Appendix C :

Power Simulation for Study on Optimum Development Scale

Appendix C : Power Simulation for Study on Optimum Development Scale

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Appendix C Power Simulation for Study on Optimum Development Scale

C1 Power Simulation Study

In order to select the optimum development scale of Kulekhani III Hydropower Project among the alternatives, whose installed capacities are set by varying peaking operation time, power simulation study was carried out by developing a simulation model

Condition for simulation itemized as follows;

1) The available discharge from the Kulekhani reservoir is determined in accordance with the optimum reservoir operation rule examined in Chapter 7 of Main Report. In addition, the maximum intake discharge of 2.0 m^3/sec taken from the Khani River is added to the available discharge released from the reservoir.
2) The river maintenance flow of 0.1 m^3/sec in the dry season and 0.3 m^3/sec in the wet season is deducted from the available discharge for the Kulekhani III Hydropower Project.
3) Minimum plant discharge is 40% of the maximum plant discharge for one unit turbine.
4) Curves of combined efficiency of generator and turbine were prepared for the simulation study purpose on the basis of the current experiences. The Curves of the combined efficiency curve is shown in Figure C.1.
5) Head loss including friction loss, bending loss, contraction loss and expansion loss was calculated based on the optimum layout examined in Chapter 6 of Main Report.
6) Tailrace rating curve was prepared based the uniform flow calculation of the tailrace tunnel. The tailrace rating curve is shown in Figure C.2.

As a result of economic comparison study described in Chapter 6 of Main Report, 4 hours peaking operation with 44.8 MW of installed capacity is selected as the optimum development plan. The output and energy of the optimum development plan is shown in Table C.1

TABLES

Appendix C

Table C.1 Results of Power Simulation of Kulekhnai III Hydropower Project (1/3) (Peak Power Output)

(Unit: MW)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Min.	Ave.	Max.	Dry Season (Dec./Mar.)	Wet Season (Apr./Nov.)
1963	44.78	44.78	44.78	10.98	9.55	15.26	21.83	28.65	29.32	37.09	23.13	44.78	9.55	29.58	44.78		
1964	44.78	44.78	44.78	9.36	7.65	11.20	25.22	27.88	44.78	42.19	18.86	44.78	7.65	30.52	44.78		
1965	44.78	44.78	44.78	11.63	14.11	13.20	41.25	44.78	44.78	39.91	30.88	44.78	11.63	34.97	44.78		
1966	44.78	44.78	44.78	7.39	8.34	8.29	20.60	31.43	44.78	36.68	21.26	44.78	7.39	29.82	44.78		
1967	44.78	44.78	42.91	1.34	5.95	12.46	27.28	44.78	44.78	36.78	21.83	44.78	1.34	31.04	44.78		
1968	44.78	44.78	44.78	12.70	9.89	18.61	28.26	32.80	21.98	38.74	25.15	44.78	9.89	30.60	44.78		
1969	44.78	44.78	43.48	0.00	9.57	10.20	16.12	22.58	22.74	13.25	4.16	44.78	0.00	23.04	44.78		
1970	44.78	44.78	14.46	1.24	4.52	13.58	33.31	44.78	44.78	41.02	23.71	44.78	1.24	29.64	44.78		
1971	44.78	44.71	44.76	11.71	22.03	36.79	44.78	43.35	44.78	35.54	23.67	44.78	11.71	36.81	44.78		
1972	44.78	44.78	44.78	15.54	11.43	12.50	23.57	44.78	44.46	31.09	19.98	44.78	11.43	31.87	44.78		
1973	44.78	44.78	44.78	14.21	10.75	19.62	44.78	41.95	44.78	44.78	43.78	44.78	10.75	36.98	44.78		
1974	44.78	44.78	44.78	11.49	10.20	12.59	24.16	30.15	44.78	39.92	20.79	44.78	10.20	31.10	44.78		
1975	44.78	44.78	44.75	0.00	8.33	14.00	29.76	44.78	44.78	41.95	22.95	44.78	0.00	32.14	44.78		
1976	44.78	44.78	44.78	8.38	11.73	14.28	37.11	23.82	29.09	27.75	18.30	44.78	8.38	29.13	44.78		
1977	44.78	44.78	44.78	11.27	12.68	12.46	22.52	21.90	19.31	13.97	10.10	44.78	10.10	25.28	44.78		
1978	44.78	35.62	14.68	12.81	16.83	23.41	33.18	44.78	40.77	40.12	23.89	44.78	12.81	31.30	44.78		
1979	44.78	44.78	44.78	15.27	11.12	11.41	25.33	38.79	41.55	19.48	16.10	44.78	11.12	29.85	44.78		
1980	44.78	44.78	44.78	9.27	6.84	16.36	30.00	34.53	40.05	23.87	15.96	44.78	6.84	29.67	44.78		
1981	44.78	44.78	44.75	8.18	12.57	9.34	20.16	22.79	22.07	16.67	9.84	44.78	8.18	25.06	44.78		
1982	44.78	44.78	29.83	5.91	5.73	9.30	20.82	21.21	23.99	9.48	8.52	44.78	5.73	22.43	44.78		
1983	44.78	44.78	20.32	3.43	13.60	10.66	18.27	22.51	30.19	36.49	27.12	44.78	3.43	26.41	44.78		
1984	44.78	44.76	42.22	0.00	5.06	13.35	17.89	19.79	24.25	34.04	18.80	44.78	0.00	25.81	44.78		
1985	44.78	44.78	43.32	1.48	10.64	16.48	21.96	21.00	39.79	42.68	25.27	44.78	1.48	29.75	44.78		
1986	44.78	44.78	44.78	9.53	12.43	18.93	18.29	24.99	44.78	39.74	21.82	44.78	9.53	30.80	44.78		
1987	44.78	44.78	44.77	10.67	6.10	4.58	13.20	44.78	44.72	41.88	25.89	44.76	4.58	30.91	44.78		
1988	44.78	44.78	43.67	8.22	11.72	15.57	21.19	26.29	44.78	31.51	17.18	44.78	8.22	29.54	44.78		
1989	44.78	44.78	44.42	1.45	6.47	15.09	27.89	24.80	41.42	37.64	20.68	44.78	1.45	29.52	44.78		
1990	44.78	44.78	44.29	0.00	12.99	18.04	26.86	31.70	44.78	38.43	18.94	44.78	0.00	30.86	44.78		
1991	44.66	44.78	44.66	9.70	6.72	12.56	20.08	18.03	23.42	14.28	13.99	44.78	6.72	24.81	44.78		
1992	44.78	44.78	37.13	3.28	10.08	11.93	10.12	15.44	14.08	6.08	0.00	44.71	0.00	20.20	44.78		
1993	44.67	4.07	2.79	1.27	13.17	10.58	24.92	44.78	20.01	26.33	16.12	44.78	1.27	21.12	44.78		
1994	44.78	44.78	44.78	10.33	12.77	13.94	12.66	14.52	13.91	3.41	0.00	44.78	0.00	21.72	44.78		
1995	44.78	44.62	30.76	0.00	9.29	12.36	13.18	35.60	44.78	29.80	44.78	44.78	0.00	29.56	44.78		
Min	44.66	4.07	2.79	0.00	4.52	4.58	10.12	14.52	13.91	3.41	0.00	44.71	0.00	20.20	44.78		
Mean	44.77	43.26	39.54	7.21	10.33	14.21	24.74	31.36	35.43	30.68	19.80	44.78	5.84	28.84	44.78		
Max	44.78	44.78	44.78	15.54	22.03	36.79	44.78	44.78	44.78	44.78	44.78	44.78	12.81	36.98	44.78		
90% Dependable																44.76	8.35

Table C.1 Results of Power Simulation of Kulekhnai III Hydropower Project (2/3) (Off Peak Power Output)

(Unit: MW)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Min.	Ave.	Max.	Dry Season (Dec./Mar.)	Wet Season (Apr./Nov.)
1963	7.29	7.29	7.29	0.00	0.00	0.00	0.00	0.00	1.31	2.43	0.00	7.29	0.00	2.74	7.29		
1964	7.29	7.29	7.29	1.22	1.22	0.00	0.00	1.55	9.83	4.86	0.00	7.29	0.00	3.99	9.83		
1965	7.29	7.29	7.29	0.00	0.00	0.00	3.65	11.60	7.29	1.22	1.22	7.29	0.00	4.51	11.60		
1966	7.29	7.29	7.29	2.43	1.22	2.43	0.00	5.08	8.94	1.22	0.00	7.29	0.00	4.21	8.94		
1967	7.29	7.29	6.08	6.08	3.65	0.00	0.00	7.29	7.29	1.22	0.00	7.29	0.00	4.46	7.29		
1968	7.29	7.29	7.29	1.22	1.22	0.00	0.00	0.00	0.00	3.65	0.00	7.29	0.00	2.94	7.29		
1969	7.29	7.29	6.08	7.29	1.22	1.22	0.00	0.00	0.00	0.00	3.65	7.29	0.00	3.44	7.29		
1970	7.29	7.29	6.08	6.08	3.65	1.22	4.43	9.19	7.29	3.65	0.00	7.29	0.00	5.29	9.19		
1971	7.29	3.65	4.86	0.00	0.00	3.65	10.07	2.43	7.29	1.65	0.00	7.29	0.00	4.02	10.07		
1972	7.29	7.29	7.29	0.00	0.00	0.00	1.92	7.83	5.33	1.22	0.00	7.29	0.00	3.79	7.83		
1973	7.29	7.29	7.29	1.22	0.00	0.00	7.29	2.43	8.88	8.67	4.86	7.29	0.00	5.21	8.88		
1974	7.29	7.29	7.29	0.00	0.00	0.00	0.00	2.27	9.98	3.65	0.00	7.29	0.00	3.76	9.98		
1975	7.29	7.29	6.08	7.29	1.22	0.00	0.00	8.01	7.98	3.65	0.00	7.29	0.00	4.68	8.01		
1976	7.29	7.29	7.29	1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.29	0.00	2.53	7.29		
1977	7.29	7.29	7.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.29	0.00	2.43	7.29		
1978	7.29	4.86	0.00	0.00	0.00	0.00	1.22	8.66	4.86	4.08	0.00	7.29	0.00	3.19	8.66		
1979	7.29	7.29	7.29	0.00	0.00	0.00	0.00	1.22	1.22	0.00	0.00	7.29	0.00	2.63	7.29		
1980	7.29	7.29	7.29	1.22	2.43	0.00	0.00	0.00	2.43	0.00	0.00	7.29	0.00	2.94	7.29		
1981	7.29	6.08	2.43	1.22	1.22	2.43	0.00	0.00	0.00	0.00	0.00	7.29	0.00	2.33	7.29		
1982	7.29	7.29	3.65	3.65	3.65	1.22	0.00	0.00	0.00	1.22	0.00	7.29	0.00	2.94	7.29		
1983	7.29	7.29	4.86	4.86	0.00	0.00	0.00	0.00	2.43	3.65	0.00	7.29	0.00	3.14	7.29		
1984	7.29	4.86	6.08	7.29	3.65	0.00	0.00	0.00	1.95	2.43	0.00	7.29	0.00	3.40	7.29		
1985	7.29	7.29	1.22	6.08	0.00	0.00	0.00	0.00	5.28	6.51	0.00	7.29	0.00	3.41	7.29		
1986	7.29	7.29	7.29	0.00	0.00	0.00	0.00	1.87	8.33	3.65	0.00	7.29	0.00	3.59	8.33		
1987	7.29	7.29	6.08	1.22	2.43	3.65	1.22	7.76	6.08	5.30	0.00	6.08	0.00	4.53	7.76		
1988	7.29	7.29	0.00	2.43	0.00	0.00	0.00	0.00	7.98	1.22	0.00	7.29	0.00	2.79	7.98		
1989	7.29	7.29	6.08	6.08	2.43	0.00	0.00	0.00	3.65	3.65	0.00	7.29	0.00	3.65	7.29		
1990	7.29	7.29	6.08	7.29	0.00	0.00	0.00	2.26	8.08	3.65	0.00	7.29	0.00	4.10	8.08		
1991	6.08	7.29	3.65	0.00	2.43	0.00	0.00	0.00	0.00	0.00	0.00	7.29	0.00	2.23	7.29		
1992	7.29	7.29	6.08	4.86	0.00	0.00	1.22	0.00	0.00	2.43	7.29	4.86	0.00	3.44	7.29		
1993	4.86	4.86	4.86	6.08	0.00	0.00	1.68	8.01	0.00	0.00	0.00	7.29	0.00	3.14	8.01		
1994	7.29	7.29	7.29	0.00	0.00	0.00	0.00	0.00	0.00	4.86	7.29	7.29	0.00	3.44	7.29		
1995	7.29	3.65	2.43	7.29	1.22	1.22	0.00	3.65	7.29	0.00	7.29	7.29	0.00	4.05	7.29		
Min	4.86	3.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.86	0.00	2.23	7.29		
Mean	7.18	6.82	5.60	2.84	0.99	0.52	0.99	2.76	4.27	2.42	0.96	7.18	0.00	3.54	8.01		
Max	7.29	7.29	7.29	7.29	3.65	3.65	10.07	11.60	9.98	8.67	7.29	7.29	0.00	5.29	11.60		
90% Dependable																7.29	0.00

Table C.1 Results of Power Simulation of Kulekhnai III Hydropower Project (3/3) (Energy)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Min.	Ave.	Max.
1963	5.75	5.11	5.59	1.32	1.19	1.84	2.72	3.55	4.32	5.17	2.78	5.84	1.19	3.76	5.84
1964	6.01	5.51	5.73	1.14	0.97	1.35	3.16	4.65	11.30	6.52	2.27	5.76	0.97	4.53	11.30
1965	5.79	5.20	5.82	1.40	1.75	1.59	6.28	12.58	7.80	4.97	3.80	5.91	1.40	5.24	12.58
1966	6.05	5.42	5.87	0.92	1.07	1.05	2.55	7.36	9.45	4.57	2.56	5.83	0.92	4.39	9.45
1967	5.97	5.09	5.35	0.72	0.79	1.50	3.38	6.72	7.75	4.62	2.63	5.69	0.72	4.18	7.75
1968	5.86	5.60	5.72	1.54	1.20	2.24	3.52	4.09	2.64	5.42	3.03	5.99	1.20	3.91	5.99
1969	5.92	5.15	5.44	0.69	1.22	1.29	2.00	2.81	2.74	1.63	0.92	5.88	0.69	2.97	5.92
1970	5.74	5.09	2.20	0.56	0.63	1.65	5.64	10.99	7.42	5.47	2.85	5.92	0.56	4.51	10.99
1971	5.77	5.06	5.58	1.41	2.73	5.66	11.83	6.09	6.61	5.38	2.85	5.94	1.41	5.41	11.83
1972	6.15	5.78	6.07	1.87	1.42	1.50	4.40	9.58	7.36	3.89	2.40	5.88	1.42	4.69	9.58
1973	5.92	5.27	5.74	1.72	1.34	2.36	6.26	5.91	9.90	9.73	6.27	6.14	1.34	5.55	9.90
1974	7.03	5.54	5.86	1.38	1.26	1.51	3.02	5.45	10.81	5.35	2.50	6.04	1.26	4.65	10.81
1975	5.92	5.24	5.68	0.68	1.07	1.68	3.75	9.37	9.71	6.03	2.76	5.83	0.68	4.81	9.71
1976	5.96	5.50	5.63	1.03	1.46	1.72	4.60	2.97	3.50	3.43	2.20	5.83	1.03	3.65	5.96
1977	5.75	5.17	5.69	1.36	1.57	1.50	2.79	2.73	2.32	1.72	1.21	6.02	1.21	3.15	6.02
1978	5.76	4.26	1.82	1.54	2.10	2.82	5.01	10.33	5.92	6.01	2.87	6.00	1.54	4.54	10.33
1979	6.25	5.73	6.16	1.84	1.38	1.37	3.17	4.93	5.09	2.42	1.94	5.92	1.37	3.85	6.25
1980	6.02	5.45	5.67	1.13	0.88	1.97	3.75	4.30	5.76	2.95	1.92	5.94	0.88	3.81	6.02
1981	5.84	5.12	5.59	1.01	1.61	1.18	2.53	2.84	2.65	2.05	1.18	6.04	1.01	3.14	6.04
1982	5.90	5.19	3.71	0.85	0.80	1.15	2.61	2.64	2.89	1.30	1.02	5.99	0.80	2.84	5.99
1983	5.85	5.15	2.65	0.53	1.69	1.28	2.29	2.80	4.25	5.22	3.26	5.74	0.53	3.39	5.85
1984	5.82	5.26	5.21	0.44	0.72	1.61	2.25	2.47	4.09	4.99	2.26	5.75	0.44	3.41	5.82
1985	5.95	5.09	5.36	0.28	1.32	1.98	2.73	2.61	6.89	8.18	3.04	5.81	0.28	4.10	8.18
1986	6.37	5.48	5.75	1.15	1.54	2.28	2.32	4.53	9.58	5.89	2.62	5.73	1.15	4.44	9.58
1987	6.11	5.27	5.63	1.30	0.81	0.61	1.81	8.23	7.27	6.80	3.12	5.74	0.61	4.39	8.23
1988	5.68	5.27	5.43	1.00	1.45	1.87	2.63	3.28	8.15	3.88	2.07	5.90	1.00	3.88	8.15
1989	6.24	5.88	5.61	0.64	0.86	1.82	3.47	3.09	6.02	5.27	2.49	5.93	0.64	3.94	6.24
1990	5.83	5.29	5.62	0.80	1.63	2.17	3.34	5.63	8.83	5.30	2.28	5.72	0.80	4.37	8.83
1991	5.71	5.26	5.57	1.17	0.89	1.51	2.48	2.24	2.82	1.78	1.68	5.83	0.89	3.08	5.83
1992	5.69	5.27	4.58	0.49	1.25	1.44	1.39	1.94	1.69	1.03	0.73	5.66	0.49	2.60	5.69
1993	5.57	0.80	0.74	0.61	1.64	1.27	4.07	9.26	2.41	3.24	1.94	5.77	0.61	3.11	9.26
1994	5.74	5.33	5.84	1.24	1.59	1.68	1.59	1.81	1.67	0.94	0.77	5.70	0.77	2.82	5.84
1995	5.68	5.04	3.90	0.78	1.19	1.53	1.62	4.50	6.31	3.73	9.18	7.35	0.78	4.23	9.18
Min	5.57	0.80	0.74	0.28	0.63	0.61	1.39	1.81	1.67	0.94	0.73	5.66	0.28	2.60	5.69
Mean	5.93	5.15	5.05	1.05	1.30	1.76	3.48	5.22	5.94	4.39	2.59	5.91	0.93	3.98	8.03
Max	7.03	5.88	6.16	1.87	2.73	5.66	11.83	12.58	11.30	9.73	9.18	7.35	1.54	5.55	12.58

FIGURES

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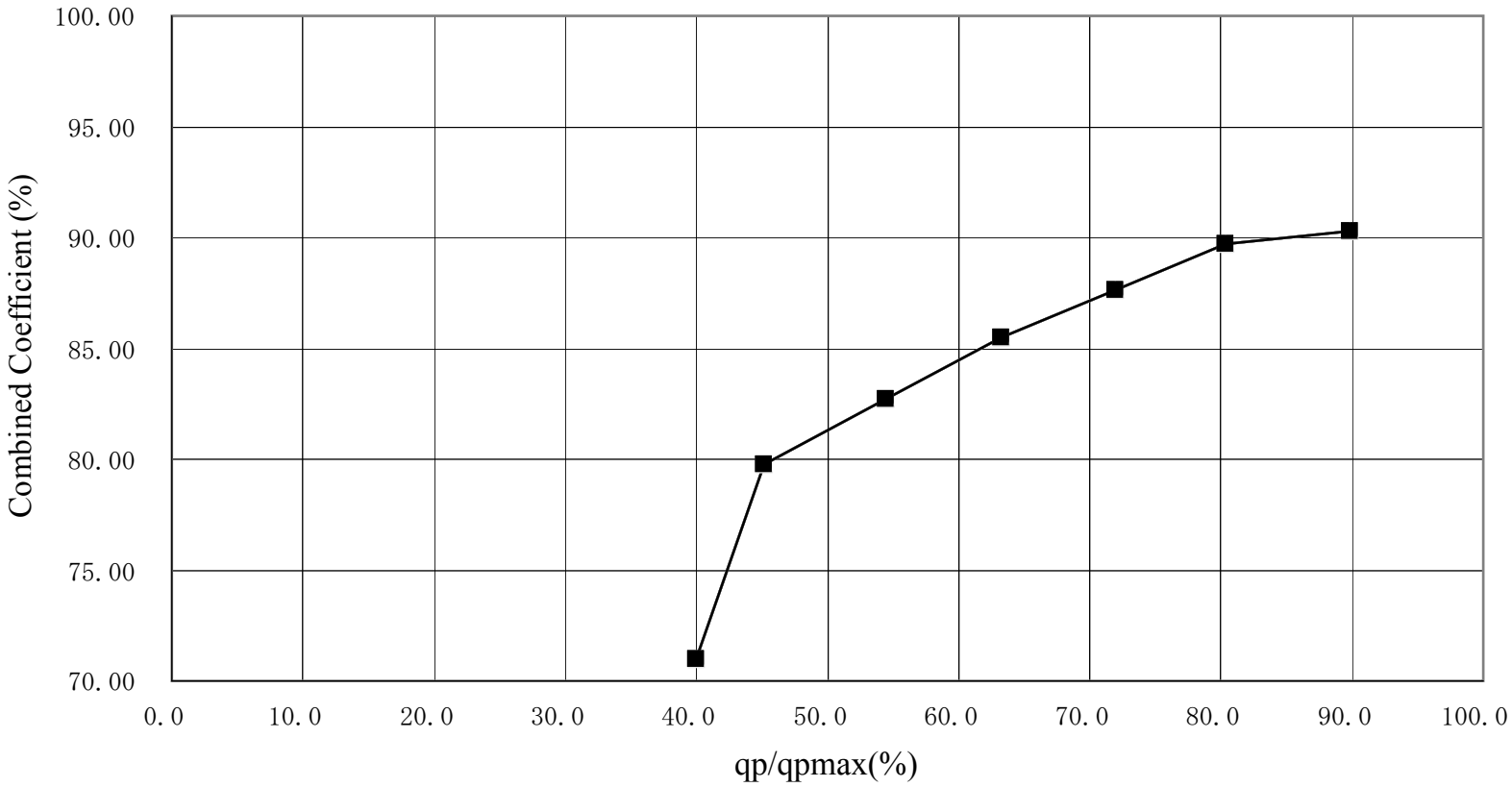

Figure C.1 Combined Efficiency Curve Kulekhani III Hydropower Project

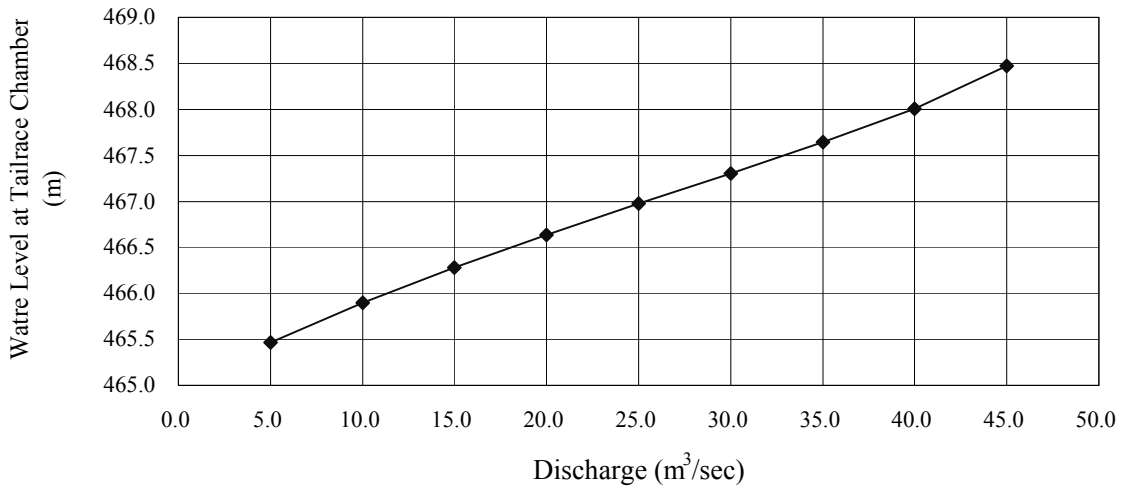

Figure C.2 Rating Curve of Tailrace

Appendix D :
Reservoir Simulation

Appendix D : Reservoir Simulation

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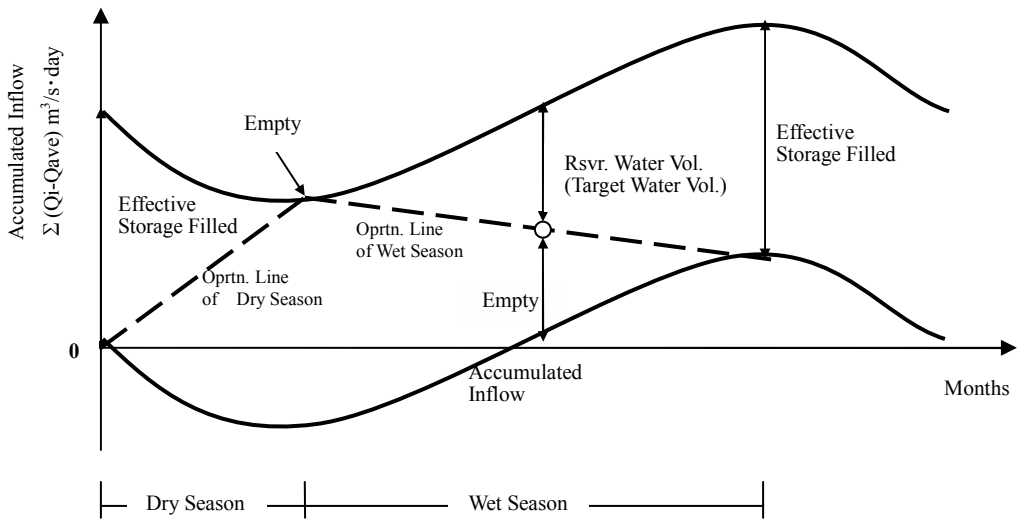
Appendix D Reservoir Simulation

D1 Mass Curve Analysis

Prior to the reservoir operation analysis, the seasonal discharge pattern and the monthly target water volume are determined by utilizing mass curves drawn from the monthly planned inflows with the respective dependability.

As illustrated below, on a mass curve the abscissa represents the day (month) and the ordinate represents the accumulated inflow in units of m^3/s-day, which is obtained by adding the difference in the planned inflow and the mean inflow for the analysis period. Storage conditions can be obtained from the ordinate, and the seasonal discharge pattern from the gradients of the operation lines.

Monthly target water volume for the reservoir operation is set by applying the water volume at the end of each month, which is obtained from the storage conditions and the operation lines on a mass curve. For effective utilization of the reservoir, the reservoir water volume is scheduled to be full at the end month of the wet season and to be empty at the end month of the dry season.



The seasonal power discharge and the monthly target water volume are determined as illustrated in Figure D1.1 by utilizing the mass curves drawn from the monthly planned inflow with the respective dependability and the seasonal operation pattern.

D2 Reservoir Simulation

D2.1 Methodology

The reservoir simulation is conducted in accordance with an equation for water balance in the reservoir and the operation rules as described below:

$$S_i = S_{i-1} + I_i - O_i$$

S_i : Reservoir water volume at the current interval
S_{i-1} : Reservoir water volume at the previous interval
I_i : Effective inflow into the reservoir at the current interval
O_i : Outflow from the reservoir at the current interval (Discharge for power generation and spill out)

(1) Rules throughout the year

- The reservoir water volume of the starting month for the simulation is the same as the target water volume of the previous month.
- In cases where the reservoir water level (W.L.) is at the designated minimum operation level (M.O.L.), the power discharge is equal to the effective reservoir inflow at the current interval.
- After the reservoir W.L. reaches the designated full supply level (F.S.L.), the plant runs at its highest achievable capacity. The reservoir inflow exceeding the power discharge is spilt out.
- In cases where the effective head is over the designated rated head, the plant runs at the maximum achievable discharge at that W.L. as much as possible.

(2) Optimization of monthly power discharge

<u>In the dry season</u>

- When the reservoir water volume at the end of the previous month is over the target water volume for that month, the seasonal power discharge is increased by the surplus water volume.

<u>In the wet season</u>

- In cases where the reservoir water volume cannot be recovered to the target water volume for that month, even when the planned inflow for that month is fully stored, the monthly power discharge is reduced to a half of the seasonal power discharge.
- In cases where the reservoir water volume is not expected to be recovered to the target water volume for that month, even when the surplus between the planned inflow and the seasonal power discharge is stored, the monthly power discharge is modified by the surplus between the current reservoir water volume and the target one for the previous month, and the surplus between the planned inflow and the seasonal power discharge.

- In cases where the reservoir water volume is expected to be recovered over the target water volume for that month when the surplus between the planned inflow and the seasonal power discharge is stored, the monthly power discharge is equal to the seasonal power discharge.

D2.2 Conditions for Simulation

Conditions applied to the reservoir simulation are as follows:

(1) Intake Discharge from Upper Rapti Tributaries

Features of the tributary intake facilities related to KL-II and KL-III are summarized below:

Intake Facility	C.A. (km^2)	Max. Intake Dis. (m^3/s)	Operation Period
KL-II			
Mandu Intake	20.0	1.0	Throughout the year
Rapti Pump Intake	28.5	0.2	Oct. to Apr.
KL-III			
Khani H/W	21.2	2.0	Throughout the year
Yangran Reg. Dam	8.1	-	Throughout the year

Compensation discharges, as maintenance flow for the river ecology, at the Khani headwork and the Yangran regulating dam are designed on the basis of the results of the natural EIA studies, as described in section 4.3.4 of the Main Report. With regard to natural runoff at the regulating dam site, it is diverted to downstream without additional supplying from the dam in cases where it is less than the compensation discharge.

(2) Storage Capacity Curve of Yangran Regulating Pond

In the regulating pond, the volume of sediment deposits is estimated to be 1,000 m^3 per year or 100,000 m^3 for 100 years (refer to Supporting Report (1), Appendix E1).

A possible shape of the sediment deposits should be predicted and verified by numerical simulations and/or hydraulic model tests and will be subject to review in the detailed design stage. In this study, there is not so sufficient data to predict it that it is estimated on the basis of the Kira's relationship. This relationship between reservoir sediment ratio and sediment slope was proposed in resultant of sediment surveys in 43 generation-purpose reservoirs in Japan.

From this relationship, the sediment profile is assumed as follows:

Reservoir Sediment Ratio; R_S	: 28 %
Original Riverbed Gradient; I_B	: 6.7 % (1/15)
Assumed Ratio of I_S/I_B	: 0.9 from Kira's relationship
Sediment Slope; I_S	: 6.0 % (1/17)

The storage capacity curve of the regulating pond is derived from topographic maps at a scale of 1/500, taking into account the sediment profile assumed above.

The sill of sediment flushing facility (S.D.L.) is set at EL. 564.0 m from the estimated volume of the sediment deposits and sediment slope. The intake sill elevation (I.W.L.) is set at EL. 568.0 m and the minimum operation level (M.O.L.) at EL. 577.0 m taking account of a clearance above I.W.L. for preventing from air entrainment.

The regulating volume is determined from the maximum plant discharge that is calculated from the firm plant discharge (90 % dependable inflow in the dry season) and the peak operation hour.

When setting the F.S.L. at EL. 597.0 m, the sediment capacity and the regulating capacity are estimated to be 123,000 m^3 and 475,000 m^3 respectively, as illustrated in Figure D2.1.

(3) Combined Efficiency of Turbine and Generator

Features and combined efficiencies of turbines and generators for KL-I and KL-II are as shown Figure D2.2 and tabulated below. Installation of 2-unit vertical shaft Francis type turbines is assumed for KL-III. Therefore, the combined efficiency curve for KL-II is used for this analysis.

	KL-I	KL-II	KL-III
Turbine Type	Vertical shaft Pelton	Vertical shaft Francis	Vertical shaft Francis
Installed Capacity (kW/unit)	30,000	16,000	Variable
Nos. of Unit (unit)	2	2	2
Max. Plant Discharge (cm^3/s/unit)	6.55	6.65	Variable
Min. Plant Discharge (cm^3/s/unit)	1.31	2.66	Variable
Rated Head (m)	550	284.1	Variable

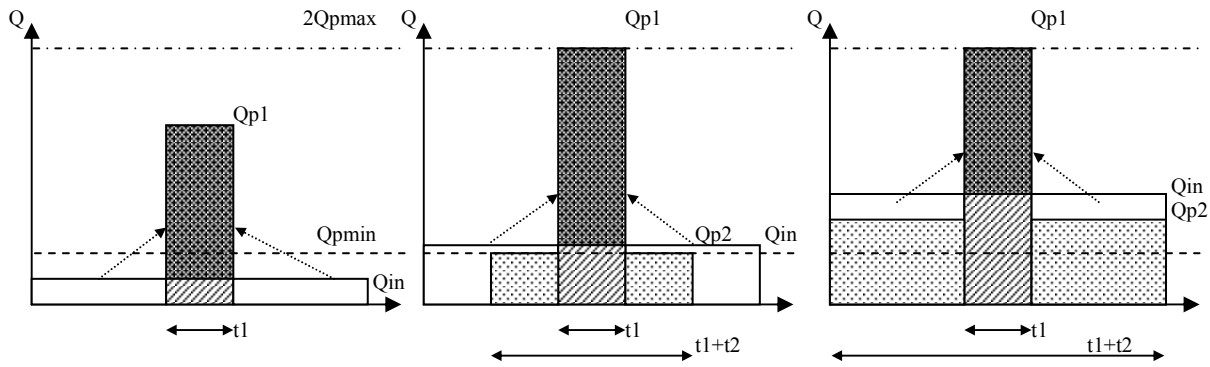
Note: Ratio of the minimum and maximum plant discharge: The ratios of 20 % for Pelton type and 40 % for Francis type are applied according to actual turbine performance.

(4) Power Operation

Priority is given to peak load supply throughout the year, considering power supply capabilities of the existing run-of-river hydropower stations in the dry season and the efficient utilization of the seasonal regulating capability of the KL series.

KL-I

The following figure shows the operation conditions depending on the available discharge for power generation.



Qin: Daily mean power discharge
Qpmax: Max. plant discharge per unit
Qpmin: Min. plant discharge per unit
Qp1: Discharge for peak operation
Qp2: Discharge for off-peak operation
t1: Peak operation hour
t2: Off-peak operation hour

- Firstly, available power discharge is utilized for production of peak energy.
- The surplus water after peak operation is used for production of off-peak energy.
- In cases where available power discharge is less than the minimum plant discharge of one unit (Qp.min), operation with "Qp.min" will continue for an achievable duration.

KL-II

The inflow to KL-II is composed of the outflow from KL-I and the diverted water from the Mandu intake and the Rapti pump intake. If the inflow is less than the minimum plant discharge of one unit, it is wasted by spillage from the Mandu headpond.

KL-III

In the latest NEA power expansion plan, KL-III is planned to supply peak power for 4 hours in the evening during the dry season by utilizing the seasonal regulating capacity of the Kulekhani reservoir and the daily regulating capacity of the regulating pond.

With regard to the peak operation hour of KL-III, it was optimized to be at 4 hours in the comparison study as described in chapter 6 of the Main Report. Therefore, it is fixed at 4 hours in this analysis.

The conditions for operation of KL-I and KL-III are detailed in Figure D2.3 and D2.4.

(5) Power Output and Energy Production

Power output and energy production are computed by applying the following equations:

$E = P \times t$

$P = g \times H_e \times Q_p \times n$

$H_e = IWL - TWL - Hl$

$Hl = \alpha \times Q_p^2$

E : Energy production (kWh)
t : Duration of operation (hrs.)
P : Power output (kW)
g : Gravity acceleration (9.8 m/s^2)
H_e : Effective head (m)
Q_p : Power discharge (m^3/s)
n : Combined efficiency of turbine and generator
IWL : Intake water level (EL. m)
TWL: Tail water level (EL. m)
Hl : Head loss (m)
α : Head loss coefficient

	KL-I	KL-II	KL-III
I.W.L. (El.m)	Average R.W.L.	911.0	/*
T.W.L. (El.m)	916.0	601.0	466.5
Head Loss Coef.	0.248	0.158	0.003

Note: /* W.L. below the one-third of available drawdown from the planned F.S.L.

The installed capacity of KL-III is obtained by assuming the following conditions:

- Firm Plant discharge : 90 % dependable inflow into the regulating pond in the dry season
- Maximum Plant Discharge : Firm plant discharge x 24 hrs. / peak operation hour (4-hour)
- Rated water level : Water level below the one-third of available drawdown from the planned F.S.L.
- Head loss coefficient : Head loss in the headrace tunnel is evaluated as $\alpha = 0.003$
- Combined efficiency : n = 0.89 is assumed from the actual performance

D2.3 Results of Simulation

To optimize the reservoir operation, comparison studies are carried out under the several conditions following a screening process as tabulated below:

Analysis Conditions	1st Screening	2nd Screening
KL-I		
- Rsvr. Planned Inflow	60%, 70%, 80% Dependable Inflow	
- Dry Season Operation	4 –month, 5-month	
- Peak Operation Hour in Dry Season	(Fixed at 8-hour)	4, 6, 8, 10, 12 hours
KL-III		
- Peak Operation Hour	(Fixed at 4-hour)	(Fixed at 4-hour)

The reservoir simulations are conducted to evaluate the operation of the KL series under the above conditions using the hydrological data over 33 years.

The result of each screening process is shown in Table D2.1 and D2.2.

Based on the results of the series of the screening processes, the conditions for the optimum reservoir operation are presented as follows:

- Planned inflow : 70 % dependable inflow
- Seasonal operation pattern : 4-month dry season operation
- Peak operation hour in dry season : 8-hour

Table D2.3 shows the results of the reservoir simulation under the above conditions.

TABLES

Appendix D

Table D2.1 Results of 1st Screening

KL-I OPERATION CONDITIONS													
Rsvr. Inflow Dependability	%	60		70		80		60		70		80	
Peaking Hours	Hour	8	4	8	4	8	4	8	4	8	4	8	4
Basic Power Discharge		Dec.-Mar.	Apr.-Nov.	Dec.-Mar.	Apr.-Nov.	Dec.-Mar.	Apr.-Nov.	Dec.-Apr.	May-Nov.	Dec.-Apr.	May-Nov.	Dec.-Apr.	May-Nov.
- Peak	m3/sec	13.10	13.10	13.10	8.22	13.10	2.52	13.10	13.10	13.10	8.22	13.10	2.10
- Off-peak	m3/sec	3.65	0.10	3.50	0.00	3.32	0.00	1.97	0.10	1.82	0.00	1.60	0.00
- Daily Mean	m3/sec	6.80	2.27	6.70	1.37	6.58	0.42	5.68	2.27	5.58	1.37	5.43	0.35
KL-III OPERATION CONDITIONS													
Peaking Hours	Hour	4	4	4	4	4	4	4	4	4	4	4	4
Rated W.L.	EL.m	591.44	-	591.38	-	591.40	-	594.10	-	593.37	-	593.46	-
Daily Mean Inflow	m3/sec	7.20	4.33	7.36	4.24	7.48	4.09	6.09	4.74	6.21	4.63	6.29	4.47
90 % -dependable Inflow	m3/sec	7.14	0.28	7.18	1.54	7.17	0.67	5.38	1.73	5.98	1.63	5.90	0.64
Firm Plant Discharge	m3/sec	42.84	-	43.08	-	43.02	-	32.28	-	35.88	-	35.40	-
Rqd. Regulating Vol.	m3	437,000	-	440,000	-	439,000	-	285,000	-	337,000	-	331,000	-
Net Head	m	119.43	-	119.31	-	119.35	-	124.47	-	123.01	-	123.20	-
Installed Capacity	MW	44.6	-	44.8	-	44.6	-	35.0	-	38.4	-	38.0	-
MEAN SPILL OUT													
- KL-I	m3/sec	0.04	0.41	0.04	0.44	0.04	0.57	0.03	0.47	0.03	0.52	0.03	0.63
- KL-II	m3/sec	0.06	0.45	0.05	0.42	0.04	0.39	0.09	0.47	0.08	0.43	0.09	0.42
90 % DEPENDABLE OUTPUT													
KL-I - Peak Output	MW	58.63	0.00	59.22	20.93	59.60	11.90	58.53	32.97	59.06	21.02	59.51	0.00
- Off-peak Output	MW	18.34	0.00	17.62	0.00	16.73	0.00	11.65	0.00	11.74	0.00	11.80	0.00
KL-II - Peak Output	MW	31.74	0.00	31.85	13.54	31.88	6.42	31.68	18.49	31.81	13.62	31.85	0.00
- Off-peak Output	MW	10.47	0.00	10.16	0.00	9.90	0.00	6.73	0.00	6.79	0.00	6.79	0.00
KL-III - Peak Output	MW	44.60	0.00	44.80	9.37	44.60	0.00	35.00	11.36	38.40	10.39	38.00	0.00
- Off-peak Output	MW	8.31	0.00	8.36	0.00	8.34	0.00	6.37	0.00	7.05	0.00	6.96	0.00
ANNUAL ENERGY PRODUCTION		Dec.-Mar.	Apr.-Nov.	Dec.-Mar.	Apr.-Nov.	Dec.-Mar.	Apr.-Nov.	Dec.-Apr.	May-Nov.	Dec.-Apr.	May-Nov.	Dec.-Apr.	May-Nov.
KL-I													
- Peak Energy	GWh	54.18	45.38	55.67	42.04	56.84	31.71	67.47	42.04	69.32	37.79	71.00	25.84
- Off-peak Energy	GWh	37.54	34.54	38.24	35.37	38.78	41.31	27.81	33.84	28.06	35.38	27.88	43.55
- Seasonal Total	GWh	91.72	79.92	93.91	77.41	95.62	73.02	95.28	75.88	97.38	73.17	98.88	69.39
- Annual Total	GWh	171.64		171.32		168.64		171.16		170.55		168.27	
KL-II													
- Peak Energy	GWh	29.02	24.66	29.78	23.29	30.37	17.44	36.13	22.83	37.07	20.90	37.94	13.89
- Off-peak Energy	GWh	21.58	19.88	21.96	20.45	22.24	23.85	15.85	19.44	15.99	20.41	15.86	25.20
- Seasonal Total	GWh	50.60	44.54	51.74	43.74	52.61	41.29	51.98	42.27	53.06	41.31	53.80	39.09
- Annual Total	GWh	95.14		95.48		93.90		94.25		94.37		92.89	
KL-III													
- Peak Energy	GWh	20.02	22.46	20.72	21.21	21.13	18.13	19.69	19.94	22.13	19.35	22.44	16.65
- Off-peak Energy	GWh	1.47	3.98	1.25	4.43	1.15	6.41	3.74	5.84	1.68	5.57	1.74	7.34
- Seasonal Total	GWh	21.49	26.44	21.97	25.64	22.28	24.54	23.43	25.78	23.81	24.92	24.18	23.99
- Annual Total	GWh	47.93		47.61		46.82		49.21		48.73		48.17	
		Dec.-May	Jun.-Nov.	Dec.-May	Jun.-Nov.	Dec.-May	Jun.-Nov.	Dec.-May	Jun.-Nov.	Dec.-May	Jun.-Nov.	Dec.-May	Jun.-Nov.
KL-I													
- Peak Energy	GWh	61.93	37.63	64.67	33.04	60.55	28.00	71.64	37.88	74.01	33.10	71.62	25.22
- Off-peak Energy	GWh	38.99	33.10	38.34	35.27	38.91	41.18	28.56	33.09	28.19	35.25	28.76	42.67
- Seasonal Total	GWh	100.92	70.73	103.01	68.31	99.46	69.18	100.20	70.97	102.20	68.35	100.38	67.89
- Annual Total	GWh	171.65		171.32		168.64		171.17		170.55		168.27	
KL-II													
- Peak Energy	GWh	33.28	20.39	34.79	18.27	32.47	15.34	38.43	20.54	39.67	18.30	38.27	13.55
- Off-peak Energy	GWh	22.24	19.23	22.02	20.39	22.30	23.80	16.08	19.22	16.04	20.36	16.24	24.82
- Seasonal Total	GWh	55.52	39.62	56.81	38.66	54.77	39.14	54.51	39.76	55.71	38.66	54.51	38.37
- Annual Total	GWh	95.14		95.47		93.91		94.27		94.37		92.88	
KL-III													
- Peak Energy	GWh	22.44	20.04	22.98	18.95	21.30	17.95	20.97	18.66	23.47	18.00	22.53	16.56
- Off-peak Energy	GWh	1.66	3.79	1.48	4.20	2.21	5.36	3.81	5.78	1.70	5.54	2.16	6.92
- Seasonal Total	GWh	24.10	23.83	24.46	23.15	23.51	23.31	24.78	24.44	25.17	23.54	24.69	23.48
- Annual Total	GWh	47.93		47.61		46.82		49.22		48.71		48.17	
ANNUAL BENEFIT													
KL-I & II (kWh-value: 9.0 Usc/kWh for primary, 4.0 Usc/kWh for secondary)													
(Dec.-May./Jun.-Nov.)													
Energy Benefit - Primary	M.US$	8.57		8.95		8.37		9.91		10.23		9.89	
- Secondary	M.US$	6.86		6.69		6.78		6.21		6.05		6.05	
- Total	M.US$	15.43		15.64		15.15		16.12		16.28		15.94	
KL-III (kW-value: 121US$/kW, kWh-value: 6.1 Usc/kWh for primary, 4.0 Usc/kWh for secondary)													
(Dec.-May./Jun.-Nov.)													
Power Benefit	M.US$	5.40		5.42		5.40		4.24		4.65		4.60	
Energy Benefit - Primary	M.US$	1.37		1.40		1.30		1.28		1.43		1.37	
- Secondary	M.US$	1.02		0.99		1.02		1.13		1.01		1.03	
- Total	M.US$	2.39		2.39		2.32		2.41		2.44		2.40	
Total Benefit	M.US$	7.79		7.81		7.72		6.65		7.09		7.00	
KL-SERIES													
Total Benefit	M.US$	23.22		23.45		22.87		22.77		23.37		22.94	

Table D2.2 Results of 2nd Screening

KL-I OPERATION CONDITIONS											
Rsvr. Inflow Dependability	%	70		70		70		70		70	
Peaking Hours	Hour	4	4	6	4	8	4	10	4	12	4
Basic Power Discharge		Dec.-Mar.	Apr.-Nov.	Dec.-Mar.	Apr.-Nov.	Dec.-Mar.	Apr.-Nov.	Dec.-Mar.	Apr.-Nov.	Dec.-Mar.	Apr.-Nov.
- Peak	m^3/sec	13.10	8.22	13.10	8.22	13.10	8.22	13.10	8.22	13.10	8.22
- Off-peak	m3/sec	5.42	0.00	4.57	0.00	3.50	0.00	2.13	0.00	0.30	0.00
- Daily Mean	m3/sec	6.70	1.37	6.70	1.37	6.70	1.37	6.70	1.37	6.70	1.37
KL-III OPERATION CONDITIONS											
Peaking Hours	Hour	4	4	4	4	4	4	4	4	4	4
Rated W.L.	EL.m	590.94	-	591.34	-	591.38	-	591.44	-	591.78	-
Daily Mean Inflow	m3/sec	7.37	4.24	7.37	4.24	7.36	4.24	7.34	4.24	7.22	4.24
90 % -dependable Inflow	m3/sec	7.23	1.57	7.21	1.56	7.18	1.54	7.14	1.57	6.96	1.58
Firm Plant Discharge	m3/sec	43.38	-	43.26	-	43.08	-	42.84	-	41.76	-
Rqd. Regulating Vol.	m3	453,000	-	442,000	-	440,000	-	437,000	-	421,000	-
Net Head	m	118.79	-	119.23	-	119.31	-	119.43	-	120.05	-
Installed Capacity	MW	44.8	-	44.8	-	44.8	-	44.6	-	43.6	-
MEAN SPILL OUT											
- KL-I	m3/sec	0.04	0.44	0.04	0.44	0.04	0.44	0.04	0.44	0.04	0.44
- KL-II	m3/sec	0.03	0.42	0.04	0.42	0.05	0.42	0.06	0.42	0.18	0.42
90 % DEPENDABLE OUTPUT											
KL-I - Peak Output	MW	59.22	20.92	59.22	20.93	59.22	20.93	59.22	20.89	59.22	20.90
- Off-peak Output	MW	27.06	0.00	22.87	0.00	17.62	0.00	11.76	0.00	11.73	0.00
KL-II - Peak Output	MW	31.86	13.47	31.85	13.55	31.85	13.54	31.84	13.44	31.83	13.44
- Off-peak Output	MW	15.62	0.00	13.25	0.00	10.16	0.00	6.87	0.00	6.70	0.00
KL-III - Peak Output	MW	44.80	9.59	44.80	9.49	44.80	9.37	44.60	9.64	43.60	9.70
- Off-peak Output	MW	8.38	0.00	8.38	0.00	8.36	0.00	8.31	0.00	8.12	0.00
ANNUAL ENERGY PRODUCTION		Dec.-Mar.	Apr.-Nov.	Dec.-Mar.	Apr.-Nov.	Dec.-Mar.	Apr.-Nov.	Dec.-Mar.	Apr.-Nov.	Dec.-Mar.	Apr.-Nov.
KL-I											
- Peak Energy	GWh	28.17	42.05	41.98	42.06	55.67	42.04	55.47	55.89	55.27	69.69
- Off-peak Energy	GWh	67.35	35.37	52.85	35.36	38.24	35.37	23.47	35.40	9.13	35.37
- Seasonal Total	GWh	95.52	77.42	94.83	77.42	93.91	77.41	78.94	91.29	64.40	105.06
- Annual Total	GWh	172.94		172.25		171.32		170.23		169.46	
KL-II											
- Peak Energy	GWh	15.08	23.29	22.46	23.30	29.78	23.29	29.67	30.68	29.56	38.07
- Off-peak Energy	GWh	38.00	20.45	30.19	20.45	21.96	20.45	13.52	20.47	5.21	20.45
- Seasonal Total	GWh	53.08	43.74	52.65	43.75	51.74	43.74	43.19	51.15	34.77	58.52
- Annual Total	GWh	96.82		96.40		95.48		94.34		93.29	
KL-III											
- Peak Energy	GWh	20.70	21.28	20.71	21.24	20.72	21.21	20.62	21.27	20.18	21.11
- Off-peak Energy	GWh	1.17	4.32	1.20	4.38	1.25	4.43	1.32	4.50	1.46	4.59
- Seasonal Total	GWh	21.87	25.60	21.91	25.62	21.97	25.64	21.94	25.77	21.64	25.70
- Annual Total	GWh	47.47		47.53		47.61		47.71		47.34	
		Dec.-May	Jun.-Nov.	Dec.-May	Jun.-Nov.	Dec.-May	Jun.-Nov.	Dec.-May	Jun.-Nov.	Dec.-May	Jun.-Nov.
KL-I											
- Peak Energy	GWh	37.18	33.04	51.00	33.04	64.67	33.04	64.45	46.91	64.28	60.68
- Off-peak Energy	GWh	67.46	35.27	52.95	35.26	38.34	35.27	23.60	35.26	9.23	35.26
- Seasonal Total	GWh	104.64	68.31	103.95	68.30	103.01	68.31	88.05	82.17	73.51	95.94
- Annual Total	GWh	172.95		172.25		171.32		170.22		169.45	
KL-II											
- Peak Energy	GWh	20.09	18.27	27.49	18.27	34.79	18.27	34.66	25.69	34.58	33.05
- Off-peak Energy	GWh	38.06	20.39	30.25	20.39	22.02	20.39	13.60	20.39	5.27	20.39
- Seasonal Total	GWh	58.15	38.66	57.74	38.66	56.81	38.66	48.26	46.08	39.85	53.44
- Annual Total	GWh	96.81		96.40		95.47		94.34		93.29	
KL-III											
- Peak Energy	GWh	23.03	18.95	23.01	18.95	22.98	18.95	22.98	18.91	22.53	18.76
- Off-peak Energy	GWh	1.35	4.15	1.40	4.17	1.48	4.20	1.46	4.24	1.62	4.42
- Seasonal Total	GWh	24.38	23.10	24.41	23.12	24.46	23.15	24.44	23.15	24.15	23.18
- Annual Total	GWh	47.48		47.53		47.61		47.59		47.33	
ANNUAL BENEFIT											
KL-I & II (kWh-value: 9.0 Usc/kWh for primary, 4.0 Usc/kWh for secondary)											
(Dec.-May./Jun.-Nov.)											
Energy Benefit - Primary	M.US$	5.15		7.06		8.95		8.92		8.90	
- Secondary	M.US$	8.50		7.61		6.69		6.62		6.56	
- Total	M.US$	13.65		14.67		15.64		15.54		15.46	
KL-III (kW-value: 121US$/kW, kWh-value: 6.1 Usc/kWh for primary, 4.0 Usc/kWh for secondary)											
(Dec.-May./Jun.-Nov.)											
Power Benefit	M.US$	5.42		5.42		5.42		5.40		5.28	
Energy Benefit - Primary	M.US$	1.40		1.40		1.40		1.40		1.37	
- Secondary	M.US$	0.98		0.98		0.99		0.98		0.99	
- Total	M.US$	2.38		2.38		2.39		2.38		2.36	
Total Benefit	M.US$	7.80		7.80		7.81		7.78		7.64	
KL-SERIES											
Total Benefit	M.US$	21.45		22.47		23.45		23.32		23.10	

Table D2.3 Results of Reservoir Simulation (1/6) (KL-I Peak Output)

(Unit: MW)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Monthly Min.	Monthly Avg.	Monthly Max.	Dry Season (Dec./Mar.)	Wet Season (Apr./Nov.)
1963	59.92	59.95	59.62	46.17	40.22	39.23	29.87	41.38	44.99	60.00	60.00	59.95	29.87	50.11	60.00		
1964	59.92	59.94	59.66	39.42	32.84	39.24	40.13	44.54	60.00	60.00	60.00	59.94	32.84	51.30	60.00		
1965	59.92	59.95	59.65	49.67	58.77	39.35	53.55	60.00	60.00	60.00	60.00	59.95	39.35	56.73	60.00		
1966	59.92	59.94	59.65	30.98	34.19	26.05	31.47	47.75	60.00	60.00	60.00	59.94	26.05	49.16	60.00		
1967	59.91	59.95	59.43	24.84	24.68	39.63	41.22	60.00	60.00	60.00	60.00	59.94	24.68	50.80	60.00		
1968	59.93	59.93	59.78	48.67	43.08	39.27	40.05	41.15	41.70	53.57	60.00	59.94	39.27	50.59	60.00		
1969	59.92	59.95	59.47	24.83	38.40	32.53	0.00	20.71	21.20	21.36	21.42	59.93	0.00	34.98	59.95		
1970	59.92	59.88	22.04	19.86	19.99	32.80	46.87	60.00	60.00	60.00	60.00	59.94	19.86	46.77	60.00		
1971	59.92	59.95	59.61	45.33	58.93	53.64	59.93	60.00	60.00	60.00	60.00	59.95	45.33	58.10	60.00		
1972	59.93	59.94	59.79	58.50	48.96	39.37	43.75	59.96	60.00	60.00	60.00	59.94	39.37	55.84	60.00		
1973	59.92	59.95	59.84	48.72	44.88	39.86	60.00	60.00	60.00	60.00	60.00	59.96	39.86	56.09	60.00		
1974	59.91	59.93	59.62	46.58	40.46	39.12	35.06	44.47	60.00	60.00	60.00	59.94	35.06	52.09	60.00		
1975	59.92	59.95	59.57	24.83	33.77	39.11	40.21	60.00	60.00	60.00	60.00	59.94	24.83	51.44	60.00		
1976	59.92	59.95	59.60	35.06	44.85	40.05	60.00	41.64	48.04	60.00	60.00	59.94	35.06	52.42	60.00		
1977	59.92	59.95	59.61	44.35	49.06	39.27	39.74	20.60	20.85	20.97	21.07	59.91	20.60	41.28	59.95		
1978	60.00	50.55	28.58	39.10	58.03	47.86	44.23	59.98	60.00	60.00	60.00	59.95	28.58	52.36	60.00		
1979	59.93	59.93	59.79	58.46	48.32	39.39	40.50	60.00	59.99	52.12	55.99	59.95	39.39	54.53	60.00		
1980	59.92	59.95	59.63	39.33	28.11	40.05	60.00	60.00	58.66	60.00	52.12	59.94	28.11	53.14	60.00		
1981	59.92	59.95	59.57	32.87	45.69	26.03	22.10	20.52	20.98	21.40	21.46	59.93	20.52	37.54	59.95		
1982	59.91	59.98	43.47	19.52	21.34	32.81	39.65	20.52	21.14	0.00	21.45	59.93	0.00	33.31	59.98		
1983	59.90	59.96	30.93	13.02	50.59	39.14	26.91	41.34	47.91	59.99	59.86	59.94	13.02	45.79	59.99		
1984	59.92	59.95	59.46	14.90	20.94	39.10	37.39	40.98	33.99	60.00	59.01	59.95	14.90	45.46	60.00		
1985	59.91	59.95	59.52	6.50	43.45	54.05	40.22	40.70	51.60	60.00	60.00	59.95	6.50	49.65	60.00		
1986	59.92	59.93	59.62	42.67	53.28	59.27	40.72	44.71	60.00	60.00	60.00	59.95	40.72	55.01	60.00		
1987	59.92	59.95	59.68	45.24	27.08	19.52	12.79	60.00	60.00	60.00	60.00	59.94	12.79	48.68	60.00		
1988	59.92	59.95	59.69	35.98	46.20	39.48	40.46	41.44	60.00	60.00	56.51	59.95	35.98	51.63	60.00		
1989	59.93	59.92	59.55	19.86	26.12	43.01	40.60	41.78	57.30	60.00	59.26	59.93	19.86	48.94	60.00		
1990	59.92	59.97	59.48	29.79	43.75	39.30	40.55	44.76	60.00	60.00	57.95	59.94	29.79	51.28	60.00		
1991	59.93	59.95	59.59	41.20	28.13	39.20	39.93	20.82	41.86	43.76	50.70	59.94	20.82	45.42	59.95		
1992	59.92	59.95	49.55	13.01	39.33	39.07	15.83	20.57	20.84	20.97	21.04	59.93	13.01	35.00	59.95		
1993	59.67	10.75	7.84	19.88	52.85	39.56	47.08	59.95	42.00	60.00	58.01	59.93	7.84	43.13	60.00		
1994	59.94	59.94	59.67	49.90	57.13	39.25	39.71	20.58	21.03	21.30	21.35	59.94	20.58	42.48	59.94		
1995	59.91	60.00	46.61	29.79	33.08	33.12	41.15	60.00	60.00	60.00	60.00	59.97	29.79	50.30	60.00		
Min.	59.67	10.75	7.84	6.50	19.99	19.52	0.00	20.52	20.84	0.00	21.04	59.91	0.00	33.31	59.94		
Avg.	59.91	58.17	53.91	34.51	40.50	39.02	39.14	44.87	48.91	51.38	52.04	59.94	25.28	48.53	59.99		
Max.	60.00	60.00	59.84	58.50	58.93	59.27	60.00	60.00	60.00	60.00	60.00	59.97	45.33	58.10	60.00		
90% Dependable																59.22	20.93

Table D2.3 Results of Reservoir Simulation (2/6) (KL-I Off-peak Output)

(Unit: MW)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Monthly Min.	Monthly Avg.	Monthly Max.	Dry Season (Dec./Mar.)	Wet Season (Apr./Nov.)
1963	20.11	18.48	17.62	0.00	0.00	0.00	0.00	0.00	9.13	17.51	12.50	20.93	0.00	9.69	20.93		
1964	23.47	21.64	19.45	0.00	0.00	0.00	0.00	10.00	60.00	24.31	12.50	20.91	0.00	16.02	60.00		
1965	21.06	19.90	19.86	0.00	0.00	0.00	18.45	56.97	32.63	13.03	14.61	20.93	0.00	18.12	56.97		
1966	23.49	22.66	20.91	0.00	0.00	0.00	0.00	20.00	44.40	15.03	12.50	20.93	0.00	14.99	44.40		
1967	22.95	18.47	16.62	0.00	0.00	0.00	0.00	19.44	32.32	14.80	12.50	20.92	0.00	13.17	32.32		
1968	22.76	23.82	20.04	9.70	0.00	0.00	0.00	0.00	0.00	16.50	12.50	20.91	0.00	10.52	23.82		
1969	20.71	18.48	16.63	0.00	0.00	0.00	11.72	0.00	0.00	0.00	0.00	20.53	0.00	7.34	20.71		
1970	19.27	17.63	10.99	0.00	0.00	0.00	12.08	53.61	29.18	14.78	12.50	20.91	0.00	15.91	53.61		
1971	20.72	18.48	17.93	0.00	11.71	15.57	59.93	17.03	21.99	20.64	12.50	20.94	0.00	19.79	59.93		
1972	24.58	24.36	22.99	11.65	0.00	0.00	10.00	46.48	28.51	13.05	12.50	20.91	0.00	17.92	46.48		
1973	21.78	20.62	19.44	9.70	0.00	0.00	18.96	18.64	48.30	47.09	27.85	21.05	0.00	21.12	48.30		
1974	33.00	23.07	20.17	0.00	0.00	0.00	0.00	10.00	51.18	16.26	12.50	20.91	0.00	15.59	51.18		
1975	21.00	19.60	18.60	0.00	0.00	0.00	0.00	47.12	53.60	24.92	12.50	20.92	0.00	18.19	53.60		
1976	22.63	21.30	18.27	0.00	0.00	0.00	12.23	0.00	4.17	12.50	12.50	20.90	0.00	10.38	22.63		
1977	20.49	19.56	19.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.52	0.00	6.56	20.49		
1978	17.64	11.75	0.00	0.00	0.00	0.00	8.43	51.19	21.29	21.89	12.50	20.94	0.00	13.80	51.19		
1979	26.23	26.31	24.51	11.64	0.00	0.00	0.00	12.61	13.24	0.00	0.00	20.94	0.00	11.29	26.31		
1980	23.04	20.32	18.23	0.00	0.00	0.00	12.17	12.40	18.62	12.50	0.00	20.89	0.00	11.52	23.04		
1981	20.10	18.47	17.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.67	0.00	6.40	20.67		
1982	19.73	17.86	8.81	0.00	0.00	0.00	0.00	0.00	0.00	12.43	0.00	20.64	0.00	6.62	20.64		
1983	19.64	17.63	9.73	0.00	0.00	0.00	0.00	0.00	11.17	23.36	12.56	20.91	0.00	9.58	23.36		
1984	21.46	18.48	16.62	0.00	0.00	0.00	0.00	0.00	10.00	23.58	8.34	20.92	0.00	9.95	23.58		
1985	23.16	18.47	16.63	0.00	0.00	0.00	0.00	0.00	28.50	42.65	12.50	20.94	0.00	13.57	42.65		
1986	29.20	24.57	21.05	0.00	0.00	11.75	0.00	10.00	49.97	26.71	12.50	20.94	0.00	17.23	49.97		
1987	25.43	21.87	20.10	0.00	0.00	0.00	0.00	33.19	28.84	27.83	12.50	20.92	0.00	15.89	33.19		
1988	21.99	21.02	17.63	0.00	0.00	0.00	0.00	0.00	35.12	12.87	6.25	20.91	0.00	11.32	35.12		
1989	25.04	28.48	18.12	0.00	0.00	0.00	0.00	0.00	13.68	17.35	10.42	20.87	0.00	11.16	28.48		
1990	20.04	18.19	16.76	0.00	0.00	0.00	0.00	10.00	41.99	15.82	10.42	20.91	0.00	12.84	41.99		
1991	21.65	22.34	17.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.88	0.00	6.87	22.34		
1992	20.09	18.45	16.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.86	0.00	6.14	20.09		
1993	17.62	3.86	5.80	0.00	0.00	0.00	12.08	47.65	0.00	12.50	0.00	20.88	0.00	10.03	47.65		
1994	20.12	23.19	22.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.42	0.00	7.20	23.19		
1995	19.58	17.64	10.75	0.00	0.00	0.00	0.00	12.41	22.49	12.50	59.31	38.93	0.00	16.13	59.31		
Min.	17.62	3.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.86	0.00	6.14	20.09		
Avg.	22.11	19.91	16.90	1.29	0.35	0.83	5.34	14.81	21.53	15.53	10.22	21.32	0.00	12.51	36.61		
Max.	33.00	28.48	24.51	11.65	11.71	15.57	59.93	56.97	60.00	47.09	59.31	38.93	0.00	21.12	60.00		
90% Dependable																17.62	0.00

Table D2.3 Results of Reservoir Simulation (3/6) (KL-I Energy)

(Unit: GWh)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Monthly Min.	Monthly Avg.	Monthly Max.	Annual
1963	24.04	23.26	22.77	5.54	4.83	4.71	3.58	4.97	10.88	16.40	9.74	24.43	3.58	12.93	24.43	155.13
1964	25.65	24.77	23.65	4.73	3.94	4.71	4.82	11.34	43.20	21.05	8.20	24.42	3.94	16.71	43.20	200.49
1965	24.49	23.94	23.85	5.96	7.05	4.72	17.50	41.38	26.78	14.53	13.09	24.43	4.72	18.98	41.38	227.72
1966	25.66	25.26	24.35	3.72	4.10	3.13	3.78	17.73	33.84	15.47	9.87	24.43	3.13	15.94	33.84	191.34
1967	25.39	23.25	21.71	2.98	2.96	4.76	4.95	18.86	26.59	15.51	10.47	24.43	2.96	15.15	26.59	181.86
1968	25.31	25.82	23.97	6.28	5.17	4.71	4.81	4.94	5.00	16.13	10.19	24.42	4.71	13.06	25.82	156.74
1969	24.32	23.26	21.95	2.98	4.61	3.90	1.18	2.49	2.54	2.56	2.57	24.24	1.18	9.72	24.32	116.60
1970	23.63	22.84	8.93	2.38	2.40	3.94	11.91	39.36	24.71	15.25	9.79	24.42	2.38	15.80	39.36	189.56
1971	24.33	23.26	22.91	5.44	8.11	15.78	43.15	14.72	20.36	17.01	10.00	24.44	5.44	19.12	43.15	229.50
1972	26.18	26.08	25.38	7.46	5.88	4.72	11.25	35.09	24.06	11.35	8.23	24.43	4.72	17.51	35.09	210.10
1973	24.84	24.29	23.69	6.94	5.39	4.78	18.58	15.84	36.18	35.45	23.91	24.49	4.78	20.36	36.18	244.37
1974	30.22	25.46	23.99	5.59	4.85	4.69	4.21	11.34	37.91	16.29	8.76	24.42	4.21	16.48	37.91	197.73
1975	24.46	23.79	23.23	2.98	4.05	4.69	4.83	35.47	39.36	22.15	10.57	24.43	2.98	18.33	39.36	220.01
1976	25.24	24.61	23.07	4.21	5.38	4.81	10.56	5.00	7.78	10.42	7.78	24.42	4.21	12.77	25.24	153.28
1977	24.21	23.78	23.52	5.32	5.89	4.71	4.77	2.47	2.50	2.52	2.53	23.75	2.47	10.50	24.21	125.97
1978	22.87	17.77	6.86	4.69	6.96	5.74	10.37	37.91	18.28	19.61	9.89	24.44	4.69	15.45	37.91	185.40
1979	26.97	27.01	26.12	7.31	5.80	4.73	4.86	10.07	15.06	6.25	6.72	24.44	4.73	13.78	27.01	165.33
1980	25.44	24.14	23.06	4.72	3.37	4.81	8.70	8.61	17.01	8.03	6.25	24.41	3.37	13.21	25.44	158.57
1981	24.03	23.26	22.75	3.94	5.48	3.12	2.65	2.46	2.52	2.57	2.57	24.30	2.46	9.97	24.30	119.67
1982	23.85	22.97	14.66	2.34	2.56	3.94	4.76	2.46	2.54	0.95	2.57	24.29	0.95	8.99	24.29	107.89
1983	23.80	22.85	10.67	1.56	6.07	4.70	3.23	4.96	12.45	19.48	13.21	24.42	1.56	12.28	24.42	147.42
1984	24.68	23.26	21.46	1.79	2.51	4.69	4.49	4.92	10.08	19.40	8.56	24.43	1.79	12.52	24.68	150.27
1985	25.50	23.25	21.98	0.78	5.21	6.49	4.83	4.88	23.29	32.58	11.68	24.44	0.78	15.41	32.58	184.91
1986	28.40	26.18	24.41	5.12	6.39	8.11	4.89	11.37	37.18	23.05	10.38	24.44	4.89	17.49	37.18	209.91
1987	26.58	24.88	23.97	5.43	3.25	2.34	1.54	26.87	24.50	23.13	11.54	24.43	1.54	16.54	26.87	198.46
1988	24.94	24.48	22.79	4.32	5.54	4.74	4.86	4.97	28.27	12.25	7.48	24.42	4.32	14.09	28.27	169.06
1989	26.40	28.05	22.99	2.38	3.13	5.16	4.87	5.01	15.09	15.63	8.96	24.40	2.38	13.51	28.05	162.09
1990	24.00	23.12	22.32	3.57	5.25	4.72	4.87	11.37	32.39	15.43	8.37	24.42	3.57	14.99	32.39	179.84
1991	24.78	25.11	22.76	4.94	3.38	4.70	4.79	2.50	5.02	5.25	6.08	24.41	2.50	11.14	25.11	133.73
1992	24.03	23.25	18.90	1.56	4.72	4.69	1.90	2.47	2.50	2.52	2.52	23.44	1.56	9.37	24.03	112.49
1993	22.78	3.29	2.80	2.39	6.34	4.75	12.01	35.78	5.04	10.22	6.96	24.41	2.39	11.40	35.78	136.75
1994	24.05	25.51	25.21	5.99	6.86	4.71	4.76	2.47	2.52	2.56	2.56	24.19	2.47	10.95	25.51	131.39
1995	23.78	22.87	16.18	3.58	3.97	3.97	4.94	13.01	20.69	11.14	42.79	33.08	3.58	16.67	42.79	200.00
Min.	22.78	3.29	2.80	0.78	2.40	2.34	1.18	2.46	2.50	0.95	2.52	23.44	0.78	8.99	24.03	107.89
Avg.	24.99	23.48	20.81	4.21	4.89	5.00	7.37	13.73	18.67	14.00	9.54	24.62	3.18	14.28	31.11	**171.32**
Max.	30.22	28.05	26.12	7.46	8.11	15.78	43.15	41.38	43.20	35.45	42.79	33.08	5.44	20.36	43.20	244.37

Table D2.3 Results of Reservoir Simulation (4/6) (KL-II Peak Output)

(Unit: MW)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Monthly Min.	Monthly Avg.	Monthly Max.	Dry Season (Dec./Mar.)	Wet Season (Apr./Nov.)
1963	32.00	32.00	32.00	26.06	22.17	22.92	17.55	23.70	25.08	32.00	32.00	31.94	17.55	27.45	32.00		
1964	32.00	32.00	32.00	22.24	18.04	22.00	23.63	25.08	32.00	32.00	31.94	31.83	18.04	27.90	32.00		
1965	32.00	32.00	32.00	27.83	32.00	22.27	29.23	32.00	32.00	32.00	32.00	32.00	22.27	30.61	32.00		
1966	32.00	32.00	32.00	17.49	18.91	14.74	18.25	26.47	32.00	32.00	31.98	31.92	14.74	26.65	32.00		
1967	32.00	32.00	32.00	13.62	13.73	22.31	23.46	32.00	32.00	32.00	31.83	31.72	13.62	27.39	32.00		
1968	31.97	32.00	32.00	26.67	23.87	23.15	23.70	23.70	23.68	29.03	32.00	32.00	23.15	27.81	32.00		
1969	32.00	32.00	32.00	13.56	21.38	18.55	0.00	13.62	13.62	13.78	12.78	32.00	0.00	19.61	32.00		
1970	32.00	32.00	12.13	11.52	10.96	18.99	26.40	32.00	32.00	32.00	32.00	32.00	10.96	25.33	32.00		
1971	32.00	32.00	32.00	25.72	32.00	29.83	32.00	32.00	32.00	32.00	32.00	32.00	25.72	31.30	32.00		
1972	32.00	32.00	32.00	32.00	27.11	22.04	24.40	32.00	32.00	32.00	32.00	31.99	22.04	30.13	32.00		
1973	32.00	32.00	32.00	26.67	24.84	23.00	32.00	32.00	32.00	32.00	32.00	32.00	23.00	30.21	32.00		
1974	32.00	32.00	32.00	26.39	22.47	22.19	20.85	25.08	32.00	32.00	32.00	32.00	20.85	28.42	32.00		
1975	32.00	32.00	32.00	14.00	18.71	22.62	23.70	32.00	32.00	32.00	31.97	31.92	14.00	27.91	32.00		
1976	32.00	32.00	32.00	19.80	25.07	22.49	32.00	23.70	26.47	32.00	31.99	31.94	19.80	28.45	32.00		
1977	32.00	32.00	32.00	25.18	27.38	22.22	23.70	13.62	13.62	13.88	13.35	32.00	13.35	23.41	32.00		
1978	32.00	27.78	16.85	22.82	32.00	27.83	25.08	32.00	32.00	32.00	32.00	32.00	16.85	28.70	32.00		
1979	32.00	32.00	32.00	32.00	26.69	22.06	23.55	32.00	32.00	28.81	30.02	32.00	22.06	29.59	32.00		
1980	32.00	32.00	32.00	22.17	15.59	23.08	32.00	32.00	31.46	32.00	28.24	32.00	15.59	28.71	32.00		
1981	32.00	32.00	32.00	18.57	25.88	14.97	14.70	13.62	13.62	14.10	13.26	32.00	13.26	21.39	32.00		
1982	32.00	32.00	24.16	11.33	11.97	18.34	23.30	13.62	13.62	0.00	12.97	32.00	0.00	18.78	32.00		
1983	32.00	32.00	17.18	7.43	28.42	21.88	17.02	23.70	26.47	32.00	31.77	31.80	7.43	25.14	32.00		
1984	31.99	32.00	32.00	8.56	11.60	22.48	21.95	23.67	19.55	32.00	31.40	31.81	8.56	24.92	32.00		
1985	31.97	32.00	32.00	3.65	24.04	30.60	23.68	23.61	27.87	32.00	31.96	31.87	3.65	27.11	32.00		
1986	31.96	32.00	32.00	23.77	29.40	32.00	23.19	24.84	32.00	32.00	31.85	31.77	23.19	29.73	32.00		
1987	31.99	32.00	32.00	25.51	14.85	10.75	8.70	32.00	32.00	32.00	31.95	31.79	8.70	26.30	32.00		
1988	31.82	31.99	32.00	20.12	25.74	22.80	23.60	23.70	32.00	32.00	30.15	31.93	20.12	28.15	32.00		
1989	32.00	32.00	32.00	11.32	14.45	24.70	23.70	23.70	31.04	32.00	31.57	31.98	11.32	26.70	32.00		
1990	32.00	32.00	32.00	16.24	24.77	23.25	23.63	25.08	32.00	32.00	30.93	31.77	16.24	27.97	32.00		
1991	31.86	32.00	32.00	23.15	15.57	22.28	23.48	13.61	23.64	23.99	27.14	31.92	13.61	25.05	32.00		
1992	32.00	32.00	26.67	7.39	21.86	22.17	10.63	13.49	13.40	12.94	12.33	32.00	7.39	19.74	32.00		
1993	32.00	6.13	4.64	10.93	29.60	21.86	26.06	31.89	23.70	32.00	30.99	31.86	4.64	23.47	32.00		
1994	31.99	32.00	32.00	27.25	31.69	22.61	22.36	13.45	13.29	12.71	12.44	31.98	12.44	23.65	32.00		
1995	32.00	32.00	25.52	17.11	18.61	18.72	22.19	31.81	32.00	32.00	32.00	31.87	17.11	27.15	32.00		
Min.	31.82	6.13	4.64	3.65	10.96	10.75	0.00	13.45	13.29	0.00	12.33	31.72	0.00	18.78	32.00		
Avg.	31.99	31.09	29.06	19.33	22.47	22.17	22.42	25.05	26.79	27.79	28.02	31.93	14.58	26.51	32.00		
Max.	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	25.72	31.30	32.00		
90% Dependable																31.85	13.54

Table D2.3 Results of Reservoir Simulation (5/6) (KL-II Off-peak Output)

(Unit: MW)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Monthly Min.	Monthly Avg.	Monthly Max.	Dry Season (Dec./Mar.)	Wet Season (Apr./Nov.)
1963	11.48	10.64	10.27	0.00	0.00	0.00	0.00	0.00	5.02	11.39	7.95	11.97	0.00	5.73	11.97		
1964	13.39	12.42	11.29	0.00	0.00	0.00	0.00	5.33	32.00	15.25	7.65	11.80	0.00	9.10	32.00		
1965	11.96	11.44	11.69	0.00	0.00	0.00	10.90	30.58	19.00	9.33	9.54	12.10	0.00	10.55	30.58		
1966	13.47	13.06	12.22	0.00	0.00	0.00	0.00	10.67	24.88	9.76	7.57	11.95	0.00	8.63	24.88		
1967	13.10	10.59	9.81	0.00	0.00	0.00	0.00	12.50	18.34	9.64	7.32	11.67	0.00	7.75	18.34		
1968	12.79	13.47	11.44	5.46	0.00	0.00	0.00	0.00	0.00	10.68	8.22	12.24	0.00	6.19	13.47		
1969	12.07	10.74	9.83	0.00	0.00	0.00	8.64	0.00	0.00	0.00	0.00	11.89	0.00	4.43	12.07		
1970	11.13	10.34	6.47	0.00	0.00	0.00	6.77	29.29	17.09	10.45	8.13	12.12	0.00	9.32	29.29		
1971	11.78	10.52	10.35	0.00	7.89	9.03	32.00	10.96	13.38	13.07	8.03	12.16	0.00	11.60	32.00		
1972	14.10	14.08	13.43	6.81	0.00	0.00	5.33	25.78	16.51	9.28	7.90	12.04	0.00	10.44	25.78		
1973	12.52	11.89	11.29	5.43	0.00	0.00	12.43	11.54	26.28	26.11	16.63	12.57	0.00	12.23	26.28		
1974	17.70	13.47	11.91	0.00	0.00	0.00	0.00	5.33	27.83	11.02	7.88	12.34	0.00	8.96	27.83		
1975	12.20	11.39	10.87	0.00	0.00	0.00	0.00	26.05	29.14	14.97	7.57	11.95	0.00	10.34	29.14		
1976	12.95	12.25	10.62	0.00	0.00	0.00	8.64	0.00	2.88	8.64	7.65	11.94	0.00	6.30	12.95		
1977	11.65	11.19	11.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.79	0.00	3.81	11.79		
1978	10.58	7.07	0.00	0.00	0.00	0.00	4.68	27.90	13.26	13.63	8.19	12.28	0.00	8.13	27.90		
1979	14.88	15.11	14.21	6.85	0.00	0.00	0.00	8.75	8.95	0.00	0.00	12.13	0.00	6.74	15.11		
1980	13.23	11.74	10.69	0.00	0.00	0.00	8.53	8.64	11.46	9.02	0.00	12.15	0.00	7.12	13.23		
1981	11.65	10.65	10.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.25	0.00	3.73	12.25		
1982	11.63	10.64	5.35	0.00	0.00	0.00	0.00	0.00	0.00	9.04	0.00	12.15	0.00	4.07	12.15		
1983	11.50	10.48	5.91	0.00	0.00	0.00	0.00	0.00	6.20	13.84	7.32	11.76	0.00	5.58	13.84		
1984	12.18	10.56	9.69	0.00	0.00	0.00	0.00	0.00	5.33	13.82	4.98	11.79	0.00	5.70	13.82		
1985	13.14	10.61	9.61	0.00	0.00	0.00	0.00	0.00	15.66	23.65	7.60	11.90	0.00	7.68	23.65		
1986	16.26	13.93	11.82	0.00	0.00	5.81	0.00	5.33	27.31	15.35	7.35	11.75	0.00	9.58	27.31		
1987	14.33	12.35	11.09	0.00	0.00	0.00	0.00	19.03	16.99	16.78	7.77	11.76	0.00	9.18	19.03		
1988	12.03	11.40	9.74	0.00	0.00	0.00	0.00	0.00	20.15	8.70	3.83	12.06	0.00	6.49	20.15		
1989	14.43	16.29	10.53	0.00	0.00	0.00	0.00	0.00	8.20	11.60	6.62	12.12	0.00	6.65	16.29		
1990	11.61	10.95	10.07	0.00	0.00	0.00	0.00	5.33	23.55	10.82	6.40	11.73	0.00	7.54	23.55		
1991	11.96	12.50	10.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.93	0.00	3.88	12.50		
1992	11.37	10.60	9.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.79	0.00	3.53	11.37		
1993	10.21	2.28	3.44	0.00	0.00	0.00	6.77	25.91	0.00	8.46	0.00	11.81	0.00	5.74	25.91		
1994	11.47	12.96	12.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.49	0.00	4.04	12.96		
1995	11.13	10.15	6.22	0.00	0.00	0.00	0.00	6.81	13.85	8.68	31.67	21.12	0.00	9.14	31.67		
Min.	10.21	2.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.79	0.00	3.53	11.37		
Avg.	12.60	11.45	9.81	0.74	0.24	0.45	3.17	8.36	12.22	9.79	6.17	12.23	0.00	7.27	20.34		
Max.	17.70	16.29	14.21	6.85	7.89	9.03	32.00	30.58	32.00	26.11	31.67	21.12	0.00	12.23	32.00		
90% Dependable																10.16	0.00

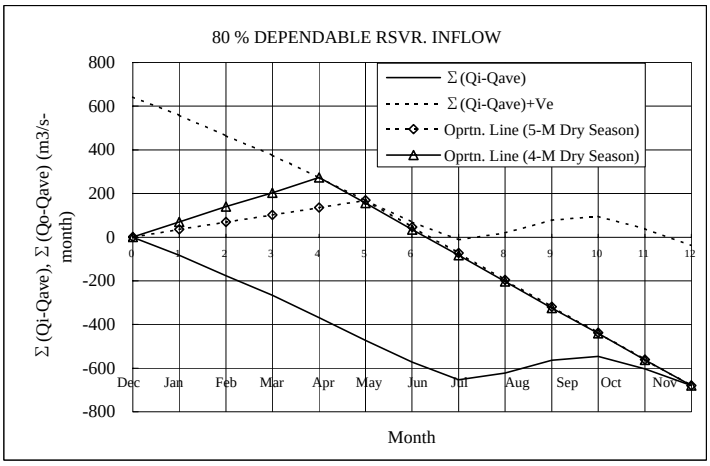
Table D2.3 Results of Reservoir Simulation (6/6) (KL-II Energy)

(Unit: GWh)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Monthly Min.	Monthly Avg.	Monthly Max.	Annual
1963	13.19	12.79	12.61	3.13	2.66	2.75	2.11	2.84	6.02	9.79	5.48	13.41	2.11	7.23	13.41	86.77
1964	14.11	13.64	13.10	2.67	2.17	2.64	2.84	6.21	23.04	12.46	4.47	13.31	2.17	9.22	23.04	110.64
1965	13.42	13.17	13.29	3.34	3.84	2.67	10.05	22.19	15.24	9.09	7.69	13.49	2.67	10.62	22.19	127.48
1966	14.14	13.95	13.54	2.10	2.27	1.77	2.19	9.58	18.77	9.22	5.46	13.40	1.77	8.87	18.77	106.39
1967	13.97	12.76	12.07	1.63	1.65	2.68	2.81	11.34	14.84	9.27	5.74	13.21	1.63	8.50	14.84	101.97
1968	13.81	14.15	13.17	3.45	2.86	2.78	2.84	2.84	2.84	9.75	5.83	13.56	2.78	7.32	14.15	87.89
1969	13.47	12.83	12.21	1.63	2.57	2.23	0.87	1.63	1.63	1.65	1.53	13.39	0.87	5.47	13.47	65.66
1970	13.02	12.64	5.06	1.38	1.32	2.28	6.57	21.41	14.09	9.52	5.55	13.50	1.32	8.86	21.41	106.33
1971	13.34	12.73	12.65	3.09	4.54	9.00	23.04	8.53	11.85	9.81	5.65	13.51	3.09	10.64	23.04	127.73
1972	14.45	14.44	14.13	4.10	3.25	2.64	6.13	19.31	13.58	6.80	4.49	13.46	2.64	9.73	19.31	116.77
1973	13.69	13.38	13.10	3.81	2.98	2.76	11.30	8.99	19.61	19.51	13.82	13.71	2.76	11.39	19.61	136.67
1974	16.17	14.15	13.40	3.17	2.70	2.66	2.50	6.21	20.54	10.01	4.83	13.60	2.50	9.16	20.54	109.94
1975	13.53	13.15	12.90	1.68	2.25	2.71	2.84	19.47	21.32	12.82	5.89	13.40	1.68	10.16	21.32	121.95
1976	13.90	13.56	12.78	2.38	3.01	2.70	6.21	2.84	4.57	6.11	4.20	13.40	2.38	7.14	13.90	85.65
1977	13.27	13.05	13.01	3.02	3.29	2.67	2.84	1.63	1.63	1.67	1.60	13.34	1.60	5.92	13.34	71.03
1978	12.76	10.06	4.04	2.74	3.84	3.34	5.82	20.58	10.63	11.52	5.62	13.58	2.74	8.71	20.58	104.52
1979	14.82	14.93	14.50	4.01	3.20	2.65	2.83	5.82	9.15	3.46	3.60	13.50	2.65	7.71	14.93	92.48
1980	14.03	13.32	12.81	2.66	1.87	2.77	4.89	4.83	9.82	4.45	3.39	13.51	1.87	7.36	14.03	88.35
1981	13.27	12.79	12.60	2.23	3.11	1.80	1.76	1.63	1.63	1.69	1.59	13.56	1.59	5.64	13.56	67.68
1982	13.26	12.79	8.37	1.36	1.44	2.20	2.80	1.63	1.63	0.69	1.56	13.51	0.69	5.10	13.51	61.24
1983	13.20	12.71	6.09	0.89	3.41	2.63	2.04	2.84	6.89	11.02	7.33	13.28	0.89	6.86	13.28	82.33
1984	13.53	12.75	11.87	1.03	1.39	2.70	2.63	2.84	5.55	10.88	4.65	13.29	1.03	6.93	13.53	83.11
1985	13.98	12.77	12.12	0.44	2.89	3.67	2.84	2.83	12.74	17.89	6.56	13.36	0.44	8.51	17.89	102.10
1986	15.47	14.36	13.35	2.85	3.53	4.33	2.78	6.18	20.23	12.94	5.70	13.26	2.78	9.58	20.23	115.00
1987	14.56	13.61	13.00	3.06	1.78	1.29	1.04	15.08	14.03	13.35	6.56	13.27	1.04	9.22	15.08	110.65
1988	13.41	13.15	12.36	2.41	3.09	2.74	2.83	2.84	15.93	7.34	4.05	13.45	2.41	7.80	15.93	93.60
1989	14.61	15.50	12.74	1.36	1.73	2.96	2.84	2.84	8.65	9.38	4.94	13.49	1.36	7.59	15.50	91.04
1990	13.25	12.94	12.51	1.95	2.97	2.79	2.84	6.21	17.97	9.44	4.59	13.25	1.95	8.39	17.97	100.71
1991	13.39	13.68	12.58	2.78	1.87	2.67	2.82	1.63	2.84	2.88	3.26	13.39	1.63	6.15	13.68	73.79
1992	13.14	12.77	10.55	0.89	2.62	2.66	1.28	1.62	1.61	1.55	1.48	12.86	0.89	5.25	13.14	63.01
1993	12.58	1.89	1.66	1.31	3.55	2.62	6.58	19.38	2.84	5.91	3.72	13.32	1.31	6.28	19.38	75.35
1994	13.18	13.90	13.73	3.27	3.80	2.71	2.68	1.61	1.59	1.52	1.49	13.19	1.49	6.06	13.90	72.70
1995	13.02	12.55	9.01	2.05	2.23	2.25	2.66	7.01	12.15	6.58	22.84	17.78	2.05	9.18	22.84	110.16
Min.	12.58	1.89	1.66	0.44	1.32	1.29	0.87	1.61	1.59	0.69	1.48	12.86	0.44	5.10	13.14	61.24
Avg.	13.73	12.93	11.54	2.36	2.72	2.84	4.22	7.65	10.47	8.18	5.31	13.53	1.84	7.96	17.01	**95.48**
Max.	16.17	15.50	14.50	4.10	4.54	9.00	23.04	22.19	23.04	19.51	22.84	17.78	3.09	11.39	23.04	136.67

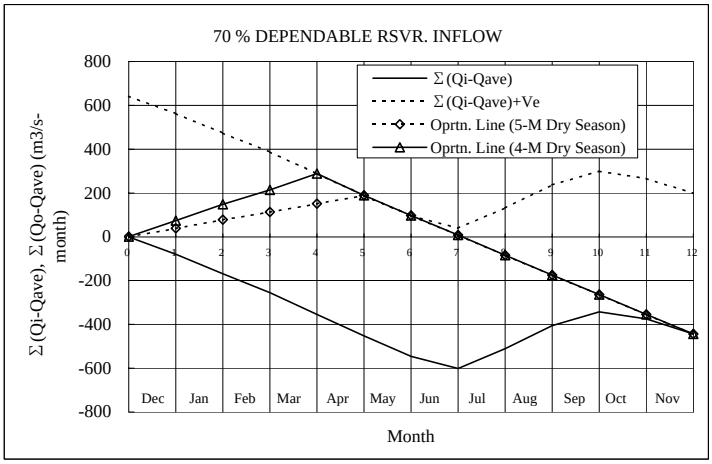
FIGURES

Appendix D



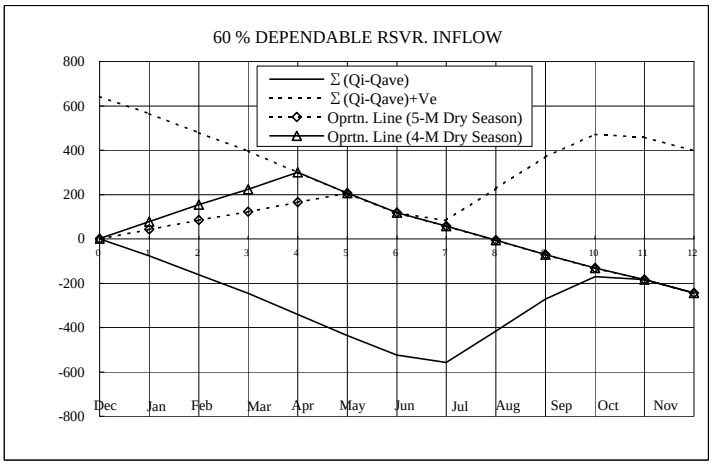
		Dry Season: 5M		Dry Season: 4M	
Month (End of)	Qi (m3/s-d)	Qo (m3/s-d)	Target V. (M.m3)	Qo (m3/s-d)	Target V. (M.m3)
Nov.	-	-	55.51	-	55.51
Dec.	1.64	**5.43**	**45.23**	**6.58**	**42.26**
Jan.	1.30	**5.43**	**34.16**	**6.58**	**28.13**
Feb	1.12	**5.43**	**23.73**	**6.58**	**14.93**
Mar	1.00	**5.43**	**11.85**	**6.58**	**0.00**
Apr	0.86	**5.43**	**0.00**	0.42	1.15
May	1.12	0.35	2.06	0.42	3.04
Jun	1.62	0.35	5.35	0.42	6.17
Jul	5.30	0.35	18.60	0.42	19.25
Aug	6.24	0.35	34.36	0.42	34.85
Sep	4.88	0.35	46.10	0.42	46.42
Oct	2.50	0.35	51.85	0.42	52.01
Nov	1.78	0.35	55.51	0.42	55.51

Qi: Dependable Rsvr. Inflow
Qo: Seasonal Power Discharge



		Dry Season: 5M		Dry Season: 4M	
Month (End of)	Qi (m3/s-d)	Qo (m3/s-d)	Target V. (M.m3)	Qo (m3/s-d)	Target V. (M.m3)
Nov.	-	-	55.51	-	55.51
Dec.	1.75	**5.58**	**45.25**	**6.70**	**42.22**
Jan.	1.44	**5.58**	**34.18**	**6.70**	**28.13**
Feb	1.25	**5.58**	**23.71**	**6.70**	**14.95**
Mar	1.12	**5.58**	**11.78**	**6.70**	**0.00**
Apr	1.03	**5.58**	**0.00**	1.37	0.00
May	1.32	1.37	0.00	1.37	0.00
Jun	2.46	1.37	2.83	1.37	2.83
Jul	7.26	1.37	18.61	1.37	18.61
Aug	7.73	1.37	35.65	1.37	35.65
Sep	6.40	1.37	48.70	1.37	48.70
Oct	3.26	1.37	53.76	1.37	53.76
Nov	2.05	1.37	55.51	1.37	55.51

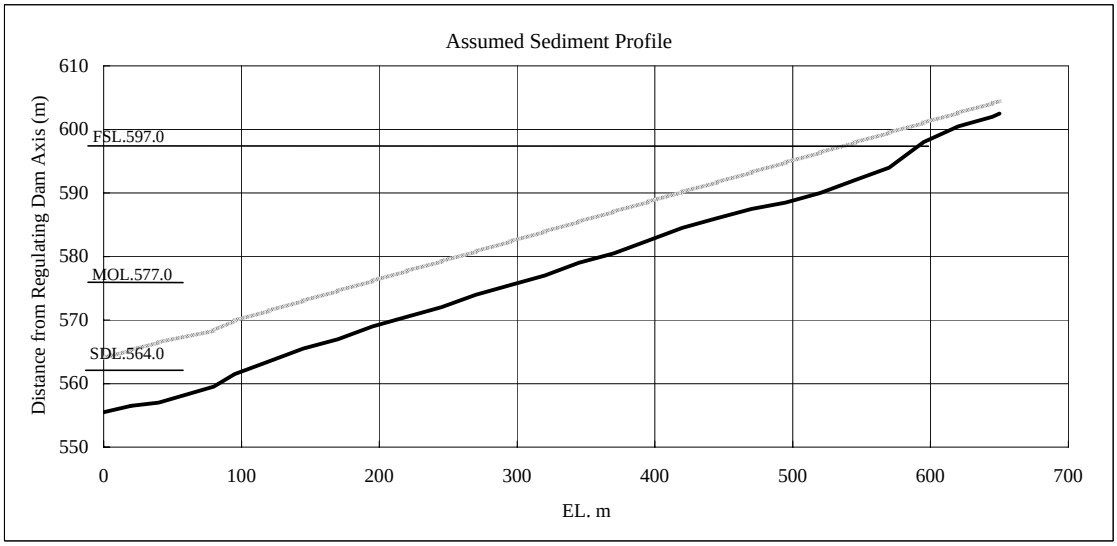
Qi: Dependable Rsvr. Inflow
Qo: Seasonal Power Discharge

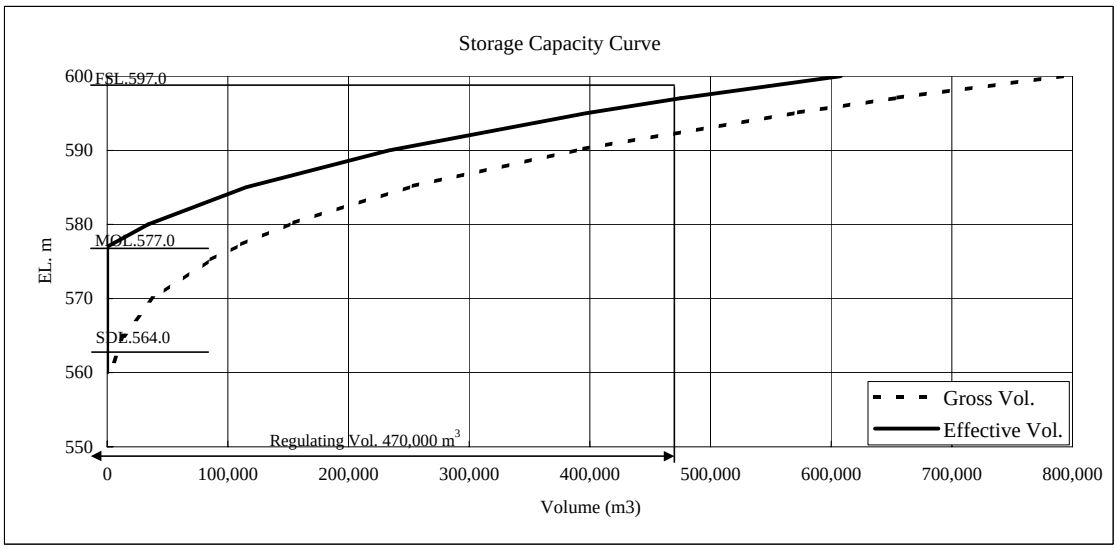


		Dry Season: 5M		Dry Season: 4M	
Month (End of)	Qi (m3/s-d)	Qo (m3/s-d)	Target V. (M.m3)	Qo (m3/s-d)	Target V. (M.m3)
Nov.	-	-	55.51	-	55.51
Dec.	1.85	**5.68**	**45.18**	**6.80**	**42.17**
Jan.	1.55	**5.68**	**34.11**	**6.80**	**28.10**
Feb	1.35	**5.68**	**23.63**	**6.80**	**14.92**
Mar	1.23	**5.68**	**11.70**	**6.80**	**0.00**
Apr	1.17	**5.68**	**0.00**	2.27	0.00
May	1.49	2.27	0.00	2.27	0.00
Jun	3.17	2.27	2.34	2.27	2.34
Jul	8.91	2.27	20.13	2.27	20.13
Aug	8.99	2.27	38.14	2.27	38.14
Sep	7.68	2.27	52.17	2.27	52.17
Oct	3.91	2.27	55.51	2.27	55.51
Nov	2.27	2.27	55.51	2.27	55.51

Qi: Dependable Rsvr. Inflow
Qo: Seasonal Power Discharge

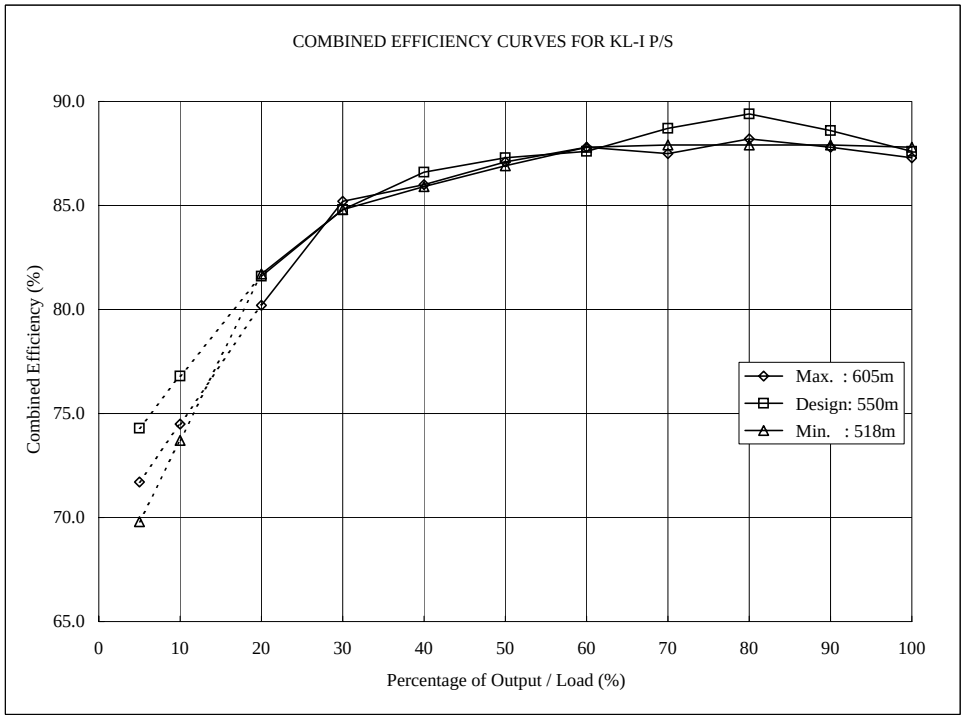
Figure D1.1 Results of Mass Curve Analysis

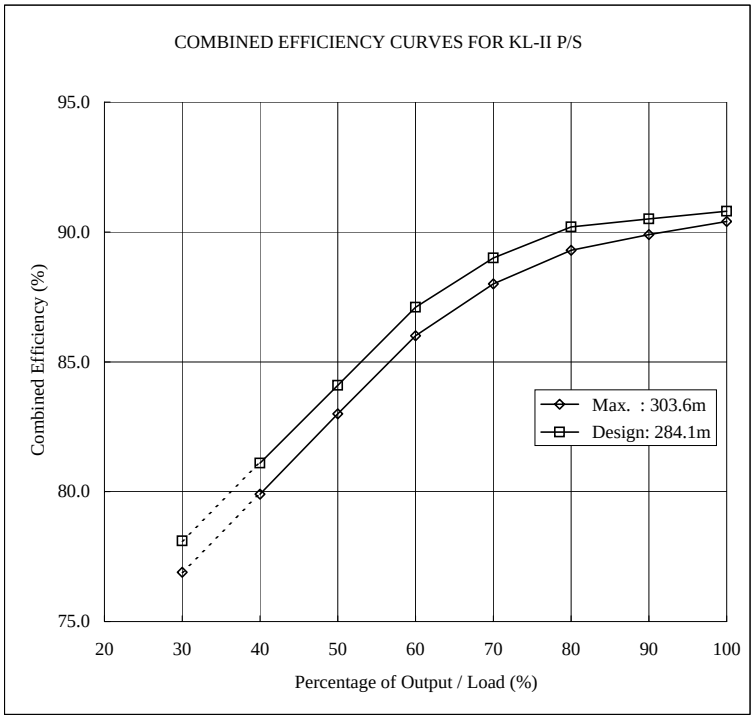




EL.	Area (m^2)	Sediment A. (m^2)	Effective A. (m^2)	Gross Vol. (m^3)	Sdmnt. Vol. (m^3)	Effective Vol. (m^3)
600	49,287	2,105	47,182	791,617	130,023	607,896
597	43,669	2,371	41,298	652,183	123,309	475,176
595	40,307	2,850	37,457	568,207	118,088	396,421
590	31,857	4,151	27,706	387,797	100,585	233,513
585	23,459	3,832	19,627	249,507	80,628	115,181
580	16,220	3,378	12,842	150,309	62,603	34,008
577	12,876	3,046	9,830	106,665	52,967	0
575	11,044	3,273	7,771	82,745	46,648	0
570	6,795	3,461	3,334	38,148	29,813	0
565	3,186	3,186	0	13,195	13,195	0
560	1,046	1,046	0	2,615	2,615	0
555	0	0	0	0	0	0

Figure D2.1 Storage Capacity Curve of Regulating Pond





Guaranteed Efficiency

Output / Load (%)	5	10	20	30	40	50	60	70	80	90	100
Generator;											
0.85 P.F.	*91.50*	*92.20*	93.55	*95.00*	96.45	*96.92*	97.38	*97.59*	97.80	*97.90*	98.00
Turbine;											
Net Head											
Max. : 605m	*78.4*	*80.8*	85.7	*89.7*	89.2	*89.9*	90.2	*89.7*	90.2	*89.7*	89.1
Design: 550m	*81.2*	*83.3*	87.2	*89.3*	89.8	*90.1*	90.0	*90.9*	91.4	*90.5*	89.4
Min. : 518m	*76.3*	*80.0*	87.3	*89.3*	89.1	*89.7*	90.2	*90.1*	89.9	*89.8*	*89.6*
Combined;											
Net Head											
Max. : 605m	71.7	74.5	80.2	85.2	86.0	87.1	87.8	87.5	88.2	87.8	87.3
Design: 550m	74.3	76.8	81.6	84.8	86.6	87.3	87.6	88.7	89.4	88.6	87.6
Min. : 518m	69.8	73.7	81.7	84.8	85.9	86.9	87.8	87.9	87.9	87.9	87.8

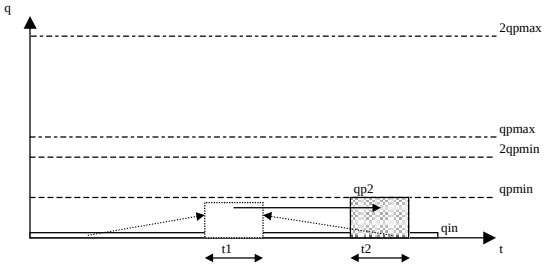
Max. Load for Generator : 35,000 kVA
Max. Output Capacity of Turbine : 31,000 kW
Estimated Value in Italics.

Guaranteed Efficiency

Output / Load (%)	30	40	50	60	70	80	90	100
Generator;								
0.85 P.F.	*96.64*	97.00	*97.37*	97.73	97.92	98.04	*98.11*	98.18
Turbine;								
Net Head								
Max. : 303.6m	*79.6*	82.4	*85.2*	88.0	89.9	91.1	*91.6*	92.1
Design: 284.1m	*80.9*	83.6	*86.4*	89.1	90.9	92.0	*92.3*	92.5
Combined;								
Net Head								
Max. : 303.6m	76.9	79.9	83.0	86.0	88.0	89.3	89.9	90.4
Design: 284.1m	78.1	81.1	84.1	87.1	89.0	90.2	90.5	90.8

Max. Load for Generator : 18,800 kVA
Max. Output Capacity of Turbine : 16,500 kW
Estimated Value in Italics.

Figure D2.2 Combined Efficiency Curves of Turbine and Generator



Pattern 1

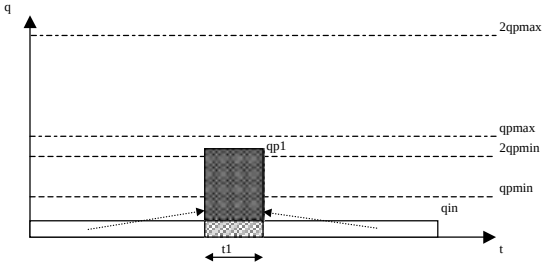
qin < qpmin*t1/24

qp1 = 0

qp2 = qpmin

t1 = 0

t2 = qin*24/qpmin



Pattern 2

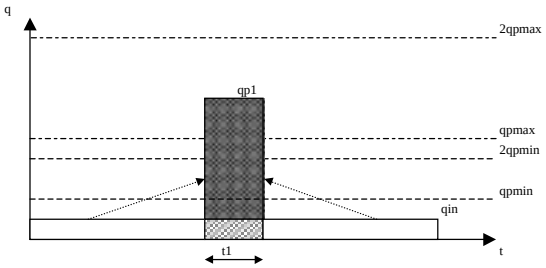
qpmin*t1/24 <= qin < qpmax*t1/24

qp1 = qin*24/t1

qp2 = 0

t1 = t1

t2 = 0



Pattern 3

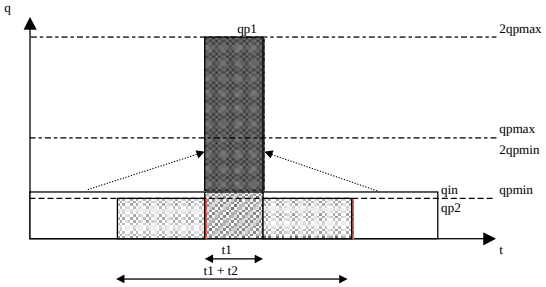
qpmax*t1/24 <= qin < 2qpmax*t1/24

qp1 = qin*24/t1

qp2 = 0

t1 = t1

t2 = 0



Pattern 4

2qpmax*t1/24 <= qin,

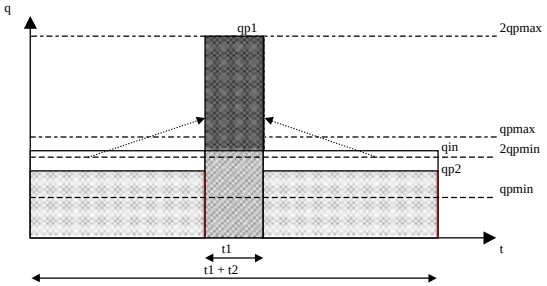
qin < (2qpmax*t1+qpmin*(24-t1))/24

qp1 = 2qpmax

qp2 = qpmin

t1 = t1

t2 = (qin*24-2qpmax*t1)/qpmin



Pattern 5

(2qpmax*t1+qpmin*(24-t1))/24 <= qin,

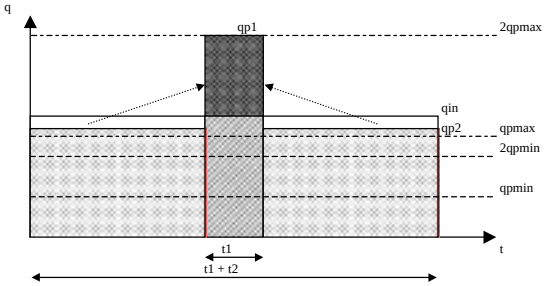
qin < (2qpmax*t1+qpmax*(24-t1))/24

qp1 = 2qpmax

qp2 = (qin*24-2qpmax*t1)/(24-t1)

t1 = t1

t2 = 24-t1



Pattern 6

(2qpmax*t1+qpmax*(24-t1))/24 <= qin,

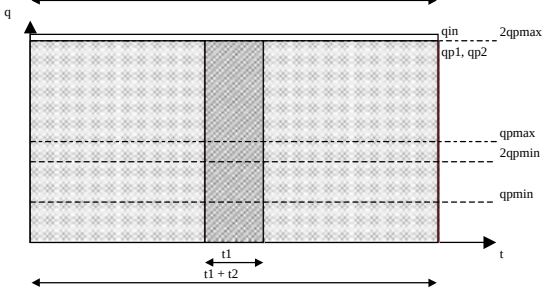
qin < 2qpmax

qp1 = 2qpmax

qp2 = (qin*24-2qpmax*t1)/(24-t1)

t1 = t1

t2 = 24-t1



Pattern 7

2qpmax*24 <= qin

qp1 = 2qpmax

qp2 = 2qpmax

t1 = t1

t2 = 24-t1

qin : Daily mean plant discharge

qpmax : Maximum plant discharge

qpmin : Minimum plant discharge

qp1 : Discharge for peak generation

qp2 : Discharge for off-peak generation

t1 : Peak operation hour

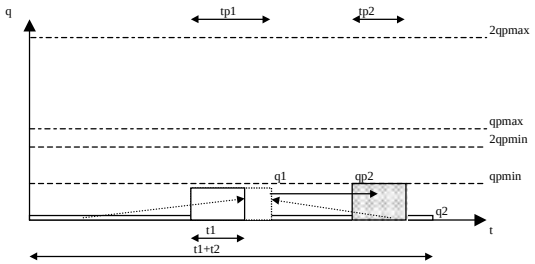
t2 : Off-peak operation hour

Plant discharge for peak generation utilizing daily mean plant discharge.

Plant discharge for peak generation utilizing reservoir volume.

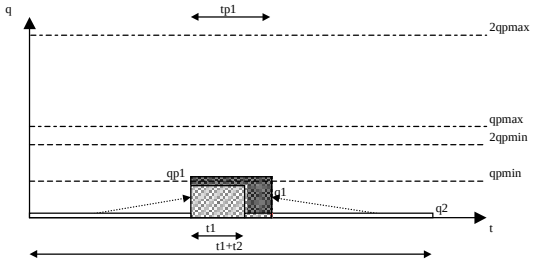
Plant discharge for off-peak generation.

Figure D2.3 Conditions for Operation of KL-I

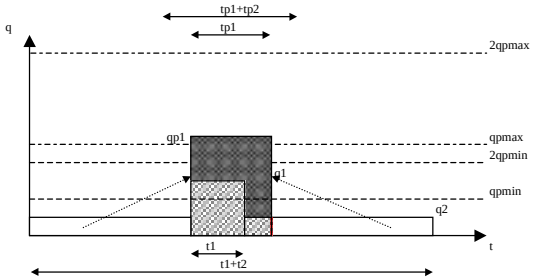


Vin = q1*t1+q2*t2
Vin1 = q1*t1+min(q2*(24-t1), Ve)

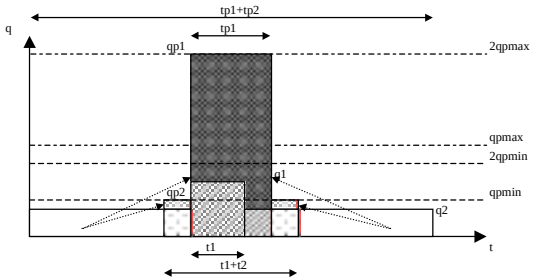
Pattern 1
Vin1 < qpmin*tp1
qp1 = 0
qp2 = qpmin
tp1 = 0
tp2 = Vin1/qpmin
V2 = 0



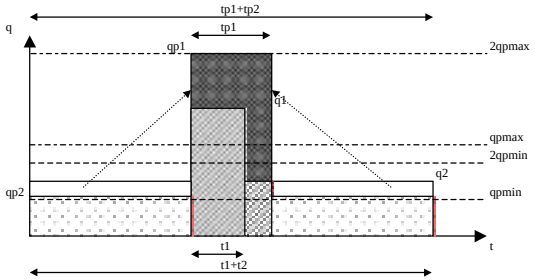
Pattern 2-1
qpmin*tp1 <= Vin1 < qpmax*tp1
qp1 = Vin1/tp1
tp1 = tp1
V1 = (qp1-q1)*t1+(qp1-q2)*(tp1-t1)
Vin2 = Vin-qp1*tp1
Vin2 <= 0
qp2 = 0
tp2 = 0
V2 = 0



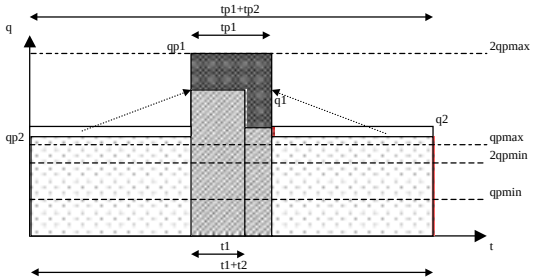
Pattern 2-2
qpmax*tp1 <= Vin1 < 2qpmax*tp1
qp1 = Vin1/tp1
tp1 = tp1
V1 = (qp1-q1)*t1+(qp1-q2)*(tp1-t1)
Vin2 = Vin-qp1*tp1
Vin2 <= 0
qp2 = 0
tp2 = 0
V2 = 0



Pattern 3-1
2qpmax*tp1 <= Vin1
qp1 = 2qpmax
tp1 = tp1
V1 = (qp1-q1)*t1+(qp1-q2)*(tp1-t1)
Vin2 = Vin-qp1*tp1
0 <= Vin2 < qpmin*(24-tp1)
V1+V2 <= Ve
qp2 = qpmin
tp2 = Vin2/(qpmin-q2)
V2 = (qpmin-q2)*tp2



Pattern 3-2
2qpmax*tp1 < Vin1
qp1 = 2qpmax
tp1 = tp1
V1 = (qp1-q1)*t1+(qp1-q2)*(tp1-t1)
Vin2 = Vin-qp1*tp1
qpmin*(24-tp1) <= Vin2 < qpmax*(24-tp1)
qp2 = Vin2/tp2
tp2 = 24-tp1
V2 = 0



Pattern 3-3
2qpmax*tp1 <= Vin1
qp1 = 2qpmax
tp1 = tp1
V1 = (qp1-q1)*t1+(qp1-q2)*(tp1-t1)
Vin2 = Vin-qp1*tp1
qpmax*(24-tp1) <= Vin2 < 2qpmin*(24-tp1)
qp2 = Vin2/tp2
tp2 = 24-tp1
V2 = 0

q1 : Inflow utilized for peak generation
q2 : Inflow utilized for off-peak generation
t1 : Duration Time of peak operation inflow
t2 : Duration Time of off-peak operation inflow
qpmax : Maximum plant discharge
qpmin : Minimum plant discharge
qp1 : Discharge for peak generation
qp2 : Discharge for off-peak generation
tp1 : Peak operation hour
tp2 : Off-peak operation hour
Ve : Effective volume of regulating pond
Vin : Total inflow volume into regulating pond
Vin1 : Inflow volume available for peak generation
Vin2 : Inflow volume available for off-peak generation
V1 : Regulating volume for peak generation
V2 : Regulating volume for off-peak generation

Plant discharge for peak generation utilizing peak operation inflow.

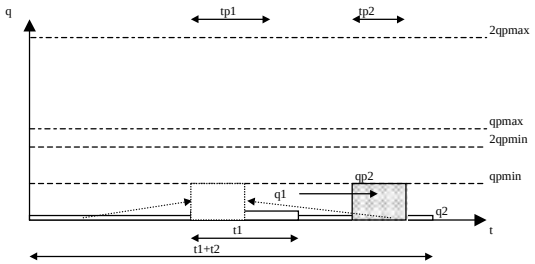
Plant discharge for peak generation utilizing regulating volume.

Plant discharge for off-peak generation utilizing peak operation inflow.

Plant discharge for off-peak generation utilizing regulating volume.

Plant discharge for off-peak generation utilizing off-peak operation inflow.

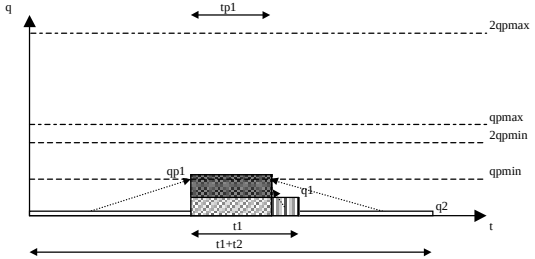
Figure D2.4 Conditions for Operation of KL-III (1/2)



Vin = q1*t1+q2*t2
Vin1 = q1*t1+min(q2*(24-tp1), Ve)

Pattern 1

Vin1 < qpmin*tp1
- qp1 = 0
- qp2 = qpmin
- tp1 = 0
- tp2 = Vin1/qpmin
- V2 = 0

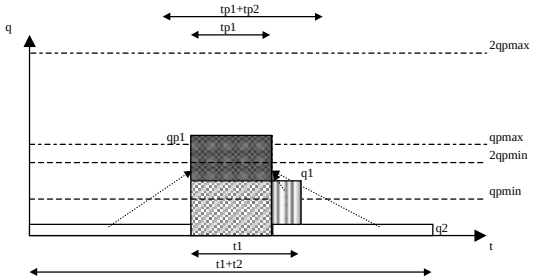


Vin1 = q1*tp1+min(q1*(t1-tp1)+q2*(24-t1), Ve)

Pattern 2-1

qpmin*tp1 <= Vin1 < qpmax*tp1
- qp1 = Vin1/tp1
- tp1 = tp1
- V1 = (qp1-q1)*tp1

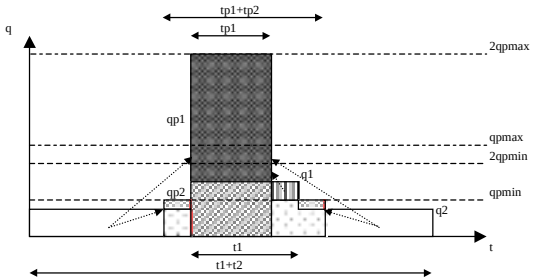
Vin2 = Vin-qp1*tp1
Vin2 <= 0
- qp2 = 0
- tp2 = 0
- V2 = 0



Pattern 2-2

qpmax*tp1 <= Vin1 < 2qpmax*tp1
- qp1 = Vin1/tp1
- tp1 = tp1
- V1 = (qp1-q1)*tp1

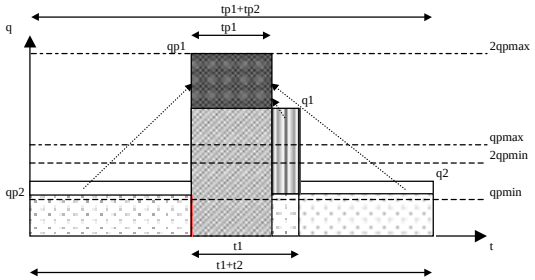
Vin2 = Vin-qp1*tp1
Vin2 <= 0
- qp2 = 0
- tp2 = 0
- V2 = 0



Pattern 3-1

2qpmax*tp1 <= Vin1
- qp1 = 2qpmax
- tp1 = tp1
- V1 = (qp1-q1)*tp1

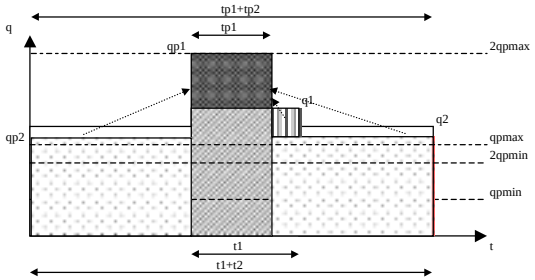
Vin2 = Vin-qp1*tp1
0 <= Vin2 < qpmin*(24-tp1)
V1+V2 <= Ve
- qp2 = qpmin
- tp2 = Vin2/(qpmin-q2)
- V2 = (qpmin-q2)*tp2-(q1-qpmin)*(t1-tp1)



Pattern 3-2

2qpmax*tp1 < Vin1
- qp1 = 2qpmax
- tp1 = tp1
- V1 = (qp1-q1)*tp1

Vin2 = Vin-qp1*tp1
qpmin*(24-tp1) <= Vin2 < qpmax*(24-tp1)
- qp2 = Vin2/tp2
- tp2 = 24-tp1
- V2 = 0



Pattern 3-3

2qpmax*tp1 < Vin1
- qp1 = 2qpmax
- tp1 = tp1
- V1 = (qp1-q1)*tp1

Vin2 = Vin-qp1*tp1
qpmax*(24-tp1) <= Vin2 < 2qpmax*(24-tp1)
- qp2 = Vin2/tp2
- tp2 = 24-tp1
- V2 = 0

q1 : Inflow utilized for peak generation
q2 : Inflow utilized for off-peak generation
t1 : Duration Time of peak operation inflow
t2 : Duration Time of off-peak operation inflow
qpmax : Maximum plant discharge
qpmin : Minimum plant discharge
qp1 : Discharge for peak generation
qp2 : Discharge for off-peak generation
tp1 : Peak operation hour
tp2 : Off-peak operation hour
Ve : Effective volume of regulating pond
Vin : Total inflow volume into regulating pond
Vin1 : Inflow volume available for peak generation
Vin2 : Inflow volume available for off-peak generation
V1 : Regulating volume for peak generation
V2 : Regulating volume for off-peak generation

Plant discharge for peak generation utilizing peak operation inflow.

Plant discharge for peak generation utilizing regulating volume.

Plant discharge for off-peak generation utilizing peak operation inflow.

Plant discharge for off-peak generation utilizing regulating volume.

Plant discharge for off-peak generation utilizing off-peak operation inflow.

Figure D2.4 Conditions for Operation of KL-III (2/2)