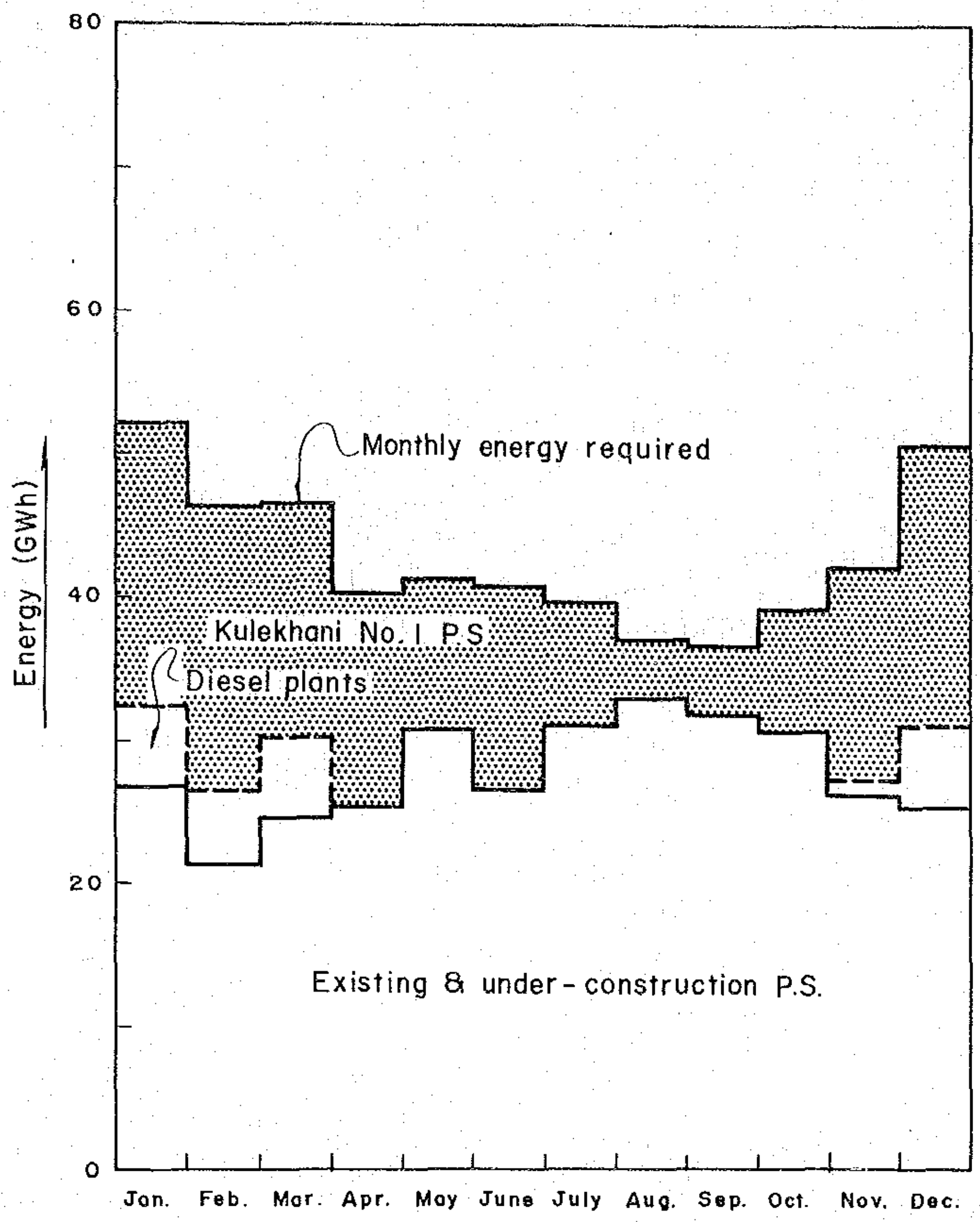


FIG. 6.2 MONTHLY POWER GENERATION PLAN (CASE I)

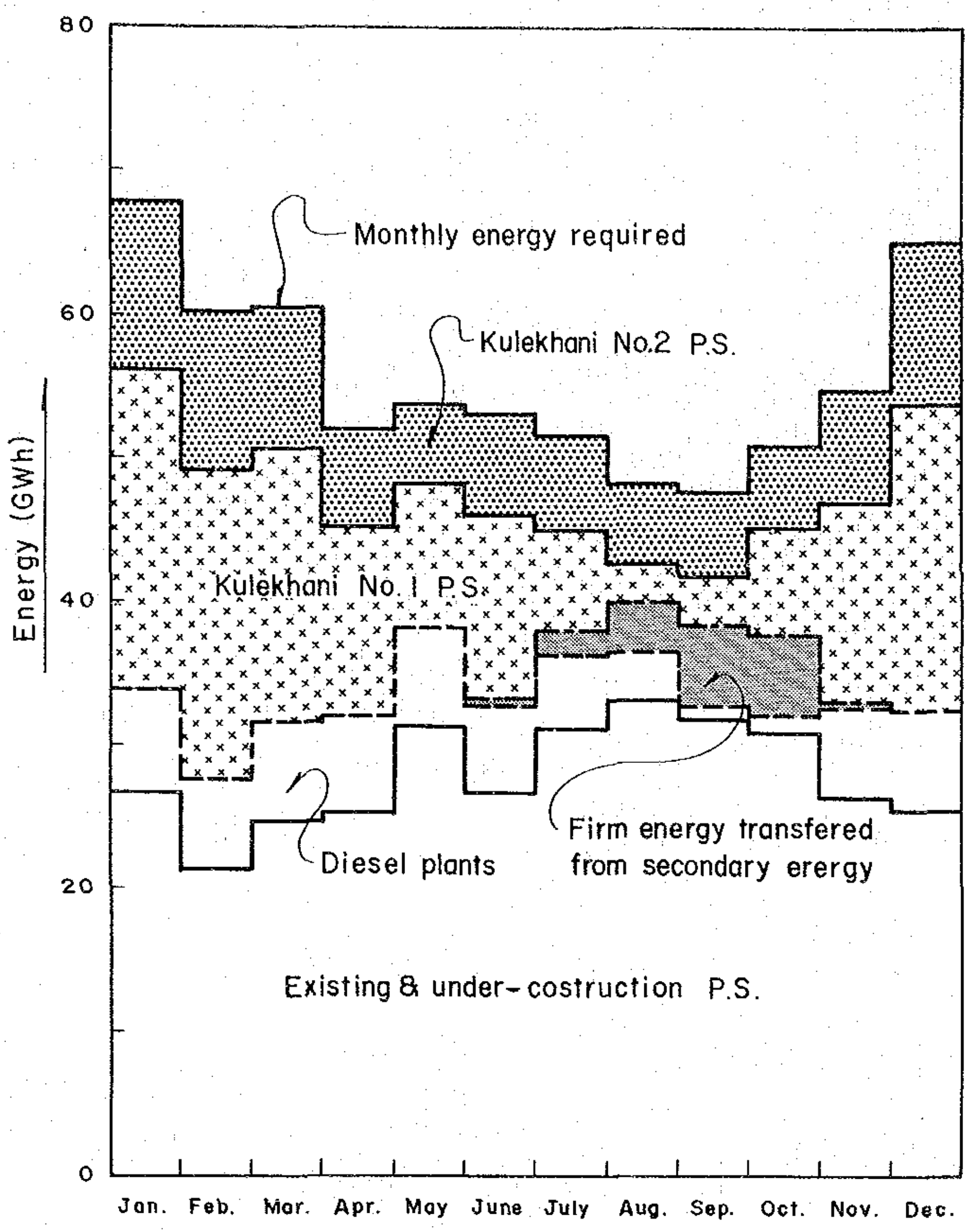


FIG. 6.3 MONTHLY POWER GENERATION PLAN (CASE 2)

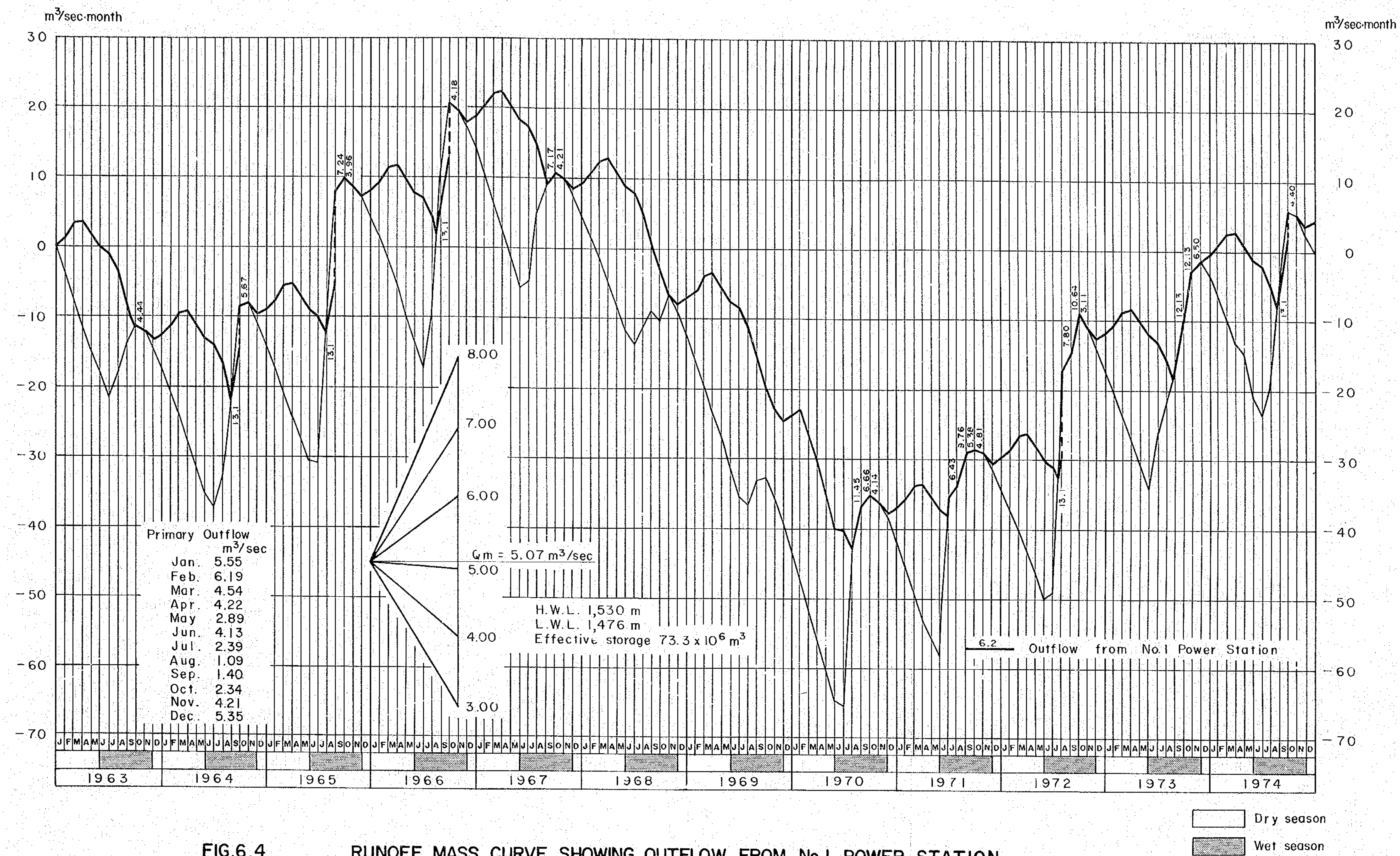
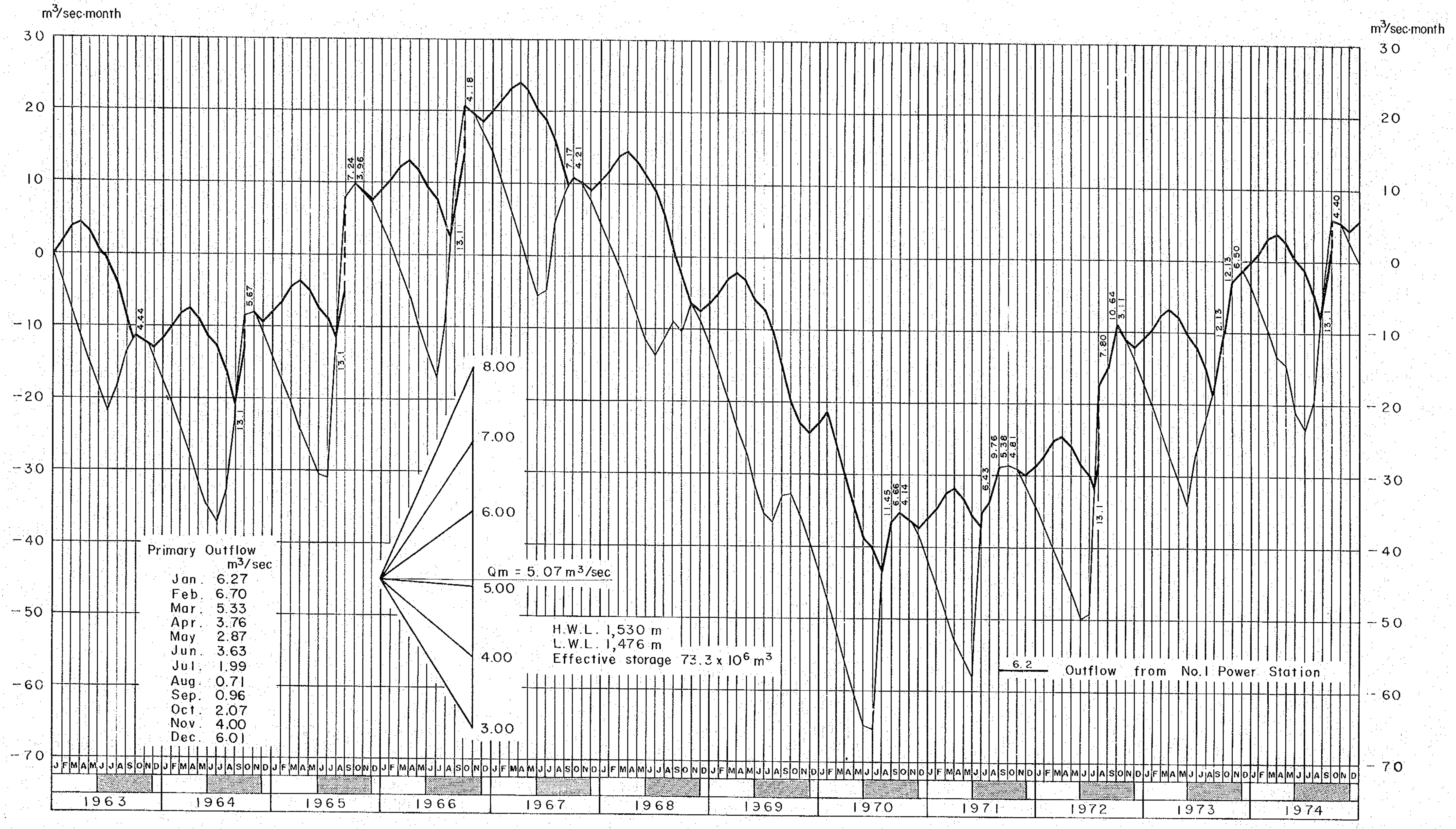


FIG.6.4 RUNOFF MASS CURVE SHOWING OUTFLOW FROM No.1 POWER STATION

(In Case of Single Operation of No.1 P.S.)



Dry season
Wet season

FIG.6.5 RUNOFF MASS CURVE SHOWING OUTFLOW FROM No.1 POWER STATION
(In Case of Combined Operation of No.1 P.S. and No.2 P.S.)

CHAPTER VII

DESIGN AND CONSTRUCTION PLAN

7.1 General

The preliminary design of the Kulekhani No.2 Hydroelectric Project is prepared based on the basic layout determined in the previous chapter. The project involves the construction of the following structures: A 54 m long diversion weir on the Mandu river (called Mandu diversion weir), an intake on the Mandu river, about a 6 km long headrace tunnel, a tributary intake on the Rani river (called Rani tributary intake), a surge tank and about an 850 m long penstock tunnel, an aboveground power station with an installed capacity of 33,000 kW including about a 160 m long tailrace, a 132 kV transmission line 32 km long between Kathmandu and Hetauda, and extension of the existing New Teku substation at Kathmandu and Hetauda substation. See Drawing No. 4 showing a general layout of this.

The preliminary design of each structure described hereinafter was made based on a topographic map of 1 to 1,000 in scale with 2 m contour, intervals, which was prepared on the basis of aerial photographs which were taken during the investigation in 1978.

The construction plan is studied in detail to estimate the construction cost on the feasibility study level. The actual basic cost data of the Kulekhani No.1 Power Station are fully referred to in determining the unit price for the cost estimate of this project.

7.2 Design of Structures

7.2.1 Mandu diversion weir and intake

The proposed site for the Mandu diversion weir is located on the Mandu river immediately downstream from the outlet of the tailrace tunnel of the Kulekhani No.1 Power Station. The foundation rock for the weir is grey coloured hard sandstone-semi-schist; it lies under a 12 m thick river gravel deposit in the riverbed.

The weir will be provided with an overflow section for entire width of the river channel for the passage of a 50-year probable flood. The overflow crest of the weir will be set at EL.906 m coinciding approximately to the present riverbed elevation. The weir will be equipped with gates which at the closed position will retain water up to EL.912.5 m. The active storage capacity of 12,000 m^3 will be available between EL.910.5 m and EL.912.5 m. The gates will be, two in number, of vertical lift type, of 12.5 m x 7 m size. See Drawing No. 5 and 6.

A sand flushing channel, which is located in the right section of the weir structure, will be provided with a 5.0 m x 10 m gate. The width will be 5.0 m, and the bottom will be set at EL.903 m. The channel will be used not only for flushing sand deposits, but for controlling the water level in the pondage by partial operation of the gate.

The outflow from the No.1 Power Station will be directly led to the intake of the No.2 Power Station through a conduit connecting the tailrace of the No.1 Power Station and the intake to avoid the water being mixed with water of the Mandu river which includes high sediment load. The conduit between the tailrace outlet of the No.1 Power Station and the diversion weir will be a hemicycle rectangular concrete conduit of 3.0 m in inside width and height and 84 m in total length. The conduit will be connected to a steel pipeline embedded in the diversion weir. Water will be led through the pipe to the intake.

A diversion tunnel of 2.5 m inside diameter and 145 m in total length will be constructed branching off from the conduit at a point 35 m downstream from the outlet of the tailrace tunnel of the No.1 Power Station to the right bank of the Rapti main stem, 350 m upstream from the confluence of the Rapti river and Mandu river. The diversion tunnel will be utilized to divert the discharge from the No.1 Power Station to the Rapti river during the construction of the Mandu weir, and also when the maintenance of the diversion weir and intake structure is required after commissioning of the No.2 Power Station.

The intake will be located on the right bank of the Mandu river adjacent to the diversion weir. Water retained by the diversion weir will be led to a settling basin for desilting, and then led to the intake tank. In the settling basin, flow velocity will be limited below 0.3 m/sec, even if the maximum discharge of 5 m^3/sec is taken from the Mandu river. The entrance sill of the basin will be set at EL.908.5 m, 2.5 m above the crest of the diversion weir. Two control gates, large-and small-sizes will be provided in an opening on the partition wall between the settling basin and intake tank. The bottom of opening is set at EL. 910.5 m. The small gate is operated for the control of small discharge in the dry season and the large gate is opened in wet season to take larger runoff in the Mandu river.

Water from the No.1 Power Station and that from the Mandu river will be collected in the intake tank and then will be fed into the headrace tunnel. The tank will be provided with a non-gated spillway on the left side for maintaining the tank water level below EL.910.5 m which will correspond to the maximum tailwater level for the Pelton turbine in the No.1 Power Station. The normal operation water level and low water level are set at EL.910 m and EL.907.5 m, respectively.

The inlet structure connecting to the headrace tunnel will be equipped with fixed trash racks. The elevation of entrance sill will be set at EL.900 m. For closing the headrace tunnel, a vertical roller gate, 2.5 m square, is equipped at the end of intake structure.

7.2.2 Headrace tunnel

The proposed route of the headrace tunnel of 5,800 m in length passes through the mountain mass composed mainly of sandstone-semi-schist layers though there are alternating layers of sandstone-slate in a very limited portion.

The headrace tunnel will be a pressure tunnel with circular cross section. The inside diameter of the tunnel will be 2.5 m which is the practical minimum size in view of economical and effective construction. The tunnel will be divided into two divisions by adits for construction; the first division of 2,500 m and the second division of 3,300 m. Construction adits will be excavated near the Mandu intake, near the Rani tributary intake and near the surge tank.

7.2.3 Rani tributary intake

The Rani river, a tributary of the Rapti river, will cross the headrace tunnel about 2.9 km downstream from the Mandu intake. The Rani tributary intake will be constructed on the Rani river about 1.3 km upstream from the confluence of the Rapti river and the Rani river to take river flow from a catchment area of about 4 km^2. The intake structure will be composed of an intake weir, a settling basin and an inclined shaft. The intake weir will be a 39 m long and 7.5 m high concrete weir. The overflow crest is set at EL.917.0 m. Water taken from the inlet which will be constructed immediately upstream from the intake weir will be desilted through the settling basin and then led to the headrace tunnel through the inclined shaft. The maximum intake discharge will be 1.0 m^3/sec. See Drawing No.7.

7.2.4 Surge tank

A surge tank will be constructed at the downstream end of the headrace tunnel. The surge tank will be concrete lined vertical shaft of 8 m in inside diameter and 42 m in height having an orifice of 3 m x 0.85 m in size. A calculation showed that the maximum up-surging would be 10 m above the high head water surface in case of instantaneous full load rejection and the maximum down-surging will be 20 m below the low head water surface in case of instantaneous load increase from half to full load. See Drawing No.8.

7.2.5 Penstock tunnel

Without a more-favourable alternative route, the proposed penstock line is obliged to pass through a biotite schists zone highly decomposed to the depth of about 20 m to 35 m from the surface. Further, the underlying layer of approximately 10 m is also considerably weathered. The construction of the surface type penstock line requires a costly special treatment to secure a reliable foundation for anchor blocks and saddle piers. A comparison of construction costs between the surface penstock and underground penstock is in favour of the latter, as described in APPENDIX III. The penstock line will be constructed underground.

The underground penstock tunnel is designed to be a steel-lined tunnel, which will be constructed between the surge tank and powerhouse. The total length of penstock tunnel will be 860 m, consisting of 390 m of upper portion dipping at 48 degree and 470 m of the level portion at the downstream end. The inside diameter of the penstock tunnel is designed to decrease gradually downstream from 2.1 to 1.7 m in the inclined portion whereas the level portion remains constant at 1.7 m. See Drawing No.8.

7.2.6 Powerhouse and switchyard

The power station will be located on the left bank of the Kani river about 600 m upstream from the confluence of the Kani river and the Rapti river. The proposed power station site is covered with a 2.2 to 2.5 m thick surface of soil, and the underlying layer of 5 to 9 meters consists of decomposed rocks. Solid rocks are found at EL.601 to 606 m; they are composed of alternation of sandstone and slate, and they have sufficient bearing capacity. The foundation of the power station will be set on solid rock.

The powerhouse will be 34 m in length, 12.5 m in width and 33 m in height housing two 15,000 kW and one 3,000 kW generating units.

The water from turbine will be released to the Kani river through a tailrace of 160 m in length. The tailrace will be a double-box culvert of 2.0 m in height and 2.5 m in width.

The switchyard will be located to the southeast of the powerhouse. The proposed area of 100 m x 50 m will accommodate the transformer and switching equipment.

7.2.7 Generating equipment

The generating equipment in the Kulekhani No.2 Power Station will be two units of 15,200 kW each and one unit of 3,000 kW.

Each turbine for the two large units will be of a vertical-shaft Francis type and will generate the rated output of 15,200 kW under the rated head of 278 m and rated discharge of 6.5 m^3/sec. The rated speed will be 750 rpm. The generator will be three-phase, vertical-shaft, revolving field type and will be rated at 18,000 kVA to deliver

15,200 kW of power at 85 per cent power factor in lagging. The terminal voltage of the generator will be 11 kV.

The turbine for the small unit will be horizontal-shaft Pelton type having two nozzles. The output will be rated at 3,000 kW at net head of 278 m and rated speed of 600 rpm. Generator will be three-phase, horizontal-shaft, field type and will be rated at 3,600 kVA to deliver 3,000 kW of power at 85 per cent power factor in lagging.

A main transformer for stepping up the generator voltage of 11 kV to transmission voltage of 132 kV will be rated at 39.6 MVA. The transformer will be of single-phase to form a three-phase bank, oil-immersed self-cooled type. The transformer will be installed in the outdoor switchyard on the terrace to the southeast of the powerhouse.

7.2.8 Transmission line and substation

The power generated at the Kulekhani No.2 Power Station will be delivered to the demand center through a 132 kV transmission line. The transmission line with a total length of about 32 km will be constructed between Kathmandu and Hetauda via the Kulekhani No.2 Power Station along the existing 66 kV transmission line.

At the construction stage of the Kulekhani No.2 Power Station, one 39 MVA transformer of 132/66 kV rating will be installed at the New Teku substation at Kathmandu, which will be completed in 1984, for connection with the existing power system. Equipment such as switchgear, control panel, etc. will be set at the existing Hetauda substation for connection with the existing 132 kV bus.

7.3 Construction Plan

7.3.1 Preparatory works

(1) Access road

The 6 m wide paved National Route running between Kathmandu and the Indian border and a 5 m wide gravel road of about 10 km in total length to Bhimphedi, branching from the National Route Bhainsedobhan, are available as an access to the proposed project site. However, the gravel road including bridges between Bhainsedobhan and Bhimphedi is required to be improved to enable transportion of heavy construction machinery and to allow regular traffic in all weather. This improvement work may be carried out during the construction of the Kulekhani No.1 Power Station.

New roads of 5 m in width and about 7 km in total length are to be constructed at each work site, such as the power station, surge tank, Rani tributary intake and quarry sites.

(2) Building for construction use

The job sites of the Kulekhani No.2 Power Station Project will extend over about 10 km in length. The headquarters during construction is to be located at Nibuatar, about 4 km from Bhainsedobhan where the office and camp of the Electricity Department are available for temporary use. The branch quarters are to be set up at Bhainsedobhan and near the Mandu intake site. The quarters will be provided with offices, housing and other facilities required for the supervisory and inspection group. About 30,000 m^2 of land will be required.

(3) Water supply system

The water supply facilities for this project will be installed at several sites. The planned water supply system consists of four systems covering the whole construction area: i) the Mandu intake site, ii) the Rani intake site, iii) the headquarters and concrete plant site which will be located near the headquarters, and iv) the penstock line and powerhouse site.

(4) Electric power supply system

The electric power for construction use will be supplied by three systems: (1) Mandu intake system, (2) Headquarters system, and (3) Power station system. The power for the Mandu intake site is to be provided directly from the existing substation, which was constructed near the existing Mandu bridge for the construction use of the No.1 Power Station. The headquarters system covers the headquarters, concrete plant and Rani intake, and the power is to be supplied from the said substation, through a 11 kV distribution line which is to be extended from the substation to the headquarters. The power of the power station system is also to be taken from the said 11 kV transmission line. Temporary substation for both headquarters and power station system will be newly constructed. The peak power requirement is estimated at about 2,000 kW.

7.3.2 Aggregate and concrete plants

The project requires concrete aggregate of about 40,000 m^3. The sand and gravel to be used as the aggregate can be obtained from the riverbed on the Rapti river near Nibuatar about 1.2 km downstream from the confluence with the Rani river. The sand and gravel taken from the said riverbed will be classified by a screening plant, which will be installed on the right bank of the Rapti river near the Nibuatar. The capacity of the screening plant will be about 100 ton/hr.

A concrete plant with a capacity of about 60 m^3/hr will be provided adjacent to the screening plant to supply concrete to the Mandu diversion weir and intake, Rani intake, upper portion of headrace tunnel, etc. Another concrete plant with a capacity of 30 m^3/hr will be installed at the power station site to supply concrete to powerhouse, tailrace, penstock tunnel, surge tank, lower portion of headrace tunnel, etc.

7.3.3 Diversion work of Mandu river

The construction of the Mandu diversion weir will be carried out in the dry season. The average natural runoff of the Mandu river in the dry season is about 0.3 m^3/sec. In addition to the natural runoff, the tailwater discharge of 13.1 m^3/sec in maximum from the No.1 Power Station will be released to the Mandu river. The method of diversion is as follows:

The natural runoff of the Mandu river is to be diverted to the downstream reaches of the Mandu river through a concrete pipe, which is placed on the exposed rock of the left bank. The tailwater discharge from the No.1 Power Station is to be diverted to the main stem of the Rapti river through a diversion tunnel (which will be constructed connecting directly with the tailrace tunnel of the No.1 Power Station) without releasing it to the Mandu river. The diversion tunnel will also be used when maintenance of the diversion weir and intake structures is being performed after commissioning of the No.2 Power Station.

7.3.4 Headrace tunnel

The total length of the headrace tunnel is 5,800 m. In order to shorten the construction period, the tunnel work is to be performed dividing the whole length into two sections by means of work adits. The tunnel lengths are 2,500 m for the upper section and 3,300 m for the lower section.

The tunnel is to be excavated by full-face attack method using leg drills and locker shovels. Tunnel muck is to be hauled out by battery locomotives and locker shovels. After excavation, concrete lining, mortar grouting and pressure grouting is to be followed.

7.3.5 Penstock tunnel

In order to avoid disturbance of the construction work of the powerhouse, an adit is to be constructed for construction of the penstock tunnel. The inlet will be located at the right side of the powerhouse. The excavation of the tunnel's level portion is to be made first. After reaching the inclined portion, the excavation is to be carried out upwards. Muck for the inclined portion is to fall down to the level portion after blasting rock. The tunnel muck is to be hauled out by battery locomotives and trolleys.

After excavation, steel pipes are to be brought in the level portion from the adit situated near powerhouse, and the erection of pipe and its concrete lining is to be carried out to downstream side from the bend portion which connects the inclined and level portions. In the inclined portion, steel pipes are to be carried into the tunnel from the adit located at the surge tank and its erection and concrete lining are to be performed to the upstream side from the said bend portion.

7.4 Construction Plant and Machinery

The major plant and equipment required for the construction of the project are listed as shown in Table 7.1

Table 7.1 Required Major Plant and Equipment

Item	Capacity	Quantity
Aggregate plant	100 tons/hr	1 set
Concrete plant	60 m^3/hr	1 "
- do -	30 m^3/hr	1 "
Bulldozer	27 tons	2 nos.
- do -	17 tons	5 "
Power shovel	2 m^3	2 "
- do -	1.2 m^3	3 "
Dozer shovel	1.2 m^3	1 no.
Dump truck	15 tons	10 nos.
Ordinary truck	10 tons	10 "
Crawler drill	5 tons	8 "
Rocker shovel	0.4 m^3	8 "
Battery locomotive	4 tons	5 "
Air compressor	160 ps	5 "
- do -	200 ps	5 "
Concrete pump	20 m^3/hr	6 "
Boring machine	100 m 65ø m/m	5 "
Crawler crane	30 tons	1 no.
Truck crane	25 tons	1 "
Tractor & trailer	30 tons	1 "
Road roller	10 tons	1 "
Agitator truck	3 m^3	7 nos.
Portable concrete mixer	0.2 m^3	2 nos.

7.5 Construction Materials

The quantities of main materials required for the construction works are estimated as follows. These materials will be purchased from abroad.

Cement	17,000 tons
Reinforcement bar	1,700 tons
Steel supports	1,200 tons
Steel pipe	900 tons
Trash racks	30 tons
Gates	410 tons
Explosives	1,000 tons
Fuel	10,000 kℓ

7.6 Construction Schedule

The time required for the project implementation, including the detailed design and project mobilization, is estimated, as shown in Fig.7.1, to be five and a half years. Of this three and a half years represent the time for the activities in the field required for the completion of the works, including the transmission line and substations.

At the beginning of the dry season of the first year, the preparatory works such as the construction of access roads and buildings for construction use, the provision of water supply system and electric power supply and communication systems are to be started. These preparatory works will take one year.

At the beginning of the second year, the construction of the Mandu intake weir is to be commenced after the construction plant and equipment are brought in to the project site. This work will require two years. The headrace tunnel construction, which represents the most critical work item in the schedule, is to be also started at the beginning of the second year. The beginning of the dry season of the second year will be the starting date of the Rani tributary intake and surge tank construction.

In the third year, the penstock tunnel construction is to be commenced. The third year will see full construction activities of the major works specified above. At the end of the third year, the Mandu intake, Rani intake and surge tank will be completed.

In the forth year, such civil work as the headrace tunnel, penstock tunnel and powerhouse will be carried out continuously. In this year, the tailrace construction is to be commenced. After manufacturing and transportation, the hydromechanical and electromechanical works are also to be started.

All works are scheduled to be completed before the wet season of the fifth year, test operation of the whole system is to be conducted in the wet season of the fifth year, and the Kulekhani No.2 Power Station is to be put into operation in July of that same year.

Item	Quantity	1979	1980	1981	1982	1983	1984	1985
Feasibility Study & Financial Arrangement								
Supplemental Investigation			6					
Tender Design			7					
Tender of Contract				6				
Detail Design				9				
Mobilization				3				
Preparatory Works								
Access Road	75 km				12			
Buidings & Facilities	L.S				10			
Mandu Intake	Ex. 113,000 m^3 Conc. 22,400 〃					24		
Headrace tunnel	Ex. 48,500 m^3 Conc. 18,900 〃					39		
Rani Intake	Ex. 8,100 m^3 Conc. 3,100 〃					15		
Surge Tank	Ex. 94,300 m^3 Conc. 1,100 〃					15		
Penstock	Ex. 41,200 m^3 Conc. 10,400 〃					18		
Powerhouse & Switch Yard	Ex. 46,900 m^3 Conc. 7,900 〃						15	
Tailrace	Ex. 7,600 m^3 Conc. 1,900 〃						6	
Hydro-mechanical Equipment	L.S.					Cont, Mft Tr	12	Operation
Electro-mechanical Equipment	L.S.					Cont, Mft Tr	12	Test
Substation (Extention) & Transmission Line	L.S. 32 km					Cont, Mft Tr	12	Test

FIG. 7.1 CONSTRUCTION TIME SCHEDULE

Remarks. :

Cont : Contract
Mft : Manufacturing
Tr : Transportation
Ex : Excavation
Conc : Concrete

Shaded : Wet season
Blank : Dry season
Bar with number (e.g. 9) : Months

CHAPTER VIII

COST ESTIMATE

8.1 Construction Cost

The total construction cost of the Kulekhani No.2 Hydroelectric Project was estimated at US$48 million, comprising US$40.8 million of foreign currency portion and US$7.2 million equivalent of local currency portion. The cost includes direct construction cost, engineering and administration cost, physical contingency and contingency for price escalation.

The following are the conditions on which the cost estimate was based:

- The estimate was based on prices prevailing in August 1978.
- The following exchange rates were assumed:

  1.0 US Dollar = 12.55 Nepali Rupees = 210 Japanese Yen
- The construction was assumed to be carried out by contractors selected through international competitive bidding.
- The work quantities were calculated based on a preliminary design as shown in the attached drawings.
- Unit prices for each work item included direct costs such as personnel and labour expenses, material costs, operation and depreciation costs of construction equipment, and indirect costs such as the contractor's overhead and administrative expenses. Unit prices were based on the cost of labour, material and construction machinery required for the works which were determined as the result of construction planning. However, their values were reviewed referring to the bid unit prices of the Kulekhani No.1 Power Station.
- Domestic currency would be required for the land acquisition cost, the labour cost, purchase of domestically procured materials such as timber, bricks, fuels, etc. and transportation charges in the territory of Nepal.
- Taxes and duties to be levied by the Government of Nepal, consisting of oontract tax and income tax, were included in the indirect cost of the unit prices. Other taxes and duties such as personal

Table 8.1 Summary of Construction Cost

(Unit: 10^3US$)

	Item		Foreign Currency	Local Currency	Total
I.	Preparatory Works		1,100	610	1,710
	Access road (7 km), buildings and service utilities				
II.	Civil Works		13,810	2,170	15,980
	1. Mandu diversion weir and intake		3,210	360	3,570
	Excavation:	115,200 m^3			
	Concrete:	23,900 m^3			
	2. Headrace tunnel		5,900	960	6,860
	Excavation:	48,500 m^3			
	Concrete:	18,900 m^3			
	3. Rani tributary intake		600	70	670
	Excavation:	8,100 m^3			
	Concrete:	2,000 m^3			
	4. Surge tank		700	150	850
	Excavation:	93,400 m^3			
	Concrete:	1,100 m^3			
	5. Penstock tunnel		1,970	370	2,340
	Excavation:	41,200 m^3			
	Concrete:	10,400 m^3			
	6. Powerhouse		1,080	190	1,270
	Excavation:	39,300 m^3			
	Concrete:	6,000 m^3			
	7. Tailrace		350	70	420
	Excavation:	7,600 m^3			
	Concrete:	1,900 m^3			
III.	Hydro-mechanical Equipment		4,120	400	4,520
	Trash rack and gates:	440 tons			
	Steel pipe:	900 tons			
IV.	Electro-mechanical Equipment		10,990	1,200	12,190
	1. Generating equipment (15,000 kW x 2 units, 3,000 kW x 1 unit)		8,200	750	8,950
	2. Transmission line (132 kV, 42 km)		1,340	300	1,640
	3. Substation (39.6 MVA)		1,450	150	1,600
	Total (item I to IV)		(30,020)	(4,380)	(34,400)
V.	Engineering Service		4,000	500	4,500
VI.	General Expenses		-	1,000	1,000
VII.	Contingencies		6,780	1,320	8,100
	1. Physical (10% of Items I to VI)		3,390	660	4,050
	2. Escalation		3,390	660	4,050
	Grand Total		40,800	7,200	48,000

income tax on the employees of the Contractor, and the custom duties on the equipment and materials imported by the Contractor were also taken into account in the respective unit prices.

- The cost of engineering services for detailed design and construction supervision to be rendered by a foreign consultant was estimated assuming the work period, numbers of engineering staff required, etc.
- General administrative expenses of the Government of Nepal were assumed to be about 3 per cent of the direct construction cost.
- Compensation cost for land and houses in the project area and right-of-way of the land to be required for the execution of the project, which are to be furnished by the Government of Nepal, are included in the General administration expenses of Government of Nepal.
- The physical contingency was estimated to be 10 % of the total cost. The price contingency was estimated assuming an annual escalation of 5 %.

A summary of the construction cost is shown Table 8.1

8.2 Annual Disbursement Schedule

Construction funds will be disbursed over a period of the four years needed to complete the project works. The annual fund requirement was estimated as shown in Table 8.2, based on the construction time schedule as described in Paragraph 7.5.

Table 8.2 Annual Disbursement Schedule

(Unit: 10^3US$)

Year	Foreign currency	Local currency	Total
1st year	8,400	1,500	9,900
2nd year	12,200	2,100	14,300
3rd year	13,000	2,300	15,300
4th year	7,200	1,300	8,500
Total	40,800	7,200	48,000

8.3 Operation, Maintenance and Replacement Cost

The Electricity Department of the Ministry of Water and Power will manage the operation and maintenance of the Kulekhani No.2 Power Station.

The annual operation and maintenance cost (OM cost) consists of the average annual expenditure for administration, operating personnel, equipment, supplies and other cost required to keep the Kulekhani No.2 Hydroelectric Project in efficient operating conditions. The OM cost is estimated at US$250,000 in terms of annual equivalent cost, as discussed in Appendix III and summarized as follows:

Personnel expenses	US$90,000
Maintenance and repairing cost	US$80,000
Other expenses	US$80,000
Total	US$250,000

Some parts of the proposed project facilities will periodically be replaced. They will be hydro-mechanical equipment and electro-mechanical equipment. The economic life is different by item but it is estimated to be 35 years on an average. The replacement cost, after deducting 10 % of salvage value, is estimated to be US$15,040.