Annex F: Simulated Dam Operations

Reservoir levels, reservoir spills and regulating pond operations were simulated in a model over a 47 year period. The following annex presents the outputs of this analysis.

Reservoir Operations

In order to optimise energy production, the weekly simulation of reservoir levels and power generation operations was undertaken by EDF in 1999 using the Parasifal program. The Parasifal program analysed data over a 47-year period (1953-1999) of discharge records; 14 years (1986-1999) of which are adjusted to the Nakai Dam site from discharge records on the Nam Theun at Ban Signo. The remaining years of records are based on observations from sites in other catchments and extended using regression techniques.

Power generation for the simulation was assumed to be 1070 MW, supplying 100% primary energy for 16 hours per day for six days per week and secondary energy at all other times.

The results are considered to be indicative of reservoir and power station operations, however, actual operation will depend on the timing of demand for energy by EGAT – and to a lesser extent within the Lao PDR – and on the availability of water in storage.

The EDF simulation met the proposed energy production targets. However, accuracy of the hydrological data could vary as much as ±10% and with 93% of the estimated reservoir inflow being diverted for power generation in this simulation, the operation of the power station is likely to be sensitive to any error of the estimate of reservoir inflows. If the reservoir inflow was overestimated by 10% there would be less water for power generation. Lahmeyer Internation and Worley International (1998) estimated the impact on energy production of errors in the estimated of mean reservoir inflow. The results of this analysis are presented in Table F.1

Table F.1: Impact on energy production of errors in mean flow estimation

Error in Estimated Mean Reservoir Inflow	Effect on Energy Production*
-2%	-1.0%
-4%	-2.5%
-6%	-4.1%
-8%	-5.4%
-10%	-7.2%

(Source: Lahmeyer International and Worley International (1998))
*Reductions are predominantly secondary energy

Table F.2: Spills in wet season months

Month	Number of Years with Spill	Maximum Weekly Spillway Flows (m^3/s)	Average Monthly Spillway Flows (m^3/s)
July	1	666	5
August	4	1,035	36
September	15	1,279	62
October	8	202	10
November	8	56	1

Weekly Reservoir Levels

Figure F.1 illustrates the maxima, minima and average weekly reservoir levels based on 47 years of simulation. The minimum curve shows the lowest level the reservoir reached in that week in the 47 years of simulation. However, this is not a trace of the reservoir level in the driest year, as not all the weekly minima occurred in the same year. The same holds true for the average and maximum. In most years the reservoir level fluctuates from a minimum level just above MOL and a maximum level that varies, but is usually below FSL.

Reservoir Spills

A reservoir spill occurs when the water level in the reservoir exceeds FSL of El 538.0 m. The frequency of annual spills is illustrated in the Figure F.2. Of 47 years of simulation, spills occurred in 18 years. The anticipated average annual volume of spill is 454 million m^3 with the largest annual flow of 3,428 million m^3. There are no predicted spills for the seven months of December through June in any of the 47 years. Table F.2 presents the spill data for the remaining five months of the year when spills may occur.

A minimum riparian release of 2 m^3/s, averaged over a week, will be made at all times, even during non-spilling periods. Over one week, 2 m^3/s gives a weekly volume of 1.21 million m^3.

Regulating Pond Operations

Hourly operations of the regulating pond, are presented in Figures F.3 - F.10 for four scenarios of supplying 100% primary energy for 16 hours per day for six days per week, plus differing percentages of secondary energy outside these hours. During dry season months, the power station will produce between zero and 100% secondary energy and during wet season months secondary energy production will generally not fall below 75% of maximum. Primary energy with zero secondary energy would require an average diversion of approximately 188 m^3/s, and with 100% secondary energy production, an inflow from the Power Station of 330 m^3/s is assumed. The inflow at maximum power will vary slightly, depending on the head available in the reservoir (i.e. reservoir level).

Once again, these results are indicative. With the exception of weekend days, the operation of the regulating pond will homogenize outflow compared to diurnal variations in inflows from the power station. At the weekend the aim is to reduce outflow from the regulating pond due to weekend reduction in demand from around mid-Saturday, then begin to restore outflow magnitude by mid-Monday in response to weekday peak demand. These indicative results will be a guide for operators of the regulating pond, however, operators will also need to adjust their operations in response to variations of demand.

Table F.3: Nakai Reservoir surface elevations (meters)

Week	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
1	533.64	535.51	534.91	535.45	533.76	535.72	535.66	535.62	535.50	535.61	535.61	535.05	532.10
2	533.41	535.25	534.67	535.16	533.50	535.42	535.29	535.26	535.22	535.25	535.28	534.80	531.83
3	533.17	534.90	534.42	534.85	533.27	535.11	534.94	534.95	534.94	534.94	534.92	534.55	531.54
4	532.94	534.62	534.16	534.53	533.01	534.79	534.63	534.65	534.65	534.63	534.64	534.30	531.25
5	532.68	534.32	533.89	534.21	532.74	534.45	534.31	534.34	534.35	534.32	534.33	534.03	530.93
6	532.42	534.00	533.60	533.87	532.45	534.09	533.98	534.01	534.04	533.98	534.00	533.75	530.58
7	532.15	533.68	533.32	533.52	532.15	533.72	533.63	533.67	533.71	533.63	533.67	533.46	530.30
8	531.86	533.34	533.02	533.18	531.85	533.39	533.30	533.32	533.38	533.28	533.34	533.17	530.00
9	531.54	533.01	532.72	532.81	531.51	532.99	532.94	532.97	532.98	532.92	532.97	532.80	529.72
10	531.19	532.58	532.32	532.42	531.14	532.56	532.55	532.59	532.61	532.53	532.60	532.41	529.36
11	530.83	532.22	531.98	532.09	530.75	532.18	532.16	532.18	532.23	532.13	532.22	532.07	528.98
12	530.48	531.85	531.62	531.75	530.36	531.79	531.75	531.79	531.84	531.72	531.84	531.72	528.58
13	530.09	531.44	531.25	531.39	529.95	531.40	531.39	531.43	531.43	531.38	531.43	531.35	528.31
14	529.66	531.03	530.87	531.04	529.52	531.05	531.02	530.99	531.06	531.02	531.06	530.98	527.88
15	529.22	530.57	530.47	530.57	529.06	530.60	530.63	530.60	530.60	530.57	530.60	530.58	527.44
16	528.74	530.17	530.04	530.17	528.57	530.13	530.13	530.10	530.11	530.18	530.17	530.17	527.14
17	528.22	529.68	529.59	529.66	528.05	529.62	529.62	529.58	529.57	529.67	529.64	529.64	526.81
18	527.84	529.14	529.07	529.20	527.62	529.12	529.11	529.05	529.06	529.20	529.09	529.19	526.55
19	527.50	528.62	528.52	528.75	527.24	528.53	528.53	528.54	528.58	528.62	528.54	528.65	526.34
20	527.18	527.91	527.92	528.15	526.79	527.89	527.84	527.87	527.91	528.00	527.94	528.09	525.92
21	526.84	527.14	527.15	527.55	526.39	527.19	527.10	527.14	527.18	527.33	527.25	527.39	525.52
22	526.71	526.67	526.61	526.99	526.08	526.86	526.56	526.65	526.86	527.07	526.88	526.84	525.87
23	526.78	526.50	526.45	526.63	526.00	526.97	526.25	526.48	527.04	527.66	526.95	526.67	526.45
24	526.84	526.46	526.29	526.36	525.92	527.10	525.95	526.25	527.20	528.17	527.03	526.45	526.70
25	526.91	526.45	526.43	526.36	525.84	527.20	525.66	526.19	527.33	528.67	527.12	526.24	526.92
26	527.07	525.95	526.22	526.07	525.63	527.43	525.75	525.98	527.48	529.24	527.20	526.08	527.16
27	527.42	526.74	526.57	526.77	526.29	528.27	527.14	527.67	527.57	530.26	527.22	526.53	527.52
28	527.81	527.51	526.97	527.47	526.92	529.01	528.37	529.11	527.68	531.16	527.29	526.96	527.90
29	528.16	528.19	527.44	528.11	527.52	529.71	529.44	530.31	527.82	531.98	527.33	527.40	528.27
30	528.49	528.83	528.02	528.69	528.20	530.34	530.35	531.35	528.05	532.74	527.74	528.02	528.62
31	530.38	529.51	529.92	529.55	530.76	531.75	531.92	532.35	529.84	533.46	528.64	528.13	529.26
32	532.08	530.22	531.60	530.41	532.95	533.09	533.38	533.27	531.49	534.16	529.53	528.14	529.84
33	533.54	530.84	533.02	531.17	534.81	534.31	534.71	534.14	532.88	534.85	530.32	528.15	530.39
34	534.90	531.42	534.29	531.88	536.53	535.49	535.99	534.98	534.11	535.52	531.04	528.16	530.88
35	535.71	531.96	535.19	532.46	537.50	536.28	537.32	535.58	535.16	536.61	531.69	528.59	531.40
36	535.87	532.45	535.59	532.91	537.71	536.64	538.00	535.89	535.98	538.00	532.28	529.55	531.92
37	536.04	532.92	536.00	533.34	537.91	536.98	538.00	536.18	536.77	538.00	532.85	530.39	532.39
38	536.25	533.39	536.42	533.75	538.00	537.31	538.00	536.49	537.47	538.00	533.40	531.15	532.85
39	536.55	533.83	536.83	534.14	538.00	537.59	537.99	536.83	537.98	537.99	533.91	531.83	533.27
40	536.63	534.40	536.95	534.41	537.94	537.72	537.93	536.90	537.95	537.89	534.33	532.27	533.51
41	536.70	534.97	537.11	534.68	537.87	537.85	537.86	536.97	537.92	537.78	534.74	532.71	533.76
42	536.78	535.53	537.24	534.95	537.81	537.96	537.79	537.03	537.89	537.67	535.15	533.11	534.00
43	536.86	536.08	537.36	535.22	537.75	538.00	537.76	537.10	537.86	537.60	535.58	533.52	534.26
44	536.85	536.20	537.32	535.24	537.66	537.88	537.64	537.07	537.76	537.47	535.76	533.57	534.27
45	536.78	536.12	537.18	535.13	537.52	537.69	537.45	536.96	537.58	537.30	535.82	533.47	534.15
46	536.71	536.03	537.03	535.02	537.37	537.48	537.25	536.87	537.43	537.13	535.86	533.37	534.05
47	536.64	535.96	536.88	534.92	537.23	537.29	537.04	536.77	537.26	536.99	535.90	533.26	533.93
48	536.54	535.85	536.68	534.79	537.04	537.07	536.85	536.63	537.06	536.83	535.87	533.14	533.79
49	536.38	535.68	536.44	534.59	536.79	536.83	536.64	536.40	536.77	536.65	535.73	532.95	533.57
50	536.16	535.51	536.17	534.40	536.53	536.58	536.41	536.16	536.46	536.41	535.60	532.76	533.36
51	535.93	535.34	535.95	534.21	536.29	536.30	536.18	535.98	536.17	536.15	535.45	532.58	533.14
52	535.78	535.16	535.75	534.00	536.02	536.02	535.97	535.78	535.91	535.94	535.30	532.38	532.91

Table F.3: Nakai Reservoir surface elevations (meters) (continued)

Week	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	532.65	535.49	535.94	533.66	535.73	535.61	535.77	536.32	535.75	533.66	535.91	534.80	531.53
2	532.37	535.19	535.62	533.41	535.37	535.29	535.43	535.92	535.42	533.42	535.58	534.57	531.27
3	532.08	534.89	535.28	533.16	535.00	534.95	535.09	535.54	535.08	533.16	535.24	534.36	531.01
4	531.77	534.59	534.93	532.93	534.68	534.67	534.75	535.13	534.74	532.90	534.88	534.13	530.82
5	531.47	534.28	534.58	532.65	534.36	534.36	534.41	534.73	534.39	532.63	534.53	533.90	530.60
6	531.13	533.94	534.21	532.36	534.02	534.05	534.02	534.35	534.01	532.34	534.15	533.65	530.36
7	530.79	533.60	533.84	532.05	533.70	533.67	533.69	533.97	533.69	532.05	533.76	533.40	530.16
8	530.42	533.24	533.46	531.75	533.35	533.34	533.35	533.58	533.37	531.74	533.36	533.14	529.91
9	530.04	532.89	533.06	531.42	532.99	533.00	532.95	533.17	532.97	531.39	532.99	532.83	529.65
10	529.63	532.51	532.65	531.04	532.57	532.62	532.60	532.76	532.61	531.04	532.55	532.52	529.39
11	529.29	532.14	532.27	530.69	532.17	532.23	532.22	532.33	532.21	530.64	532.16	532.21	529.14
12	528.95	531.73	531.88	530.30	531.76	531.82	531.81	531.94	531.82	530.25	531.73	531.86	528.86
13	528.57	531.39	531.47	529.87	531.40	531.39	531.38	531.54	531.39	529.82	531.37	531.51	528.57
14	528.16	531.02	531.04	529.44	531.03	531.02	531.00	531.09	531.04	529.38	531.00	531.16	528.24
15	527.76	530.54	530.58	528.97	530.56	530.63	530.59	530.62	530.58	528.93	530.60	530.80	527.91
16	527.29	530.13	530.18	528.48	530.14	530.12	530.17	530.12	530.17	528.44	530.12	530.31	527.59
17	526.99	529.60	529.74	528.00	529.63	529.60	529.65	529.61	529.66	527.90	529.63	529.80	527.22
18	526.57	529.14	529.16	527.49	529.28	529.09	529.11	529.06	529.15	527.39	529.11	529.21	526.81
19	526.18	528.58	528.58	527.00	528.91	528.54	528.59	528.47	528.54	526.93	528.55	528.61	526.41
20	525.77	527.95	527.93	526.51	528.48	527.84	527.92	527.89	527.87	526.42	527.86	527.97	525.99
21	525.55	527.30	527.24	525.95	528.03	527.14	527.18	527.20	527.16	525.86	527.21	527.27	525.59
22	525.71	526.86	526.70	525.82	527.62	526.69	526.82	526.64	526.71	525.71	526.68	526.63	525.85
23	526.07	526.61	526.50	526.28	527.29	526.50	526.90	526.50	526.58	526.01	526.47	526.47	526.48
24	526.40	526.35	526.44	526.30	526.95	526.36	526.98	526.36	526.36	526.27	526.22	526.29	526.65
25	526.29	526.23	526.42	526.31	526.58	526.02	527.03	526.25	526.22	526.24	525.97	526.13	526.81
26	526.50	526.04	526.02	526.35	526.45	525.79	527.22	526.21	526.03	526.14	525.57	525.56	527.34
27	528.41	526.51	526.08	526.61	527.31	527.24	528.04	527.74	526.56	526.76	525.91	525.75	529.39
28	529.96	527.00	526.25	526.94	528.14	528.49	528.80	529.04	527.07	527.38	526.36	526.04	531.02
29	531.25	527.50	526.67	527.33	528.87	529.57	529.50	530.15	527.55	527.97	526.92	526.36	532.37
30	532.36	528.04	527.07	527.85	529.57	530.52	530.13	531.12	528.11	528.49	527.57	526.65	533.57
31	533.10	530.45	528.39	529.10	531.63	532.26	531.87	532.83	529.03	530.36	528.70	527.18	535.06
32	533.77	532.51	529.64	530.23	533.47	533.87	533.49	534.46	529.88	532.02	529.76	527.74	536.52
33	534.43	534.26	530.72	531.21	535.15	535.36	534.97	535.98	530.63	533.45	530.71	528.26	537.77
34	535.07	535.87	531.69	532.10	536.69	536.75	536.38	537.35	531.34	534.77	531.58	528.74	538.00
35	535.50	536.95	532.49	533.56	537.66	537.53	537.18	538.00	531.89	535.67	532.36	529.49	538.00
36	535.65	537.44	533.11	535.50	538.00	537.67	537.37	538.00	532.31	536.10	533.08	530.46	538.00
37	535.81	537.87	533.70	537.25	538.00	537.81	537.55	538.00	532.73	536.52	533.78	531.36	538.00
38	536.08	538.00	534.28	538.00	538.00	537.93	537.71	538.00	533.12	536.92	534.45	532.14	538.00
39	536.39	538.00	534.79	538.00	538.00	538.00	537.86	538.00	533.49	537.28	535.03	532.78	537.99
40	536.63	538.00	534.90	538.00	537.94	538.00	537.93	537.97	533.79	537.37	535.07	532.88	537.90
41	536.84	538.00	535.00	538.00	537.88	538.00	537.99	537.94	534.07	537.45	535.11	532.98	537.79
42	537.01	538.00	535.10	538.00	537.82	538.00	538.00	537.91	534.35	537.55	535.15	533.11	537.68
43	537.18	538.00	535.22	538.00	537.80	538.00	538.00	537.88	534.64	537.69	535.22	533.24	537.63
44	537.16	537.91	535.18	537.90	537.67	537.91	537.98	537.76	534.72	537.69	535.19	533.20	537.49
45	537.05	537.78	535.09	537.71	537.53	537.77	537.94	537.58	534.70	537.58	535.13	533.09	537.30
46	536.93	537.62	534.98	537.50	537.38	537.61	537.89	537.43	534.67	537.46	535.07	532.95	537.10
47	536.82	537.47	534.88	537.32	537.23	537.44	537.85	537.28	534.64	537.34	535.03	532.82	536.95
48	536.66	537.26	534.73	537.12	537.03	537.20	537.72	537.10	534.56	537.20	534.99	532.64	536.76
49	536.46	537.00	534.52	536.87	536.77	536.95	537.48	536.85	534.39	536.97	534.99	532.44	536.54
50	536.23	536.77	534.30	536.59	536.50	536.68	537.22	536.60	534.22	536.73	535.00	532.23	536.30
51	536.00	536.55	534.09	536.33	536.21	536.41	536.96	536.34	534.04	536.49	535.02	532.00	536.05
52	535.77	536.27	533.87	536.07	535.94	536.11	536.70	536.08	533.88	536.25	535.02	531.78	535.81

Table F.3: Nakai Reservoir surface elevations (meters) (continued)

Week	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	535.53	534.68	535.72	536.02	536.07	535.58	535.98	535.47	534.30	534.72	533.23	534.13	535.76
2	535.25	534.44	535.36	535.65	535.69	535.24	535.63	535.18	534.04	534.48	532.97	533.89	535.42
3	534.92	534.19	535.00	535.30	535.35	534.95	535.31	534.89	533.77	534.24	532.70	533.65	535.07
4	534.63	533.95	534.70	534.95	535.03	534.65	534.97	534.59	533.52	534.00	532.46	533.43	534.71
5	534.32	533.70	534.40	534.60	534.69	534.34	534.60	534.29	533.25	533.76	532.19	533.17	534.40
6	534.00	533.43	534.00	534.22	534.32	534.02	534.23	533.97	532.96	533.48	531.87	532.90	534.01
7	533.68	533.18	533.68	533.85	533.95	533.69	533.85	533.66	532.67	533.20	531.58	532.63	533.69
8	533.34	532.91	533.36	533.47	533.58	533.34	533.46	533.35	532.37	532.92	531.23	532.35	533.35
9	532.99	532.62	533.01	533.07	533.20	533.00	533.06	532.95	532.06	532.61	530.89	532.06	532.99
10	532.57	532.32	532.59	532.64	532.82	532.61	532.63	532.56	531.73	532.28	530.49	531.78	532.55
11	532.18	532.01	532.23	532.28	532.42	532.23	532.25	532.19	531.39	531.93	530.07	531.47	532.16
12	531.80	531.69	531.84	531.89	532.01	531.82	531.86	531.82	531.04	531.57	529.64	531.16	531.77
13	531.39	531.35	531.46	531.52	531.64	531.39	531.46	531.43	530.65	531.20	529.19	530.84	531.42
14	531.01	531.01	531.04	531.11	531.20	531.06	531.03	531.06	530.26	530.84	528.70	530.49	531.06
15	530.61	530.55	530.59	530.68	530.74	530.66	530.57	530.60	529.83	530.47	528.20	530.11	530.62
16	530.14	530.15	530.11	530.22	530.25	530.20	530.18	530.10	529.38	530.07	527.67	529.71	530.13
17	529.64	529.66	529.60	529.74	529.74	529.76	529.68	529.58	528.90	529.57	527.12	529.29	529.61
18	529.17	529.13	529.16	529.21	529.19	529.16	529.23	529.15	528.42	529.12	526.84	528.92	529.06
19	528.57	528.51	528.63	528.54	528.55	528.55	528.83	528.73	527.96	528.59	526.66	528.48	528.52
20	527.98	527.93	528.06	527.93	527.94	527.90	528.29	528.18	527.46	528.01	526.47	527.93	527.93
21	527.28	527.20	527.34	527.14	527.15	527.22	527.66	527.59	526.94	527.31	526.25	527.27	527.15
22	526.88	526.62	526.99	526.72	526.64	526.68	527.16	527.27	526.52	526.75	526.29	526.83	526.84
23	526.92	526.40	527.25	526.57	526.62	526.50	526.95	527.38	526.33	526.56	526.57	526.90	527.13
24	526.92	526.32	527.52	526.43	526.48	526.34	526.72	527.57	526.10	526.39	526.52	526.98	527.38
25	526.94	526.13	527.76	526.24	526.29	526.42	526.48	527.69	525.89	526.47	526.51	527.03	527.67
26	526.91	525.78	528.66	526.05	526.25	526.45	526.35	527.87	525.50	526.11	526.56	527.19	528.04
27	526.74	526.64	532.18	526.72	527.28	528.60	526.99	528.54	525.61	525.88	527.02	527.82	529.06
28	526.65	527.47	534.79	527.39	528.17	530.30	527.60	529.12	525.63	525.95	527.50	528.42	529.95
29	526.78	528.20	537.09	527.98	529.00	531.68	528.20	529.69	525.62	525.97	527.94	528.98	530.76
30	527.07	528.89	538.00	528.53	529.74	532.88	528.74	530.21	525.62	526.00	528.36	529.50	531.48
31	529.30	531.23	538.00	530.62	531.62	533.97	530.61	530.63	527.65	527.68	529.52	529.99	532.92
32	531.10	533.28	538.00	532.49	533.34	535.01	532.27	531.15	529.51	529.26	530.79	530.64	534.33
33	532.52	535.07	538.00	534.08	534.88	536.00	533.71	531.75	530.99	530.56	531.88	531.25	535.66
34	533.77	536.73	538.00	535.55	536.33	536.95	535.04	532.31	532.26	531.70	532.87	531.82	536.91
35	534.56	537.94	538.00	536.44	537.37	537.49	535.93	532.86	533.17	532.40	533.52	532.55	537.57
36	534.81	538.00	538.00	536.62	537.93	537.62	536.28	533.40	533.76	532.65	533.79	533.49	537.64
37	535.23	538.00	538.00	536.80	538.00	537.75	536.63	533.94	534.33	532.91	534.08	534.37	537.72
38	535.63	538.00	538.00	536.97	538.00	537.86	536.97	534.46	534.91	533.15	534.35	535.24	537.80
39	535.98	538.00	538.00	537.16	538.00	537.98	537.23	534.93	535.39	533.42	534.63	536.03	537.86
40	535.98	537.93	538.00	537.35	537.93	538.00	537.12	535.11	535.49	533.80	534.88	536.51	537.81
41	536.00	537.86	538.00	537.51	537.87	538.00	537.05	535.28	535.56	534.18	535.12	536.91	537.76
42	536.01	537.78	538.00	537.66	537.80	538.00	536.99	535.44	535.63	534.56	535.35	537.25	537.70
43	536.04	537.76	538.00	537.81	537.77	538.00	536.98	535.61	535.72	534.94	535.59	537.57	537.70
44	536.00	537.67	537.94	537.81	537.67	537.93	536.93	535.61	535.73	534.95	535.59	537.59	537.58
45	535.91	537.55	537.85	537.75	537.51	537.80	536.84	535.51	535.71	534.81	535.50	537.49	537.41
46	535.83	537.42	537.74	537.69	537.35	537.68	536.75	535.40	535.70	534.66	535.39	537.38	537.22
47	535.74	537.31	537.63	537.63	537.17	537.56	536.66	535.31	535.69	534.50	535.30	537.28	537.02
48	535.61	537.12	537.47	537.48	536.95	537.39	536.54	535.20	535.62	534.32	535.15	537.11	536.86
49	535.44	536.86	537.22	537.21	536.68	537.12	536.36	535.03	535.46	534.12	534.96	536.86	536.64
50	535.27	536.59	536.95	536.96	536.40	536.84	536.14	534.87	535.30	533.90	534.77	536.61	536.41
51	535.08	536.33	536.68	536.69	536.16	536.54	535.96	534.71	535.13	533.71	534.57	536.37	536.17
52	534.90	536.05	536.39	536.42	535.91	536.29	535.75	534.54	534.95	533.49	534.37	536.11	535.93

Table F.3: Nakai Reservoir surface elevations (meters) (continued)

Week	1992	1993	1994	1995	1996	1997	1998	1999	Minimum	Maximum	Average
1	535.61	530.64	535.12	535.60	535.74	536.38	535.58	529.76	529.76	536.38	534.86
2	535.29	530.46	534.87	535.25	535.39	536.00	535.23	529.59	529.59	536.00	534.56
3	534.96	530.29	534.62	534.95	535.05	535.62	534.92	529.43	529.43	535.62	534.27
4	534.69	530.11	534.36	534.65	534.74	535.28	534.62	529.25	529.25	535.28	533.98
5	534.40	529.92	534.11	534.33	534.38	534.90	534.30	529.19	529.19	534.90	533.68
6	534.02	529.72	533.83	534.00	534.00	534.48	533.97	528.97	528.97	534.48	533.36
7	533.69	529.51	533.48	533.65	533.68	534.07	533.64	528.87	528.87	534.07	533.04
8	533.35	529.28	533.19	533.30	533.35	533.66	533.29	528.79	528.79	533.66	532.72
9	533.01	529.05	532.83	532.96	532.95	533.26	532.94	528.54	528.54	533.26	532.37
10	532.59	528.79	532.45	532.59	532.60	532.85	532.57	528.42	528.42	532.85	532.00
11	532.22	528.53	532.13	532.20	532.24	532.43	532.19	528.30	528.30	532.43	531.63
12	531.82	528.26	531.74	531.80	531.87	532.06	531.79	528.03	528.03	532.06	531.26
13	531.40	527.97	531.40	531.38	531.46	531.61	531.43	527.76	527.76	531.64	530.88
14	531.03	527.69	531.02	531.02	531.04	531.26	531.06	527.53	527.53	531.26	530.50
15	530.56	527.39	530.63	530.56	530.60	530.80	530.62	527.29	527.29	530.80	530.07
16	530.15	527.09	530.14	530.16	530.12	530.39	530.12	527.05	527.05	530.39	529.63
17	529.66	526.77	529.62	529.69	529.64	529.88	529.59	526.81	526.77	529.88	529.15
18	529.14	526.57	529.09	529.14	529.18	529.32	529.06	526.64	526.55	529.32	528.67
19	528.59	526.24	528.55	528.59	528.61	528.74	528.52	526.42	526.18	528.91	528.17
20	527.90	525.92	527.95	527.99	527.98	528.11	527.95	526.20	525.77	528.48	527.61
21	527.15	525.60	527.16	527.35	527.30	527.39	527.18	525.94	525.52	528.03	526.99
22	526.73	525.65	526.75	526.86	526.72	526.86	526.62	526.04	525.65	527.62	526.63
23	526.54	525.85	526.79	526.83	526.50	526.62	526.42	526.43	525.85	527.66	526.63
24	526.31	525.98	526.78	526.81	526.40	526.51	526.24	526.50	525.92	528.17	526.59
25	526.05	526.14	526.79	526.79	526.14	526.14	526.04	526.53	525.66	528.67	526.55
26	525.83	526.02	527.43	526.82	525.85	526.01	525.56	526.66	525.50	529.24	526.52
27	526.64	527.27	530.84	527.30	527.12	527.83	525.85	527.12	525.61	532.18	527.39
28	527.44	528.33	533.23	527.78	528.22	529.33	526.25	527.58	525.63	534.79	528.16
29	528.15	529.28	535.26	528.26	529.20	530.60	526.77	528.03	525.62	537.09	528.88
30	528.80	530.14	537.11	528.72	530.08	531.66	527.39	528.45	525.62	538.00	529.53
31	529.10	531.17	538.00	529.76	531.38	532.90	527.44	529.48	527.18	538.00	530.82
32	529.29	532.15	538.00	530.85	532.60	534.08	527.36	530.53	527.36	538.00	531.99
33	529.50	533.03	538.00	531.89	533.69	535.20	527.28	531.44	527.28	538.00	533.03
34	529.68	533.87	538.00	532.81	534.73	536.27	527.23	532.27	527.23	538.00	533.97
35	530.00	534.41	538.00	533.72	536.27	537.03	527.59	532.81	527.59	538.00	534.71
36	530.44	534.63	538.00	534.60	538.00	537.42	528.41	533.05	528.41	538.00	535.19
37	530.87	534.96	538.00	535.39	538.00	537.77	529.18	533.30	529.18	538.00	535.56
38	531.30	535.28	538.00	536.18	538.00	538.00	529.89	533.53	529.89	538.00	535.89
39	531.66	535.60	537.99	536.85	538.00	538.00	530.51	533.77	530.51	538.00	536.16
40	531.75	535.84	537.91	537.07	538.00	537.95	530.49	533.91	530.49	538.00	536.26
41	531.84	536.07	537.82	537.28	538.00	537.89	530.45	534.06	530.45	538.00	536.35
42	531.96	536.30	537.72	537.48	538.00	537.83	530.52	534.19	530.52	538.00	536.44
43	532.08	536.52	537.67	537.69	538.00	537.80	530.60	534.34	530.60	538.00	536.55
44	532.06	536.53	537.56	537.66	537.99	537.67	530.59	534.38	530.59	537.99	536.51
45	531.97	536.42	537.39	537.53	537.96	537.48	530.54	534.34	530.54	537.96	536.40
46	531.88	536.31	537.23	537.41	537.92	537.27	530.49	534.31	530.49	537.92	536.28
47	531.80	536.20	537.07	537.27	537.89	537.06	530.44	534.27	530.44	537.89	536.17
48	531.67	536.07	536.85	537.10	537.77	536.86	530.37	534.17	530.37	537.77	536.02
49	531.48	535.89	536.63	536.86	537.53	536.62	530.25	533.99	530.25	537.53	535.81
50	531.29	535.73	536.37	536.62	537.29	536.39	530.15	533.79	530.15	537.29	535.59
51	531.11	535.55	536.14	536.36	537.02	536.14	530.03	533.58	530.03	537.02	535.37
52	530.90	535.38	535.93	536.09	536.73	535.89	529.92	533.38	529.92	536.73	535.14

Table F.4: Nakai Dam spills (million m³)

Week	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
10	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18	–	–	–	–	–	–	–	–	–	–	–	–	–	–
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20	–	–	–	–	–	–	–	–	–	–	–	–	–	–
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–
24	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–
27	–	–	–	–	–	–	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30	–	–	–	–	–	–	–	–	–	–	–	–	–	–
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–
34	–	–	–	–	–	–	–	–	–	–	–	–	–	–
35	–	–	–	–	–	–	–	–	–	–	233	–	–	–
36	–	–	–	–	–	–	–	26.9	–	–	558	–	–	–
37	–	–	–	–	–	–	–	199	–	–	562	–	–	–
38	–	–	–	–	129	–	295	199	–	–	562	–	–	–
39	–	–	–	–	180	–	562	170	29.1	–	485	–	–	–
40	–	–	–	–	13.1	–	1.46	–	49.5	–	–	–	–	–
41	–	–	–	–	16.7	–	1.17	–	49.5	–	–	–	–	–
42	–	–	–	–	16.7	–	2.05	–	49.5	28.3	–	–	–	–
43	–	–	–	–	16.7	–	2.31	–	50.3	34.6	–	–	–	–
44	–	–	–	–	5.09	–	1.5	–	13.4	16.7	–	–	–	–
45	–	–	–	–	–	–	–	–	–	–	–	–	–	–
46	–	–	–	–	–	–	–	–	–	–	–	–	–	–
47	–	–	–	–	–	–	–	–	–	–	–	–	–	–
48	–	–	–	–	–	–	–	–	–	–	–	–	–	–
49	–	–	–	–	–	–	–	–	–	–	–	–	–	–
50	–	–	–	–	–	–	–	–	–	–	–	–	–	–
51	–	–	–	–	–	–	–	–	–	–	–	–	–	–
52	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Annual	–	–	–	–	377	–	866	594	241	79.5	2400	–	–	–

Table F.4: Nakai Dam spills (million m^3) (continued)

Week	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
10	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18	–	–	–	–	–	–	–	–	–	–	–	–	–	–
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20	–	–	–	–	–	–	–	–	–	–	–	–	–	–
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–
24	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–
27	–	–	–	–	–	–	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30	–	–	–	–	403	–	–	–	–	–	–	–	–	–
31	–	–	–	–	391	–	–	–	–	–	–	–	–	–
32	–	–	–	–	317	–	–	–	–	–	–	–	–	–
33	–	–	–	–	319	–	–	–	–	–	–	–	–	–
34	–	393	–	–	319	–	–	–	–	–	–	–	–	–
35	–	363	–	–	281	–	–	–	–	–	–	–	–	–
36	–	159	–	400	225	–	–	–	–	–	–	–	–	–
37	–	157	–	434	224	–	221	–	–	–	–	–	–	–
38	–	158	–	439	225	–	262	–	–	–	–	–	–	–
39	–	136	–	369	212	–	224	–	–	–	–	–	–	–
40	–	–	–	–	119	–	–	31.4	–	–	–	–	–	–
41	–	–	–	–	119	–	–	44.6	–	–	–	–	–	–
42	–	–	–	–	119	–	–	44.6	–	–	–	–	–	–
43	–	–	–	–	122	–	–	44.6	–	–	–	–	–	–
44	–	–	–	–	34	–	–	12.7	–	–	–	–	–	–
45	–	–	–	–	–	–	–	–	–	–	–	–	–	–
46	–	–	–	–	–	–	–	–	–	–	–	–	–	–
47	–	–	–	–	–	–	–	–	–	–	–	–	–	–
48	–	–	–	–	–	–	–	–	–	–	–	–	–	–
49	–	–	–	–	–	–	–	–	–	–	–	–	–	–
50	–	–	–	–	–	–	–	–	–	–	–	–	–	–
51	–	–	–	–	–	–	–	–	–	–	–	–	–	–
52	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Annual	–	1366	–	1642	3428	–	707	178	–	–	–	–	–	–

Table F.4: Nakai Dam spills (million m^3) (continued)

Week	1991	1992	1993	1994	1995	1996	1997	1998	1999	Average	Maximum	Minimum
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	–	–
3	–	–	–	–	–	–	–	–	–	–	–	–
4	–	–	–	–	–	–	–	–	–	–	–	–
5	–	–	–	–	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–	–	–	–	–
7	–	–	–	–	–	–	–	–	–	–	–	–
8	–	–	–	–	–	–	–	–	–	–	–	–
9	–	–	–	–	–	–	–	–	–	–	–	–
10	–	–	–	–	–	–	–	–	–	–	–	–
11	–	–	–	–	–	–	–	–	–	–	–	–
12	–	–	–	–	–	–	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–	–	–	–
14	–	–	–	–	–	–	–	–	–	–	–	–
15	–	–	–	–	–	–	–	–	–	–	–	–
16	–	–	–	–	–	–	–	–	–	–	–	–
17	–	–	–	–	–	–	–	–	–	–	–	–
18	–	–	–	–	–	–	–	–	–	–	–	–
19	–	–	–	–	–	–	–	–	–	–	–	–
20	–	–	–	–	–	–	–	–	–	–	–	–
21	–	–	–	–	–	–	–	–	–	–	–	–
22	–	–	–	–	–	–	–	–	–	–	–	–
23	–	–	–	–	–	–	–	–	–	–	–	–
24	–	–	–	–	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	–	–	–	–	–	–
26	–	–	–	–	–	–	–	–	–	–	–	–
27	–	–	–	–	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–	–	–	–	–
30	–	–	–	–	–	–	–	–	–	8.6	403	–
31	–	–	–	219	–	–	–	–	–	13.0	391	–
32	–	–	–	626	–	–	–	–	–	20.1	626	–
33	–	–	–	626	–	–	–	–	–	20.1	626	–
34	–	–	–	626	–	–	–	–	–	28.5	626	–
35	–	–	–	410	–	–	–	–	–	27.4	410	–
36	–	–	–	118	–	41	–	–	–	38.0	558	–
37	–	–	–	118	–	774	–	–	–	82.5	774	–
38	–	–	–	118	–	774	36.8	–	–	94.3	774	–
39	–	–	–	101	–	673	137	–	–	93.2	673	–
40	–	–	–	–	–	53.2	–	–	–	5.7	119	–
41	–	–	–	–	–	53.2	–	–	–	6.0	119	–
42	–	–	–	–	–	53.2	–	–	–	6.7	119	–
43	–	–	–	–	–	53.2	–	–	–	7.7	122	–
44	–	–	–	–	–	16.6	–	–	–	2.5	34	–
45	–	–	–	–	–	–	–	–	–	–	–	–
46	–	–	–	–	–	–	–	–	–	–	–	–
47	–	–	–	–	–	–	–	–	–	–	–	–
48	–	–	–	–	–	–	–	–	–	–	–	–
49	–	–	–	–	–	–	–	–	–	–	–	–
50	–	–	–	–	–	–	–	–	–	–	–	–
51	–	–	–	–	–	–	–	–	–	–	–	–
52	–	–	–	–	–	–	–	–	–	–	–	–
Annual	–	–	–	2963	–	2491	174	–	–	454	3428	–

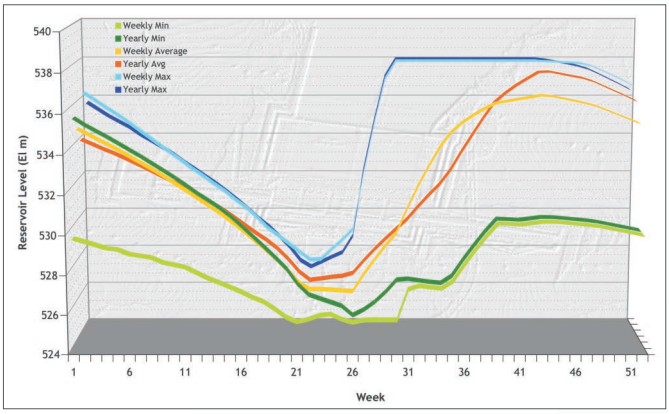

Figure F.1: Nakai Reservoir operation simulation

"Weekly Min": This is an artificicial hydrological year, created by selecting for each week of the year, the driest week over the extended period.

"Yearly Min": Driest year on record, recorded hydrologial data for 1998

"Weekly Average": This is an artificial hydrological year, created by calculating the mean for each week of the year, over the extended period.

"Yearly Avg": An average year, recorded hydrologial data for 1990

"Weekly Max": This is an artificial hydrological year, created by selecting for each week of the year, the wettest week over the extended period.

"Yearly Max": Wettest year on record, recorded hydrologial data for 1981

(Recording Period for hyrological data: 1953-1999)

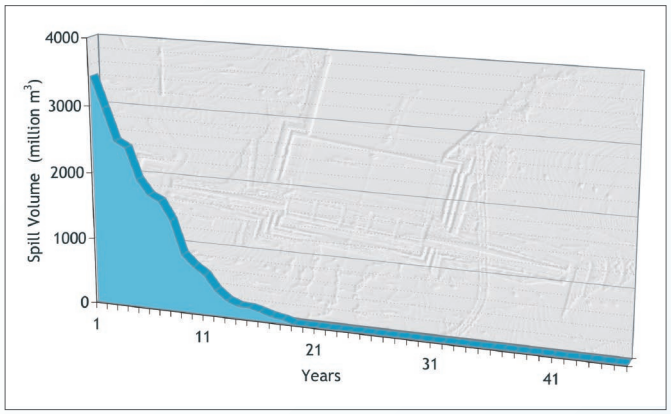

Figure F.2: Frequency of annual spills for the Nakai Dam

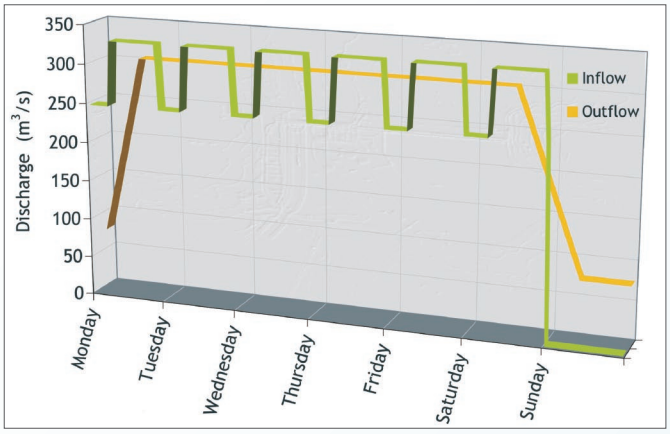

Figure F.3: Regulating pond inflow and outflow when generating 75% secondary energy

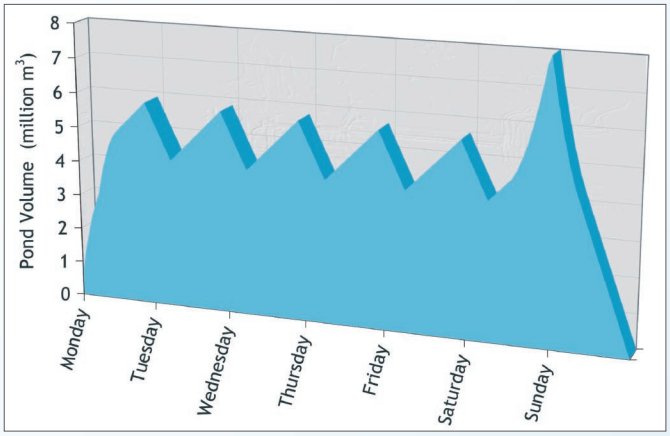

Figure F.4: Regulating pond volume when generating 75% secondary energy

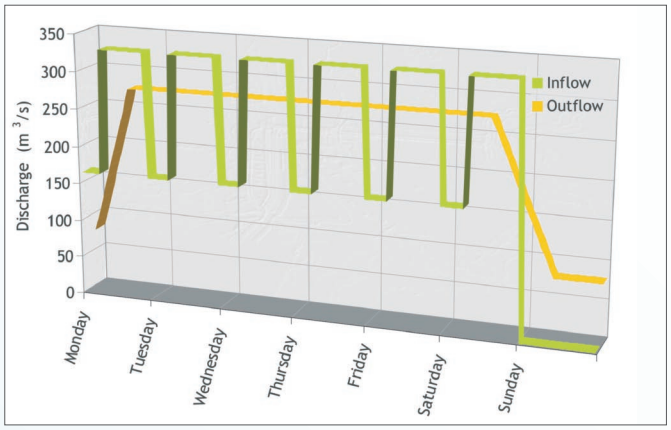

Figure F.5: Regulating pond inflow and outflow when generating 50% secondary energy

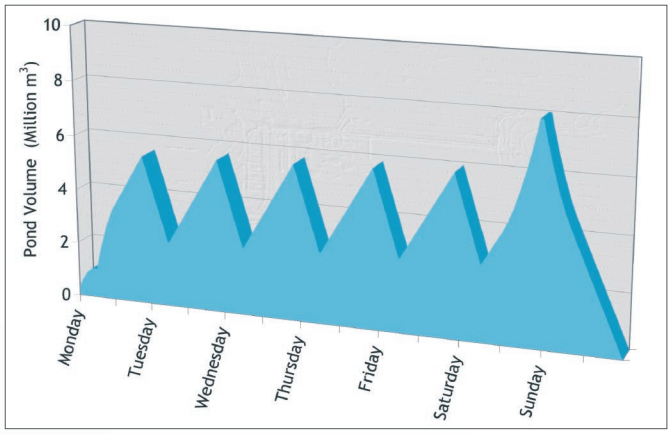

Figure F.6: Regulating pond volume when generating 50% secondary energy

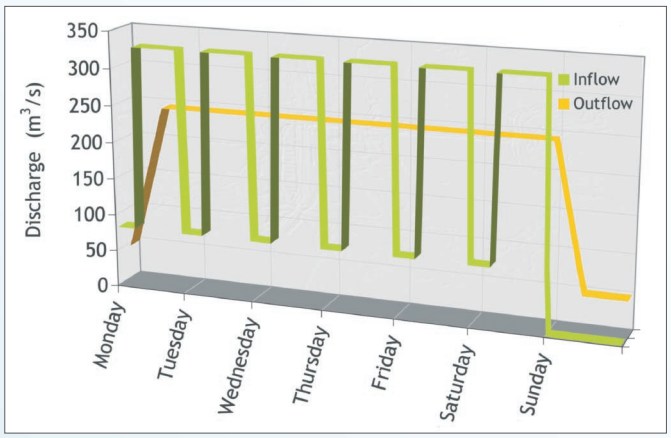

Figure F.7: Regulating pond inflow and discharge when generating 25% secondary energy

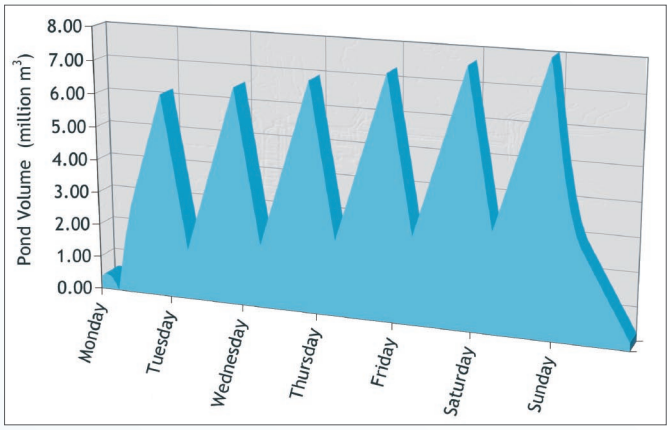

Figure F.8: Regulating pond volume when generating 25% secondary energy

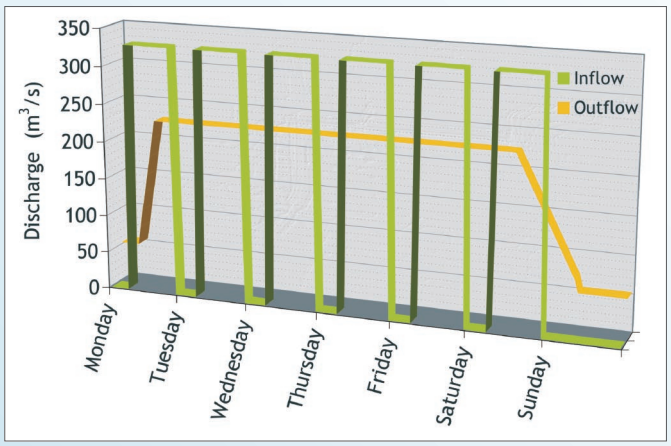

Figure F.9: Regulating pond inflow and outflow when generating zero secondary energy

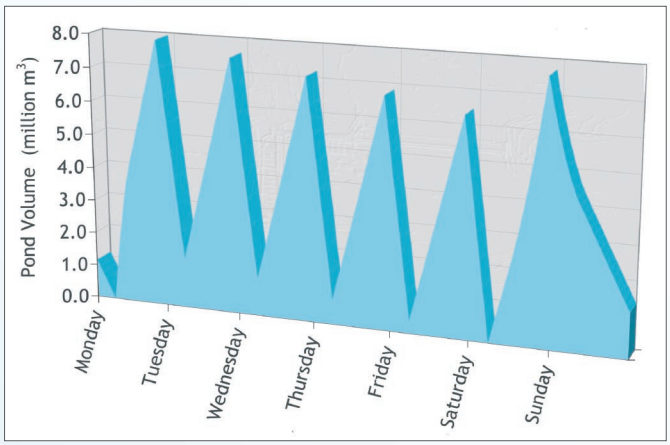

Figure F.10: Regulating pond volume when generating zero secondary energy