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LAKES AND RESERVOIRS IN INDONESIA: THEIR UTILIZATIONS AND PROBLEMS

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ABSTRACT

Indonesia has a lot of lakes and reservoirs, but not all of them have been inventorized. The estimate total area of Indonesian natural lakes is about 1 million ha and the reservoirs about 53,000 ha. They are used for various purposes such as for domestic use, fishery, agriculture, industry, electricity, recreation etc. The rapid population growth rate and the rapid development in all sectors raises a lot of environmental problems including those concerning the lakes and reservoirs. Various major problems are faced such as sedimentation, domestic waste, industrial waste, pesticides, eutrophication and aquatic weeds. Sound management of the aquatic resources is needed although it is not easy. It needs a good coordination and participation of the experts, institutions and the public as well.

Keywords: lakes, reservoirs, pollution, eutrophication, aquatic weeds, lake management

INTRODUCTION

Indonesia is a vast archipelagic country in the tropic lying in the cross road between Asia and Australia, and between the Pacific and the Indian Ocean. The total area of Indonesia is about 5 million km^2 comprised of land about 1.9 million km^2 and territorial and inland seas about 3.1 million km^2. The maximum length from the westernmost to the easternmost points is about 5,000 km. It consists of more than 17,000 islands with a total length of coastline more than 80,000 km.

The total Indonesian population is about 180 million (1988) which is number five in the world, and is still growing at a rate of about 2.1 %. The average population density is 85/km^2. The population, however, is not evenly distributed. About 60 % of the total population lives in Java, an island with an area of only 7 % of the total land, where the populatin density is as high as 755/km^2. On the other hand in Irian Jaya and Maluku the population is very sparse with a density of only 6/km^2. It is estimated that by the year 2000 the total Indonesian population will reach 210 million people with a growth rate levelling about 1.8 % .

Limited land area confronted with high population growth rate and coupled with the raising living standard raises a lot of environmental problems. The increasing demand for space, food, water, and industrial products forces Indonesia to intensify the utilization of her natural resources. In many instances conflicting interests occur. On one side the natural resource should be exploited but on the other side we have to protect them so as not to impair the environment we are living in. Although the development now is directed toward the principle of sustainable development, in which there is a harmonious relations between utilization and conservation of resources, yet it is not easy to put it into practice in the real world.

Parts of the natural resources comprise the inland waters such as lakes, reservoirs, rivers, and swamps which provide various water uses e.g. for drinking, fishery, agriculture, industry, electricity, recreation etc. The demand for water is kept increasing while the water supply is limited, and in many instances the conditions are deteriorating. It is obvious that water resources will become one of the most important environmental issues in the days to come.

In this scheme the present paper attempts to give a review on the inland water resources in Indonesia with special emphasis on the utilization and problems of the lakes and reservoirs.

LAKES

According to Soerjani (21) the total area of Indonesian natural lakes is about 1 million ha which is about 54 % of the existing 1.85 million ha of all lakes in Southeast Asia. Major natural lakes in Indonesia are found mostly in Sumatra (48 %), Sulawesi (47 %), and a few in Kalimantan (3.5 %) and other islands. The total number of lakes in Indonesia has not been inventorized. A list of major lakes in Indonesia and their surface area, maximum depth, and elevation is presented in Tabel 1.

Our knowledge on these lakes is generally still very meagre or even does not exist at all for many of them. Ecology of most of the major lakes in Irian Jaya, for instance, from the low land to the high montane ones is practically unknown. Lake study in Indonesia was started by the German "Sunda Expedition" in 1928 - 1929. During their 10 months limnological works, thorough studies were conducted on 15 lakes in Sumatra, Java and Kalimantan (17). The reports, written by over 100 experts, were published mostly in *Archiv für Hydrobiologie (Supplement)* between 1931 and 1958 and still become important references for inland water ecological studies. After 1950 some ecological studies on Indonesian lakes were conducted but rather sporadically and mostly done by the Inland Fisheries Research Institute, Asean Tropical Biology Institute (BIOTROP), University of Indonesia and Department of Public Works.

The largest lake is Lake Toba (112,970 ha) in Sumatra with a maximum depth 529 m and the second is Lake Towuti (56,108 ha) in Sulawesi with a maximum depth 203 m. The deepest lake in Indonesia is Lake Matano (590 m) also in Sulawesi, with the

Tabel 1. Major lakes in Indonesia

Province/Island	Lake	Max. area (ha)	Max. depth (m)	Elevation (m)	Reference No.
Aceh/Sumatra	1. Laut Tawar	7,000	80	1,100	19
North Sumatra	2. Toba	112,970	529	905	18
West Sumatra	3. Maninjau	9,790	169	465	16
	4. Singkarak	10,780	269	362	16
	5. Dibawah	1,200	80	800	19
	6. Diatas	1,220	44	1,531	16
Jambi/Sumatra	7. Kerinci	5,700	110	783	20
South Sumatra	8. Ranau	6,000	180	600	19
West Kalimantan	9. Sentarum	80,000	8	35	20
Central Kalimantan	10. Sembuluh	7,500	?	30	20
East Kalimantan	11. Semayang	12,000	6	?	19
	12. Jempang	15,000	6	?	19
North Sulawesi	13. Tondano	5,000	20	600	30
	14. Limboto	5,600	2.5	25	30
Central Sulawesi	15. Poso	32,320	450	500	30
	16. Lindu	3,200	100	1,000	30
South Sulawesi	17. Matano	16,408	590	382	30
	18. Mahalona	2,440	73	310	30
	19. Towuti	56,108	203	293	30
	20. Tempe (+Sidenreng & Buaya)	35,000	2	5	30
Bali	21. Batur	1,590	88	1,031	16
Irian Jaya	22. Ayamaru	2,200	20	250	5
	23. Anggi (Gigi)	2,500	?	1,780	5
	24. Yamur	3,750	?	90	5
	25. Tigi	3,000	?	1,740	5
	26. Paniai	14,150	50	1,742	5
	27. Rombebai	14,000	?	?	20
	28. Sentani	9,360	52	70	5

surface at altitude 382 m the bottom is actually below the sea level.

The origin of many Indonesian lakes is not much known. Lakes Matano, Mahalona and Towuti in Sulawesi were formed tectonically or as a consequence of the movements of the earth's continental plates. These are ancient lakes formed about 1.6 million years ago and contain 26 endemic freshwater animal species (30). Volcanic and caldera lakes are usually found at higher altitudes e.g.: Lakes Laut Tawar, Diatas, and Ranau in Sumatra; Ranu Lamongan in Jawa; Batur in Bali. Lake Toba of Sumatra, the biggest caldera lake in the world, originated from great volcanic eruptions in subsequent events starting about 75,000 years ago

(29). In the low land, Lake Tempe may be mentioned as a depression which appears to be a remnant of an ancient strait connecting Gulf of Bone and Makassar Strait (30). In wet season this lake may be flooded and becomes united with two adjacent lakes, Sidenreng and Buaya.

Many of the lakes have certain relations with the adjacent river system such as the oxbow lakes which may be found in various formations like those found many along the Idenburg River in Irian Jaya. In the inland low land of Sumatra and Kalimantan flood lakes are common where the adjacent rivers seasonally flood and feed the lakes during the rainy season. In the dry season these lakes become dry or almost dry. They generally have high potential fishery production.

The lake water is utilized not only for the long known traditional uses (domestic and fishery) but also for industry, electricity, recreation and tourism. It is estimated that in general fish yield from the lakes is still low, only about 30 % of the potential production (6), but in some lakes overfishing has already occurred such as in Lake Tempe.

Quite interesting is the recent case of Lake Toba. The water was tapped with a rate of 107 m^3/s for a big electric power generator (603 MW) supporting a big aluminium industry (maximum production 225,000 ton/year). This apparently affected a serious lowering of the surface level of the lake from 905.7 to 902.6 m above mean sea level (31) which never happened before. This situation has become a great environmental issues in the last recent years. An international conference on this lake has just been held (May 1990) to discuss the problem as seen from different views.

RESERVOIRS

Traditional irrigation has been long known in Indonesia, it dates back to the 8th century as proved by an old stone inscription along the River Brantas (East Java) describing the opening of an irrigation and flood control system (4). During the early Dutch colonial period small irrigation constructions were built, and in 1919 the first big dam was built at Kali Badak, near the city of Blitar. The construction of Jatiluhur Reservoir (finished in 1967) damming the River Citarum marked the start of modern concept of reservoir in Indonesia, and it is the first multipurpose reservoir in a big scale. The resevoir has an area of 8,300 ha, a volume of 2,970 x 10^6 m^3, and its water is used for irrigation, electricity, fisheries, tourism, and water supply for municipal purposes. Two more reservoirs were built later in the upper course of the river, respectively the Saguling Reservoir in 1985, and Cirata Reservoir in 1988 (2).

Hardjamulia and Suwignyo (7) classify three types of reservoirs in Indonesia: field, irrigation, and multipurpose. Field reservoirs are built by damming creeks or diking valleys to meet the water needs of local community. Irrigation reservoirs supply water for agricultural purposes, they are built by damming relatively small rivers. Multipurpose reservoirs are created by

Table 2: The major reservoirs of Indonesia and their characteristics (source: Hardjamulia and Suwignyo, 1988)

Reservoir	Purpose[a]	Volume (X 10^6 m^3)	Area (km^2)	Drawdown (m)	Annual fish yield (kg/ha)	Fish species[b]
			West Java			
Darma	I	40	4.0		270	T,C,L
Lido	I		0.3			T,C,L
Jatiluhur	F,E,I	2970	83.0	32.0	15	T,C,L,H,S,P,M
Saguling	E	982	53.4	20.0		T,C,L,J,S,M
Cirata	E	2165	62.0	20.0		
			Central Java			
Cacaban	I	86				
Sempor	E,I	52		29.0		
Wonogiri	F,E,I	736	90.0	9.0		T,C,L,H,S,P
Wadaslintang[c]	E,I	443	14.6	61.0		
Kedung Ombo[c]	E,I	723	46.0	25.0		
			East Java			
Prijetan	I	10	2.2		50	
Pacal	I	41	4.5		380	
Selorejo	F,E,I	62	4.0	24.0	250	T,C,L,P,S
Karangkates	F,E,I	343	15.0	26.0	50	T,C,L,H,M,S
Lahor	E,I	37	2.6	19.0	50	T,C,L,H,M,S
Wlingi	E,I	24	3.8	1.5	25	
Bening	E,I	37	5.7	12.0	150	T,L,S
Wonorejo[c]	E,I	122	3.8	42.0		
			Lampung (Sumatra)			
Way Jepara	I	50				
Way Rarem	I	72		6.8		
			South Kalimantan			
Riam Kanan	F,E,I	1200	92	8.0		T,C,L,H,S,M
			West Nusa Tenggara			
Batujai	I	17	8.9	5.0		

[a]I, irrigation; F, flood control; E, electricity.
[b]T, *Tilapia mossambica* and *Tilapia nilotica*; C, common carp (*Cyprinus carpio*); L, lampam (*Puntius gonionatus*); H, hampala (*Hampala macrolepidota*); S, snakehead (*Ophicephalus seriatus*); P, pangasius (*Pangasius pangasius*); M, macrones (*Macrones nemurus*)
[c] , Reservoir under construction.

impounding relatively large rivers for irrigation,flood control, electricity, and to supply water for industrial and municipal purposes. The total area of reservoirs in Indonesia is estimated about 53,000 ha (7). An illustration of major reservoirs in Indonesia and their characteristics is presented in Table 2. More and more reservoirs are built elsewhere to meet the increasing demand for irrigation, electricity, flood control etc.

One of the new reservoir is Kedung Ombo (Central Jawa), inundation began in January 1989 and is planned to irrigate 59,645 ha rice fields and generate 22.5 MW electricity. For this project about 5,400 farmer families of the population from the inundated area should be resettled or transmigrated to other place which it self poses great social problems. The displaced traditional farmer who choose to stay near the lake have to turn their life for new jobs created by the new reservoir environment. As experienced from the earlier construction of other reservoir, Saguling, most of the displaced people from the inundated area (about 3,000 families) still chose to stay around the new reservoir, and they have turned their life from the former land farmer to become fish farmer and get better income by applying the floating net aquaculture or other agroaquaculture activities (2, 3).

MAJOR PROBLEMS

(1) Sedimentation

Forest clearance, traditional shifting cultiviation, and improper land use practices by neglecting the principles of land and water conservation has resulted the problems of erosion and sedimentation. The decrease of vegetation cover in a watershed affects the characteristics of river discharge, flood may occur in the wet season and drought in the dry season. Eroded top soil is washed into the river causing the water turbid by heavy sediment load. A great part of the transported material may be deposited in the lakes or in the reservoirs and thus shorten their economic life time. A number of cases may be taken as examples.

Lake Tempe in South Sulawesi is becoming shallower with a sedimentation rate of about 10 - 20 cm/year and the fish production is declining very much especially if compared to those a few decades ago (22). A recent study, however, shows that when the sediment outflow via the Cenrana River is also considered the net sediment accumulation is only 1 cm/year (30). The same is true for many other lakes such as Lake Tondano and Lake Limboto, both in North Sulawesi. Lake Tondano receives an annual input of eroded sediment about 4,000 tons or sedimentation rate about 20 cm/year due to the sediment inflow from the many inlets and erosion from surrounding agricultural activities (30). Lake Limboto which originally had an area about 6,000 ha, now decreasing to about 5,000 ha, and the depth which formerly about 30 m now becomes about 2.5 m (19, 30).

Reservoirs also get the negative impact of erosion. The upper Citarum basin leading to Saguling Reservoir (West Java) has an erosion rate ranging from 1.82 to 5.20 mm/year with a mean 3.35 mm/year (2). Hydrological conditions of the upper Citarum basin are changing, particularly during the last decades, but unfortunately the change is leading to an increased erosion rate. Gajah Mungkur reservoir (Central Java) has even larger sedimentation rate of about 8.58 mm/year. It is estimated that with this rate the life time of this reservoir becomes much shorter than originally expected.

Integrated watershed management programmes have been launched in many regions where one of the objectives is to control the soil erosion. Efforts have been done to remedy the situation among others with regreening and reforestation of the upper region of the watershed. Based on the critical land condition, the Government of Indonesia has identified a total of 39 watersheds as priority for integrated management, development and upgrading activities in the current Five Year Development Programme (1989-1994) among others the watersheds of the rivers Citarum, Cimanuk, Citanduy, Solo, Serayu-Lok Ulo, Brantas (Java), Asahan (Sumatra), Sadang, and Bila-Walanae (Sulawesi).

(2) Domestic Waste

Water pollution due to domestic waste generally may be associated with high population concentration near rivers or other water bodies. River systems crossing big cities such as Jakarta, Bandung, Semarang, and Surabaya, have suffered from the heavy load of domestic waste. As an illutration the case of Jakarta and its vicinity is described shortly below.

Within 60 km radius from Jakarta there lies three cities *viz*. Bogor, Tangerang, Bekasi which grow fastly and tend to become united physically with metropolitan Jakarta. The whole area is popularly known with an acronym Jabotabek. Twelve main rivers and their tributaries and various canals flow through the area forming a complex river system. The population of Jabotabek is about 11,9 million people (1984). Municipal sewerage system does not exist in this area. It is estimated that about 3 million people of the population dispose their waste directly (15). This means that 5,3 million people or 44,75 % of the population of Jabotabek contribute their waste to the rivers. In term of BOD (Biochemical Oxygen Demand) this input is estimated equal to about 120 ton BOD/day. If the population growth rate in this area is assumed constant about 2,5 % then in the year 2000 about 5,57 million people will dispose their waste into the river and the pollution load will be 178 ton BOD/day (15). The pollution-loaded rivers and canals flows to the sea or through flood control reservoir such as Pluit Reservoir, North Jakarta. This reservoir is in fact has been over loaded.

Saguling Reservoir also receives the effluent of three major cities (Bandung, Cimahi,Padalarang) through the river Citarum and makes the reservoir eutrophicated.

All the river waters as well as adjacent shallow well waters in Jakarta have been contaminated with coliform bacteria. Detergent used by the population is another source of pollutant which also contaminate the water system of Jakarta (24). The foam it produces sometimes may be seen in the river courses and this too poses a problem for the municipal drinking water plant. Beside that, the phosphorus of the detergent may contribute to the euptrophication of the water.

(3) Industrial waste

A great number of factories dispose their waste into the open waters without or with only partial treatment causing a great pollution problem. Some factories, even the large ones, which own waste treatment plants have not been able to treat their waste properly (8). Small scale or home industries which are also abundant generally do not treat their waste at all but their contribution to the water pollution is usually overlooked. A lot of cases have been reported on the degrading quality of the open waters due to the industrial waste. Although the Government has decreed the Environmental Act (1982) which regulate a.o. the pollution control, the implementation and law enforcement is still inadequate.

A short glimpse may be paid again to the industries in Jabotabek area as potential for water pollution. A study by Puslitbang Pengairan (15) has shown that more than 250 industries which may be classified as potential water polluters are located in this area. Industries which dispose considerable organic wastes to the open waters are : textile industry, paper industry, and leather industry. Altogether they contribute about 42,0 ton BOD/day which is about 35 % of the total domestic waste load.

Toxic and dangerous substances may also be discharged into the water system and affect the aquatic life. Heavy metals have been found in several aquatic organisms from the coastal waters of Jakarta which indicate the bioaccumulation of the toxic heavy metals generally disposed from industries (9). It is also reported (26) that heavy metals especially mercury and lead were in high concentration in the River Sunter of Jakarta.

Around a small lake ,Situ Rawa Kalong, Bogor, five industries (electroplating, garment, aluminium ware, plastic ware, and cosmetics) dispose their waste into the lake making the water highly polluted. Studies on the ecological impacts and restroration are still underway by the Reserach and Development Centre for Limnolgy supported by the local gaovernment.

To cope with the water pollution problems, especially in the rivers, a Clean River Programme (Prokasih) was lauched in 1989 where the government, industries and the public are involved to clean up 20 rivers in eight provinces which have been regarded as very seriously polluted.

(4) Pesticides

Intensive and extensive agricultural techniques have brought Indonesia from the biggest rice importer in the world to sucessfully self suport her own food needs. This has been made possible by modern agricultural practices using qualified seeds, irrigation improvement, fertilizer, and pesticides. The use of pesticides is actually increasing from year to year. Extensive use of pesticides in agriculture as well as in health programmes can pollute the water systems. The application of pesticides, especially the persistent ones can do harm to aquatic life and other organisms as well through the food chain mechanism.

Most of the pesticides used are insecticides, followed by herbicides and fungicides. There are about 48 kinds of insecticides currently used in Indonesia which have been registered at the Pesticide Committee of Indonesia (25) which may be grouped into organophosphates, organochlorines, carbamates, and miscellaneous compounds. Of all the insecticides, diazinon (organophosphate) is used in the largest quantity. DDT (organochlorine) is of restricted use for malaria control only, however it happened occasionally that DDT is used in agriculture by farmers. The organochlorines are well known for their long persistency and can be highly magnified biologically from the lower to the higher trophic levels.

Pesticide residues have been measured in several places in Indonesia. It has been summarized by Sumatra (26) that DDT residues and their metabolites were found in several component of the environment in many places in Java. They were found in water, sediment, benthos, fish, and agriculture land. Other organochlorines which were also found in some of the samples were endosulfan, aldrin, dieldrin, and lindane. On the other hand Koesoemadinata (11) using the common carp (*Cyprinus carpio*) and tawes (*Puntius gonionotus*) as test fishes found that about 64 % of the insecticides formulations commonly used for pest control in irrigation fields were highly toxic to fish, 20 % moderately toxic, and only 16 % of low toxicity.

(5) Eutrophication and Aquatic Weeds

Eutrophication or the exessive nutrient enrichment of the water bodies may enhance the growth of unwanted plants or aquatic weeds. The source of eutrophication may come from domestic waste, washing of agricultural fertilizer and erosion of the watershed.

Pancho and Soerjani (14) listed 112 aquatic weeds occurring in the Southeast Asian countries, while Tjitrosupomo *et al.* (28) mentioned about 150 species in Indonesia not including algae. In the Lake of Rawapening (Central Jawa) 215 species of aquatic weeds were reported by Notosudarmo *et al.* (13). These figures alone give an idea of the rich varieties of aquatic plants in Indonesia.

Not all of these plants are indigenous to Indonesia. Water hyacinth (*Eichornia crassipes*), for instance, was imported to Indonesia in 1894 and again *Salvinia molesta* came in 1951 (27). In a short time after their introduction these aquatic weeds had spread all over the open waters. They got easily established in their new environment and spread so rapidly that native aquatic plant could be suppressed.

Suryani and Widyanto (23) listed 20 aquatic weeds in Indonesia in order of their importance which is determined by their wide distribution, significant nuisance resulted, difficulties in controlling, and poor or unknown utilization. The top four on the list are *Eichornia crassipes*, *Salvinia molesta*, *Pistia stratiotes* and *Hydrilla verticillata*.

Heavy infestation of aquatic weeds has become real nuisance to many of our lakes, and reservoirs. This is due to their rapid vegetative growth rate. Soerjani and Widyanto (23) for instance, showed that in the optimum condition as found in Bogor the leaf addition rates of *Eichornia, Salvinia, and Pistia* varied between 7.5 - 12.5 %/day and their fresh weight increase between 13.8 - 27.9 % /day. In the field the area covered by *Salvinia molesta* can double in extent every 2.2 days under optimum growth conditions (30).

Excessive growth of aquatic weeds may have harmful or disadvantageous effects to fisheries, irrigation, water transportation, generation of electricity, aesthetics, and human health. Beside that, these plants also play important roles in evapotranspiration and silting process of lakes, waterways, swamps, marshes, pools and other wet places because of their accelarating effect in the process.

In the lake Rawa Pening (Central Jawa) several species of aquatic weeds (mainly *Eichornia*) forming large and thick mat of floating island which is very difficult to control and the coverage sometimes up to 1000 ha or about 50 % of the surface area (28). A new reservoir, Waduk Saguling (West Jawa), filled in 1985 has been infested by *Eichornia*. The beautiful Lake Kerinci (Sumatra) is also facing the same menace where more than 500 ha has been covered. In South Sulawesi, during dry season aquatic weeds may cover about 45 % of the surface area of Lakes Tempe and Sidenreng (12). Similar situation has been reported from all over Indonesia.

The explosion of aquatic plants is not always happening to macrophytes but to phytoplankton as well. In the reservoir of Jatiluhur (West Jawa), the blooming of the planktonic blue-green algae, *Microcystis* sp., has been reported (10) but the occurrence has diminished after two more reservoirs were built (Saguling and Cirata) in the upper reaches of the same river. Blooming of *Microcystis* also happens in many lakes, for instance in the artificial lake of Sunter (Jakarta) built in 1979. Formerly the lake was still in good condition and used for water sport and recreation, but today, about ten years afterward, the quality of the water becomes so much deteriorated, so that almost no people like to swim in the very thick "soup" of *Microcystis* which sometimes producing strong foul smell.

Attempts to control the aquatic weeds in Indonesia has been done mechanically and chemically but only with partial success. Mechanical control is done by removing the plants out of the water. The very fast proliferation of the plants, however, has made most of the efforts fail. Chemical control using herbicides has also been attempted but growing concern on our environment has not favoured the wide use of chemical measures. Biological control using herbivorous grass carp (*Ctenopharyngodon idella*) has also been tried but still in experimental stage. Other alternatives are by utilizing the plant mass such as for animal feed, compost, biogas, handicraft, paper production, medium for mushroom culture etc, but these have been done only in small scales due to their small economic profit. In fact, the best way to control the aquatic weeds is still to be sought which should be ecologically safe, feasible and economical.

Eutrophication and lake restoration study is being done by the Research and Development Centre for Limnology in Lake Bojongsari and Situ Rawakalong (West Java). Injection of oxygenated water into the lower hypolimnion layer as applied at Lake Bojongsari gives promising results, further studies are still under way.

(6) Conversion of Lakes

The high population pressure on the land and the ignorance on the values of the lake ecosystem functions have caused many of our lakes, especially the smaller and shallower ones, are dried or converted to other functions and hence the numbers and total area are decreasing. Many of the lakes are becoming dried because the waterways leading to the lakes are obstructed or diverted and thus shorten the life of the lakes. In other cases they are converted to agricultural land, rice field, housing, industry etc. An inventory of lakes in the districts of Bogor-Tangerang-Bekasi (West Java, surrounding Jakarta) conducted in 1986 has revealed that the number of small lakes in this area (ranging in size between <3 to 30 ha) has decreased from the original 173 to 128 or about 26 % of them has gone , or in term of area a decrease from 1608 ha to 791 ha (1). The government has taken steps to stop further elimination of the lakes and restotations are enhanced. No information available from other regions but it is likely that the same conditions occur as well.

LAKE MANAGEMENT

A natural aquatic environment is not a completely closed system. The condition of a lake, for instance, is very much influenced by the input coming from the surrounding land, and on the contrary the lake also influences the land. Management of a lake, therefore, should be based on a large information concerning all the factors determining the condition of the aquatic system, directly or indirectly. It deals not only with the physical aspects of the environment, but also with the socio-economical aspects. Sound management should be done with an holistic approach where interrelationships and interdependencies among various factors should be thoroughly considered. In the real practice, environmental management is not easy. It needs a good coordination among various experts of different disciplines, involvement of government at various levels, non-government organizations, and the general public as well.

In Indonesia the Office of the State Minister of Environment has a leading role in the coordination of major environmental programmes. At the provincial level the Local Development Planning Board (Bappeda) holds the main coordination functions.

From the legal point of view the issuance of the Environmental Act No. 4/1982 is very important concerning the basic provisions for the management of living environment. The basic principle is that the management of the living environment is based upon the sustenance of the capability of the harmonious and balanced environment to support sustainable development for the improvement of human welfare. To mitigate the risk of pollution and destruction of environment every plan which is considered likely to have significant impact on the environment must be accompanied with EIA (Environmental Impact Analysis) as stated in the Government Regulation No.29/1986. The protection of the living environment shall be based on environmental quality standards, covering air and water quality standards (Decree of State Minister for Environment No. 2/1988) which is to be used as basis for environmental management.

It is apparent that for the implementation a great number of experts are needed. To meet this requirement environmental education is enhanced. Centres for Environmental Studies have been set up at many of the state universities throughout Indonesia. Some of these centres have done various studies on water quality and environmental impacts on the aquatic ecosystems. The role of research institutions in many of the government departments have also been promoted and involved in facing the multidimensional environmental problems in the country. In line with this, public education in environment is also enhanced.

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