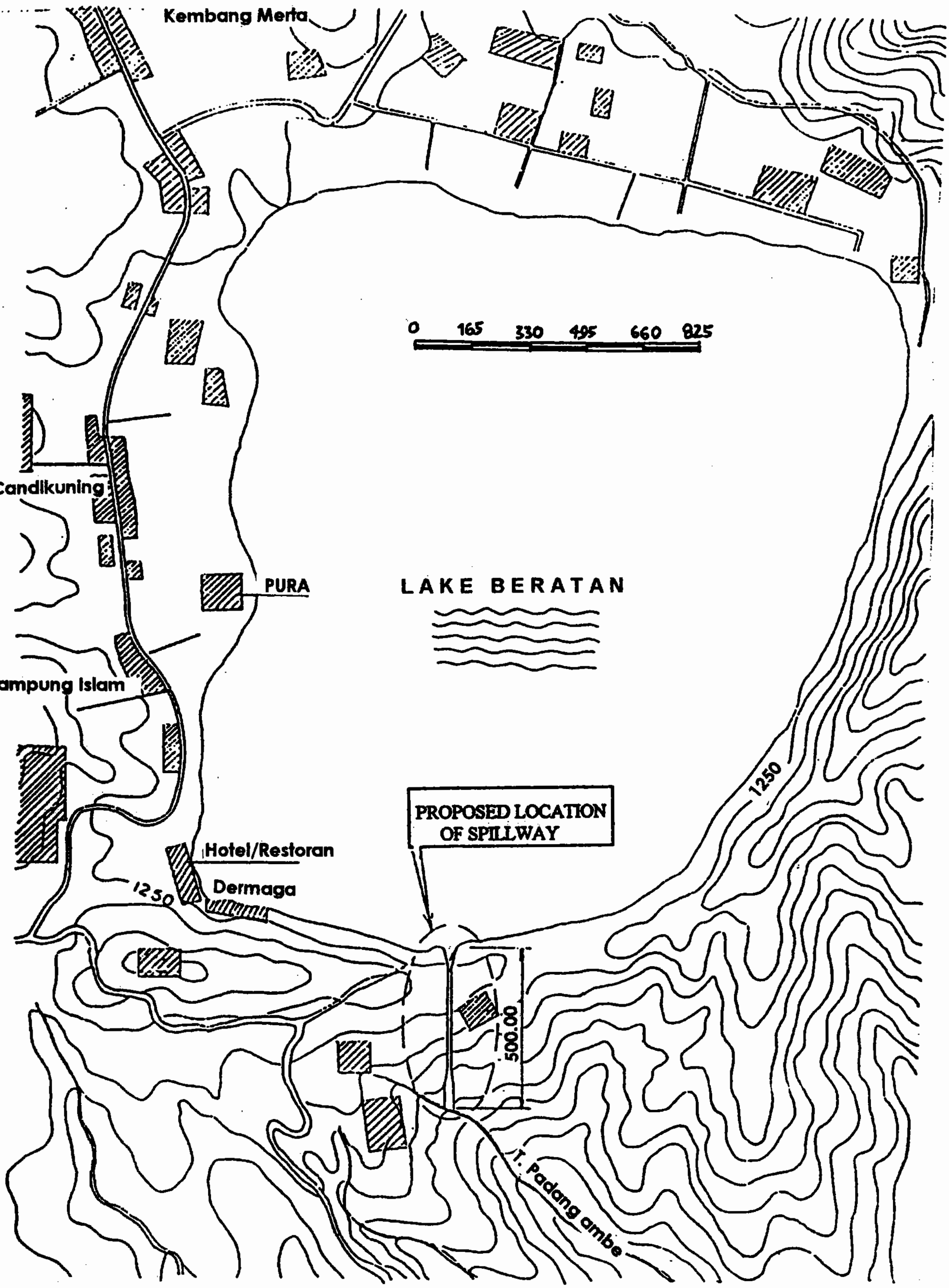

Figure 1. Situation map of Lake Beratan, Bali, Indonesia

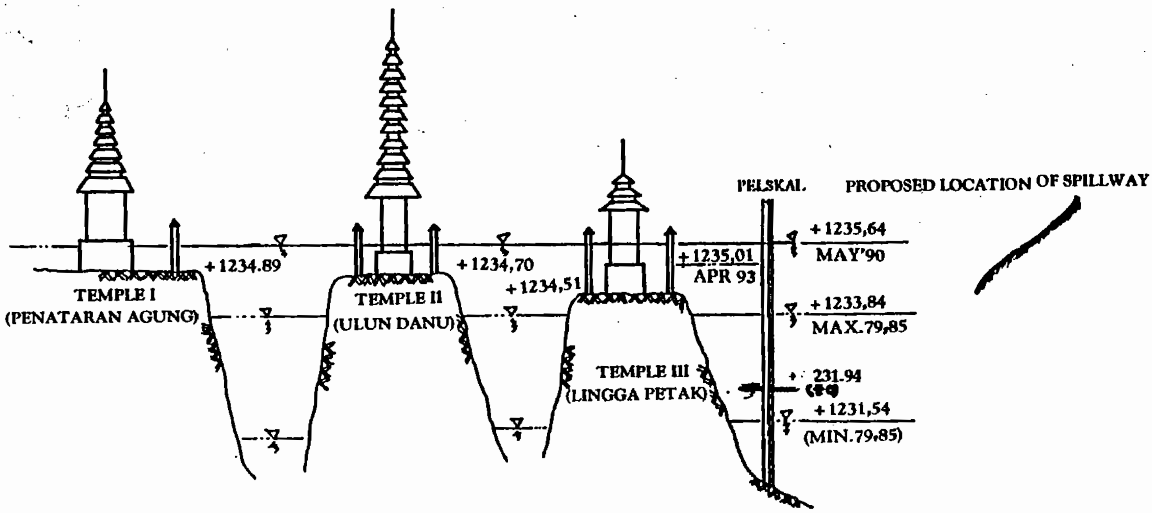

Figure 2. Temples yard elevation to show the position with the water surface fluctuation

minimum and maximum water surface elevation was 1233.85 m and +1237.85 m (Peilschaal reading) respectively. The monthly fluctuation of the water surface elevation of Lake Beratan during the period of January 1969 to December 1991 is presented in Figure 3.

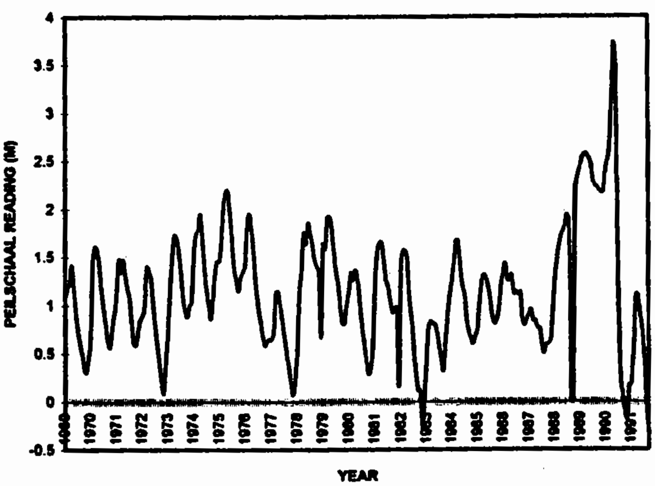

Figure 3. Monthly fluctuation of water surface elevation (January 1969 to December 1991)

The flugtuation of the water surface elevation of Lake Beratan is highly related to the rainfall volume at its cathment area.

From the observation of the rainfall height at the Candikuning rainfall station, it is known that during the 10 year period (January 1960 - December 1969), the monthly rainfall pattern tends to be relatively regular. The dry month generally to be between May and October with the rainfall height of less than 100 mm. The wet month is generally occurs between November and April, with the highest rainfall height ever happened is 503,9 mm. The amount of rainfall in the dry months is about 14.37 % of the west months, and therefore showing the high degree of lack of water in the dry months. Rainfall distribution is generally spread out along the year, however, it also often to be no rain during one month or two months. The monthly rainfall height varies from 146,37 mm to 339,00 mm in the wet season. The change in rainfall pattern in the catchment area may effect the water surface elevation of Lake Beratan *(Needs Assessment and Assistance in the Preparation of Water Resources Management Plan for Bali, 1993)*. It was recorded from the peilschaal that the inundation (referred to zero level) was 2.18 mand 2.19 m in April and May of 1990 the freferable maximum, of 2.16 or at water surface elevation 1236.19 m.

HIDRAULIC SIMULATION OF LAKE BERATAN

A simple governing equation for the spillway routing is utilized for the development of hydraulic simulation of Lake Beratan, i.e.,

$$I = O - \left(\frac{\Delta S}{\Delta t}\right) \qquad 1)$$

where :

I = inflow discharge
O = outflow
ΔS = volume of water
Δt = time

In order to make the calculation easy, the above equation is then changed into the following form :

$$\left(\frac{I_1 + I_2}{2}\right)\Delta t + \left(\frac{O_1 + O_2}{2}\right)\Delta t = S_2 - S_1 \qquad 2)$$

where :

S_1 = reservoir storage at initial time t
S_2 = reservoir storage at end time t
I_1 = inflow to the lake at initial time t
I_2 = inflow to the lake at end time t
O_1 = outflow through spillway at initial time t
O_2 = outflow through spillway at end time t

The amount of water spilled out through spillway is calculated based on the A. Harrold formula, (Design of Small Dams, 1987), i.e.,

$$Q = C\,B\,H^{1,5} \qquad 3)$$

Where :

Q = discharge through spillway (m^3/s)
C = coefficient of overflow through spillway crest (~2,2)
B = width of spillway (m)
H = depth of flow over the spillway crest (m)

The development of hydraulic simulation of Lake Beratan is based of the principle of hydraulic flood routing of spillway, and a FRSPILL computer program is assembled. The required data for the purpose of simulation may be described as follows:

1. The inflow pattern of Lake Beratan in the form of water surface fluctuation during 1969 to 1991.
2. The storage characteristic of Lake Beratan in the form of relationship between the water surface elevation versus storage area versus storage volume.

From the above mentioned data, the width and elevation of the spillway crest is then introduced to the FRSPILL to study the water surface fluctuation, the inundation pattern (depth and duration), and the annual discharge spilled out from the lake.

RESULTS AND DISCUSSIONS

By the use of the FRSPILL, the variation on width and elevation of spillway crest may give the information on the pattern of inundation and discharge through spillway as indicated in Table 1 (based on the 1990 inflow pattern)

It can be seen from Table 1 that at a given characteristic of spillway crest (30.00 m width and +1235.00 m elevation) the maximum inundation on the yard of each temple is 0.00 m, and 0.52 m, and 0.57 m for Temple Penataran Agung, Temple Lingga Petak and Temple Ulun Danu, respectively. This magnitude of inundation is considerably small, besides the occurrance of such situation is rarely in the case.

In term of 1990 inflow pattern, the 8.639 million m3 discharge spilled out from the lake, is also considered very small, particulary in the conservation of water view point. The contribution to the raise in peak discharge at the down stream channel due to the presence of the spillway is considerably negligible. Further simulation of FRSPILL with various inflow pattern will give the information on the frequency of overflowing.

CONCLUSION

1. Hydraulic simulation of Lake Beratan by the use of FRSPILL can give better illustration to see various condition of the spillway characteristic.
2. The presence of the spillway with the characteristic of 30.00 m width and 1235.00 m crest elevation may give the optimum goal by means of reducing the inundation at the temple yard, as well as the conservation of water.

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REFERENCES

United States Department of the Interior, Bureau of Reclamation, 1987, *Design of Small Dams*, United States Government Printing Office, Denver, Colorado, USA.

GEO ACE Eng. Consultant in association with BINAKARYA Eng. Consultant, 1995, *Study of the Development of the Water Resources Potentiality and its Conservation*, Water Management and Flood Control Project, Department of public Works.

Canadian International Development Agency, 1993, *Needs Assessment and Assistance in the Preparation of Water Resources Management Plan for Bali*, Department of Publics Works.

Table 1 Simulation result from FRSPILL with various spilway crest characteristic

No.	Spillway Crest Characteristic		Depth of Inundation (m)			Duration of Inundation (days)			Spill (million,m^3)
	Width (m)	Elevation (m)	Temple 1 (Penataran Agung)	Temple 2 (Lingga Petak)	Temple 3 (Ulun Danu)	Temple 1	Temple 2	Temple 3	
1	30.00	1235.00	0.00	0.52	0.57	0	109	109	8.639
2	25.00	1235.00	0.01	0.54	0.59	13	112	112	8.647
3	35.00	1235.00	0.00	0.51	0.55	0	108	108	8.635
4	30.00	1235.25	0.24	0.77	0.82	108	108	108	7.761