ICIWRM – 2000, Proceedings of International Conference on Integrated Water Resources Management for Sustainable Development, 19 – 21 December, 2000, New Delhi, India

Environmentally sound management of lake Erhai and the Xier river basin

INTERNATIONAL ENVIRONMENTAL TECHNOLOGY CENTRE[1]

Abstract

Lake Erhai is a freshwater lake nestled like a pearl on a plateau in the central part of the Dali Bai Autonomous Prefecture, Yunnan Province, People's Republic of China. The Lake has a surface area of 250 km^2, average depth of 10.2 m, and a capacity of 2.93 billion m^3. Its drainage area includes parts of Eryuan County including the City of Dali. Despite the numerous brooks and streams draining into Lake Erhai from the Cangshan Mountains, the Lake has only one outlet, the Xier River, which flows into the Lancangjiang River and, ultimately, into the Mekong drainage system. Lake Erhai is famous for its beautiful scenery and has a long history associated with the distinctive culture of the people of Bai nationality. The steep, snow-covered Cangshan Mountains and the clean blue waters of the Lake, reflecting the 2,200 meter mountain peaks and forming the habitats for various plants and wildlife, form a very beautiful picture and people can hardly tear themselves away from its beauty.

A number of environmental problems have emerged from the economic development of the area causing important environmental impacts in the lake and the basin. However, because of the great importance attached to the environment of the drainage area of Lake Erhai, China have joined together with international institutions to protect and restore this freshwater body.

This paper is the integrated result of the investigations, analyses, and syntheses carried out in the area by relevant departments of the Country, in cooperation with UNEP-IETC and other agencies. It reports on the outcome of the environmental planning program carried out under the auspices of the United Nations Environment Programme (UNEP), and the success of pilot-scale projects for the development of environmental infrastructure conducted under the auspices of the United Nations Development Programme (UNDP) in China.

For administrative reasons, recommendations given in this report regarding environmental management within the study area are made at the Prefectural level. Such recommendations, therefore, are wider in scope than the Lake Erhai and Xi'er River system. However, as many of the recommendations also apply to the Lancangjiang River drainage basin and the Mekong River, this level is considered appropriate to meeting the objectives of the project.

INTRODUCTION

The main objectives of the environmental planning and management plan of the Lake Erhai basin was the protection of the lake's water quality and quantity and also preserve the biodiversity.

---

[1] Presented by Vicente J. R. Santiago Fandino

Lake Erhai (Figs 1, 2 and 3) is a through-flow lake located within a 2,565 km^2 drainage basin situated upstream of the 146 km^2 Xi'er River watershed, between latitudes 25^0 25'N and 26^0 16'N, and longitudes 99^0 32'E and 100^0 27'E in China. The 23 km long Xi'er River flows out of Lake Erhai, forming part of the Lancangjiang River drainage system, which, in turn, is part of the headwaters system of the Mekong River. Since 1992, water abstracted from Lake Erhai has been used to augment the water resources of Binchuan County. The study area, shown in Figures 1 includes Dali City, Dali County and part of Eryuan County within the Dali Prefecture, Yunnan Province, Peoples' Republic of China. The area has a population of 716,900.

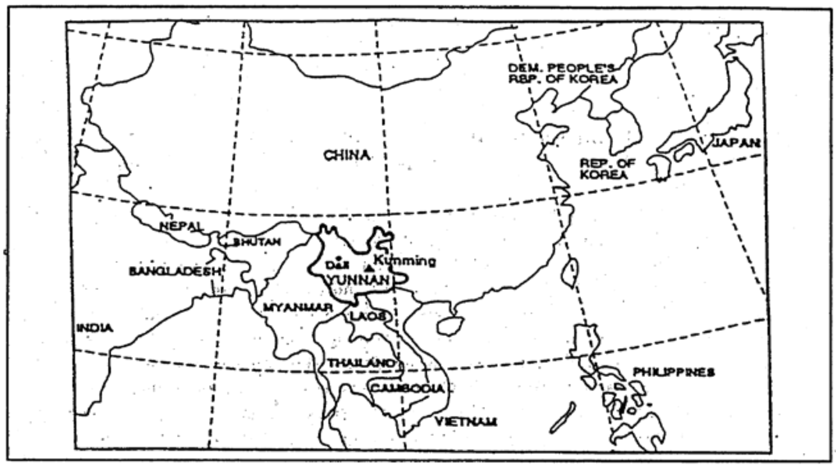

Figure 1. Lake Erhai. Geographic Localization of the Yunnan Province, China.

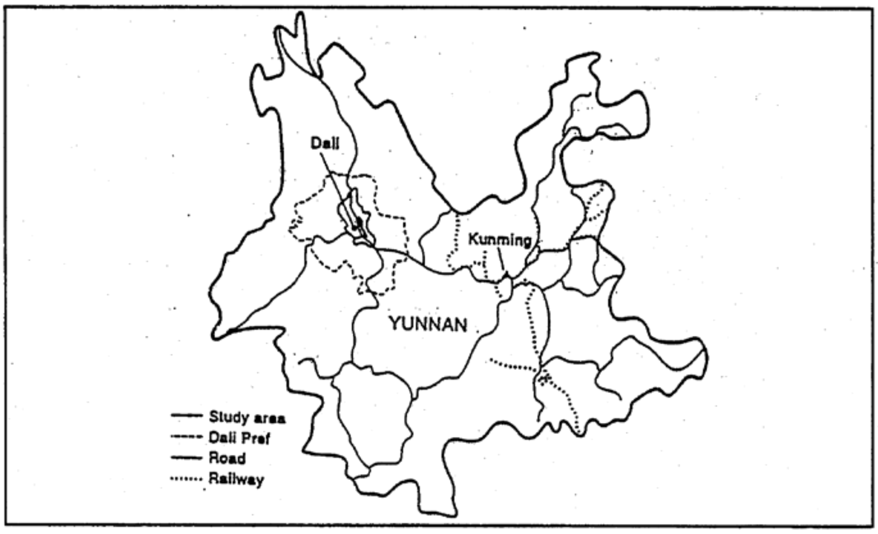

Figure 2. Lake Erhai. Geographic localization of Dali City, China.

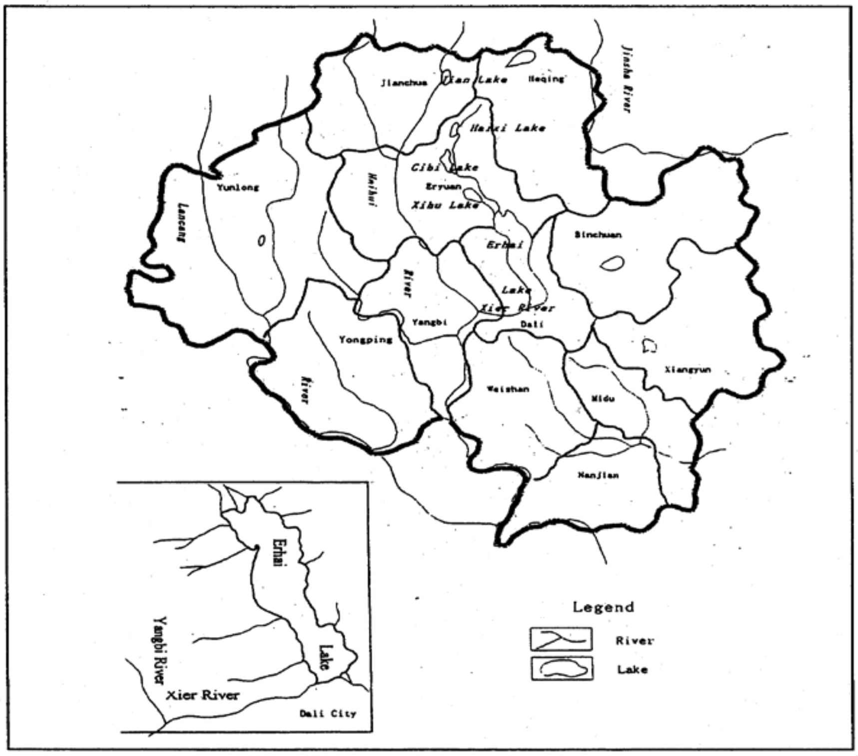

Figure 3. Lake Erhai and Xier River Basin. China.

The Dali Prefecture is characterized by a mountainous topography, with three principle ridges running in an approximately northwesterly-southeasterly direction through the Prefecture. These ridges are formed by the Laojun, Diancang, and Ailao mountain ranges The eastern part of the Dali Prefecture lies on the Yangtze paraplatform at an altitude of 2,800 m above sea level, while the western part of the Prefecture lies within the Shanjiang fold at an altitude of 3,074 m to 4,122 m above sea level. Lake Erhai lies in a deep valley between these two features.

The study area is situated within a gorge located in the southwestern portion of the Southern Hengduan Mountains. It is bordered on the west by the Cangshan Mountain range; lacustrine, alluvial and proluvial deposits accumulating on the eastern slopes of the Cangshan Mountains formed Lake Erhai during the early Pleistocene. The gorge in which the lake is situated slopes from the plateau in the northwest in a southeasterly direction. Thus, three categories of landform--mountain, basin, and valley--exist within the study area. Among the surrounding mountain peaks, Yunling to the northwest of the lake, is the dominant one.

Climatically, the basin lies within the low latitude, subtropical monsoonal climatic zone. The annual mean temperature is about 15^{o}C, ranging from 5^{o}C during the coldest month (January) to 25^{o}C during the hottest month (July), with an average relative humidity of

66 percent. The average annual sunshine is between 2,250 to 2,480 h yr^{-1}. Prevailing winds are from the southwest at an average velocity of 2.3 m s^{-1}. The average annual precipitation is 1,048 mm, concentrated during the period between June and October. The area has abundant sunshine and an equitable climate.

The average annual surface runoff in the Lake Erhai area is 1.5×10^9 m^3. Water entering Lake Erhai is derived mainly from rainfall and snowmelt. Lake Erhai is the fourth lake in a chain of lakes, To the west of Lake Erhai are 18 montane rivers draining to the lake from the slopes of the Cangshan range, while, to the south and east, the Boluo, Haichao and Yulong rivers and several smaller streams flow into the lake.

The only outflow of Lake Erhai is the Xi'er River, which flows into the Heihui River at Yangbi Pingpo, a drop in altitude of 610 m. The Heihui River then joins the Lancangjiang River as part of the Mekong River system. In the early 1990s, a diversion tunnel was constructed on the southern shore of the lake to divert water to Binchuan County.

The Cangshan Mountains and the Lake Erhai district of the Dali Prefecture is a national natural reserve and there is a varied type of topography and typical stereoscopic climate of high mountains, there are a number of rich and diverse ecosystems in the area, including forest, meadow, desert, plateau and wetland ecosystems. The Cangshan Mountains, bordering the study area, form one of the habitat types, being a well-known example of an high mountain floral system. Similarly, Lake Erhai is the second largest upland lake in China, and is a typical representative of upland freshwater lakes.

The Cangshan and Erhai natural reserve is also rich in animal and plant resources. To date, 2,330 species of seed plants, 15 percent of the total number of seed plants in Yunnan Province have been identified within the study area. Of these plant species, 46 species are hydrophytes present in Lake Erhai. There are also 195 species of algae in the lake. Within the natural preserve, there are 26 species of rare and endangered wildlife and a large quantity of various crop species of economic import. Four of these crop species are under second grade national protection and ten are under third grade national protection. Three crop species are endemic species to China; four are found only in Yunnan Province, and five only in the Cangshan Mountain preserve. The area is also rich in floral resources, including all eight of the flowers for which Yunnan Province is famous. As a center for rhododendrons, the Cangshan Mountain area boasts 44 kinds of different rhododendron, accounting for 10 percent of the total number of variants in China and 18 percent of the total number in Yunnan. In addition, 601 species of medicinal plants, belonging to 199 families, grow in the area.

Based on wildlife inventories, there are 285 species within the natural reserve (consisting of 82 species of mammals, 170 species of birds, and 33 species of fish). In addition, there are 148 species of lower animals. Of the total number of wildlife species present in the study area, eight are under first grade national protection and 15 under second grade national protection. Aquatic animal species also abound, with 33 fish species present. The Dali bow fish and Erhai carp are endemic species to Lake Erhai and are under second grade national protection, while the Dali carp and spring carp are under second grade provincial protection.

The current development regime of the study area is composed of ten main elements, including economic sectors such as agriculture, tourism, forestry, net-cage fish culture, manufacturing, quarrying, in-lake navigation and fisheries, lime-kiln/brick-kiln operations, water supply, and miscellaneous activities. Among these elements, six play very important roles in the whole system; namely, agriculture, tourism, forestry, net-cage fish culture, manufacturing, and water supply.

Three major components of the agricultural sector are related to water quality and quantity in Lake Erhai and the Xi'er River; namely, soil use and cropping patterns, livestock management, and human activities. Generally, the main crops in the area are rice, wheat, corn, and vegetables. The main types of livestock are oxen, sheep, pigs, and domestic fowls (chickens, ducks, geese, and turkeys). Human activities in support of agricultural operations are related to the provision of water for irrigation. Irrigation water is allocated on the basis of types of farming activities, pipe capacities, and levels of potential economic returns. Water quality impacts are related to nonpoint source pollutants that arise from these agricultural activities. Soil erosion and wash-off of surplus nutrients from fertilizers and manure applied to the land surface are the principal pathways by which pollutants reach the aquatic environment. High dissolved- and particulate-phase nitrogen and phosphorus concentrations contribute to the eutrophication of surface and ground waters.

Industrial activities generate 17.6 million tons/year of wastewater from pulp and paper manufacturing, chemical, food-processing, and leather and textile industries which are the primary polluters. Industries also consume a large amount of Lake Erhai water. During the 1994/1995 fiscal year, industrial water consumption in the study area was about 23 million m3/year (1995 data) and less than one-quarter of this volume, or about 4.3 million m3, was recycled water.

In-lake net and cage fish culture is one of the major sources of organic contaminants entering Lake Erhai. The principal environmental impact of caged fish culture is associated with the inefficient use of supplemental feed by the fish. A significant proportion of the supplemental nutrients provided (estimated at between 70 and 80 percent) is not consumed by the fish. These excess nutrients contribute to the eutrophication of the lake and have impacts on in-lake recreation and other water uses. Further, of those nutrients consumed by the fishes, some portion is released back into the aquatic environment as excreta, exacerbating the level of organic pollution in the lake. Processing of farmed fishes also results in the discharge of wastewater to Lake Erhai and the Xi'er River. The increase of in-lake fisheries activities are expected to bring economic benefits but negative effects include conflict with in-lake tourism activities, impacts on aquatic ecosystem and biodiversity, vessel oil leakage, and wastewater emissions from fish processing industries which may surely lead to environmental and economic consequences. Finally, fisheries although they contribute significantly to the economy of the region also represents conflicts with the lake's navigation

The Dali Nationality Autonomous Prefecture where the Lake Erhai and Xier River Basin is located was recently identified as a center for sightseeing and tourism by the central government. Tourist activities are expected to become one of the most important economic sectors and will bring major economic benefits, in the form of the development and/or expansion of the service sector, souvenir industry, and lake-related recreational industry. On the other hand the increment of tourism activities , including increased in-lake recreational activity, will generate and discharge sewage and solid waste. Where such discharges occur within the lake, impacts on the quality and levels of production of the in-lake fisheries and net and caged fish culture industry will likely occur. Provision of tourist infrastructure, while benefiting the construction industry, can reduce the available area of agricultural land, lead to a change in the pattern of agricultural production within the region, and cause increased compaction of the lands.

The physical impacts of tourism on Lake Erhai are relatively limited. For example, when fully occupied, the hotels would have approximately 10,000 guests compared with a population of more than 700,000 in the study area. As the hotels usually are better served with sewerage and solid waste disposal facilities than the average residences, and even if the visitors consume more water and energy, and travel more along the roads than the average inhabitant, the resulting environmental loads are still marginal in comparison with other loads. Likewise, while impacts from construction and traffic are generally experienced in the region, tourism contributes only marginally to these problems. Exceptions do occur locally, however. For example, in Dali Old Town, tourist traffic may constitute the larger part of total traffic volume.

In the same vein, the socio-economic impacts of tourism are unlikely to constitute a matter of special concern. The tourism sector in Dali employs some 10,000 employees, in comparison to an estimated workforce of 400,000 in the basin (estimated as 57 percent of 691,000 inhabitants in the basin). Conversely, the contribution of tourism to the basin economy is substantial (estimated to be between 10 percent and 15 percent, or even higher) as a result of the greater value-added per employee within the tourism sector. Comparing the environmental impacts of an additional job in the tourism industry with the impacts of an additional job in manufacturing, it is most likely that the impact will be less for the additional job in the tourism industry.

With regard to cultural impacts, as tourism currently caters mainly to Chinese visitors and only marginally to foreigners, there are likely to be few cultural difficulties encountered. Most visitors will share a common language and culture, although people from different parts of China may differ ethnically from the populace within the Lake Erhai basin. The major impact of tourism is most likely to be related to the general increase in economic activity in the region than to tourism activities in particular. Tourism, however, can generate revenues that can be used for investment in a better environment, which will, in turn, continue to attract tourists and their monies. This is a basis for development of environmental sustainability, a constructive symbiosis between tourism development and the environment in general.

While forestry activities generally have a lower economic rate of return than the other economic activities, it helps to reduce soil and nutrient losses that currently contribute to the degradation of Lake Erhai, and in maintaining biodiversity, but unfortunately this industry is discharging of organic-rich wastewater to the Xi’er River by the pulp and paper industries.

Quarrying is a major economic activity in the region. In the western portions of the basin, along the Cangshan Mountains, the majority of the bedrock is marble which is extracted for use as a decorative and construction material for buildings throughout Asia. Stone products contribute significant economic benefits, which extend beyond quarrying operations to related industries, such as construction and production of construction materials, but also has important environmental impacts due to the exposure of soils to erosive processes and increased soil loss to the lake. The scars in the landscape can adversely affect tourism by degrading the aesthetics of the quarry area (although the quarries can become secondary tourist destinations if provision is made for viewing of the quarrying operations and sale of locally produced stone goods). Along with the eastern shoreline of the lake, excavations along a number of hillsides have led to damage of the lakeshore landscape that are unlikely to be amenable to landscape restoration activities. Quarrying also competes with agricultural and forestry activities for land, and contributes to increased solid waste generation and emissions of suspended solids (creating both air and water pollution problems). Conflicts exist between environmental protection, economic development, and resource management objectives within this economic sector.

Lake navigation is an important means of transportation having significant economic benefits in the Lake and it contributes to the generation of income from tourism activities. Nevertheless, it causes important conflicts with the lake's fisheries activities and the cage fish culture industry; also and increased sewage and garbage discharges and oil spills from vessels is having important impacts on the quality of the water.

Lime and brick production have a direct effect on the forests as the shortage of coal and other energy sources in the region calls for the use of trees as fuel. Currently, due to unsustainable forestry practices, this stress contributes significantly to reduced forest cover, increased soil erosion, and decreased biodiversity. In addition, the excavation of specific soils which form the raw materials for lime and brick production exacerbate soil erosion problems. Disposal of lime-kiln and brick-kiln residues on the lands surrounding the production facilities also contributes to land degradation and loss of aesthetic value which affects both the aquatic environment and other regional economic activities (including tourism).

Agriculture is the major water consumer in the area using between 120×10^6 and 140×10^6 m^3/year) while residential/industrial users consume 40×10^6 m^3/year. Of the estimated sustainable yield (about 700×10^6 m^3/year), most of the remaining water is normally used for power generation with some being diverted to external systems.

While some economic activities contribute to environmental degradation and water pollution in Lake Erhai and the Xi'er River, economic activities also generate the revenues, needed for environmental protection and pollution abatement. On the other hand, there are limited natural resources and pollutant loading capacity in the basin area, which imply necessity for effective use of them. Figure 4 shows the relationships between various economic activities in the study area. Most economic activities are related to each other in some way.

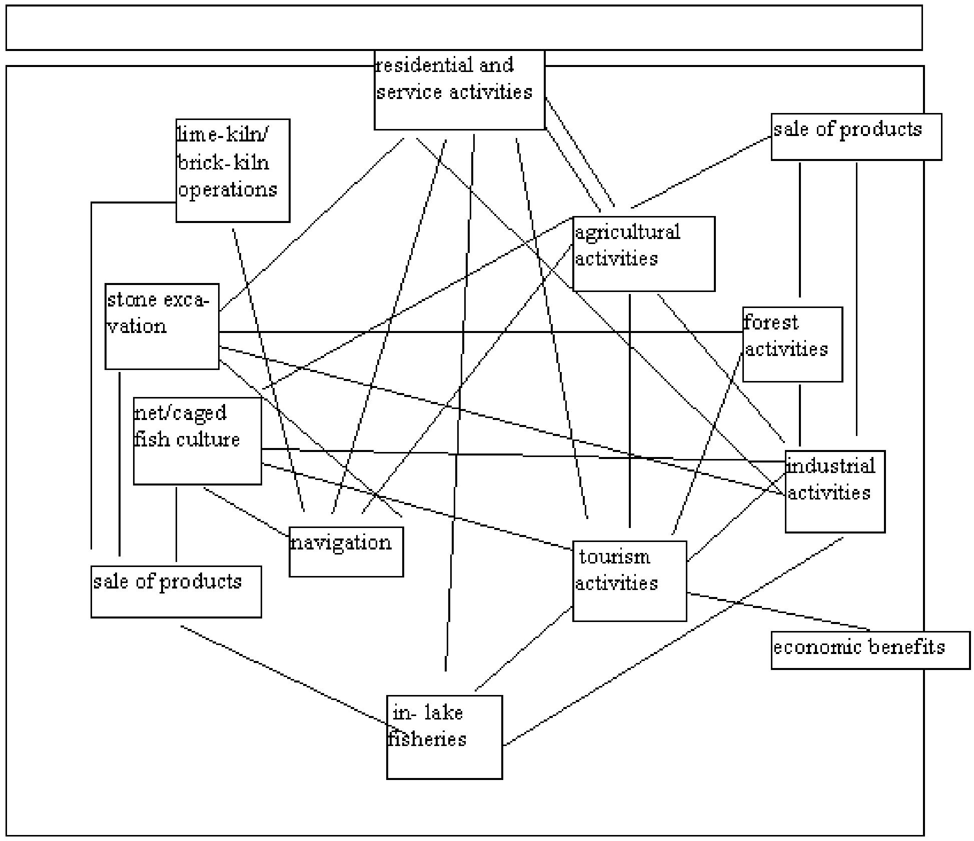

Figure 4. Relationships between various economic activities.

Any change in one component may lead to a series of consequences to, and responses from, the other components. Therefore, both economic and environmental planning within such a system must be based upon consideration of the whole system. Consideration of individual components, and even independent consideration of several components, cannot adequately reflect the responses of the overall system. This means that even a good plan based upon an individual economic sector, or even several economic sectors, may not be a good plan for the entire system if some related component was neglected. Therefore, systems analysis methods are essential for an integrated assessment of this complex system. Such methods must form the basis for sound environmental planning leading to the sustainable development of the basin.

Figure 5 shows the relationships between economic activities and related pollution problems in the area. As might be inferred from the relationships between economic activities, most activities are not only related to each other but also to a number of pollution problems. Any change in an economic activity may lead to a series of consequences that affect and effect a number of other activities and related environmental problems. Further, pollution problems are also related to each other. For example, point and non point source pollution may affect biodiversity, while solid and hazardous waste generation may contribute to both point and nonpoint source pollution depending on disposal techniques used. Nevertheless, these relationships among and between activities and related pollution problems provide opportunities to achieve effective levels of pollution control and sustainable resource management while achieving economic growth (e.g., through targeted pollution control engineering projects and environmental management initiatives within regional development activities).

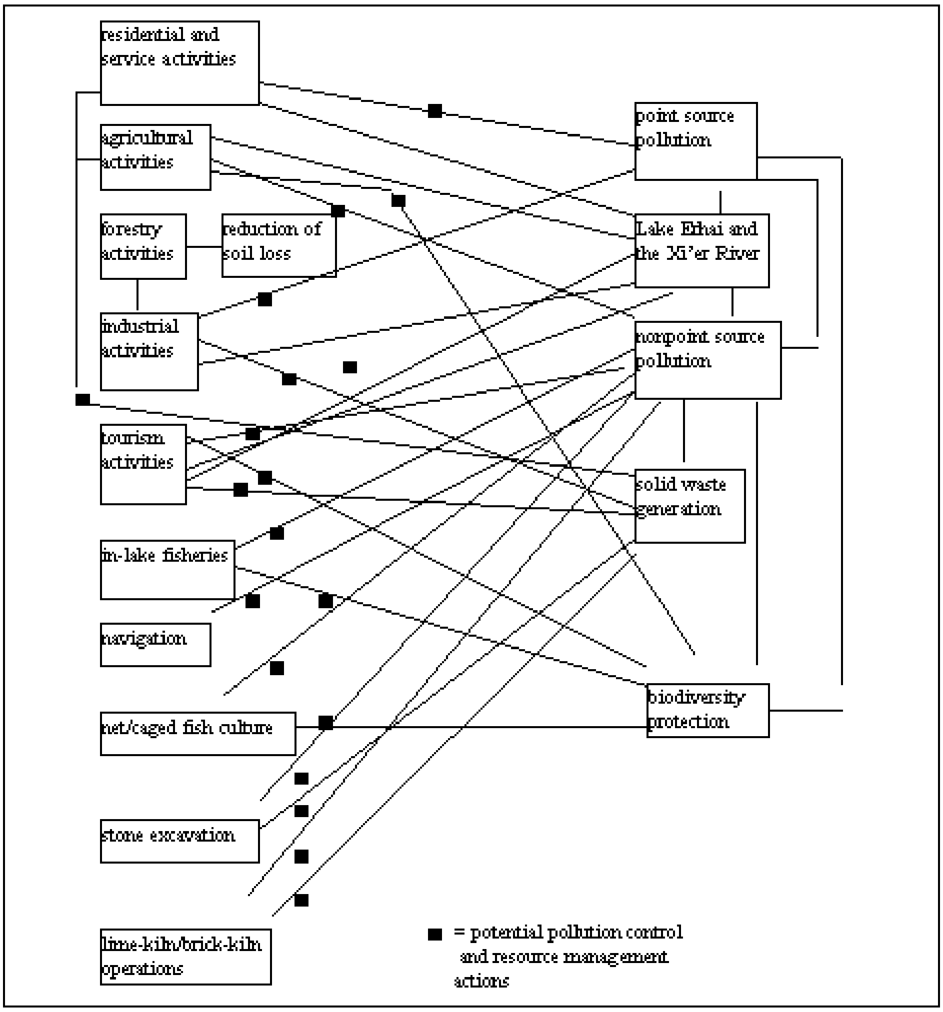

Figure 5. Relationships between economic activities and related pollution problems.

A systems analysis methodology used in environmental planning within the Lake Erhai and Xi'er River basin must be able to integrate a number of characteristics and consequences within this complex system and be sensitive to temporal variations in order to generate effective and realistic environmental planning alternatives. Thus, the development of tools for dynamic optimization and inclusion of systems dynamics in analyzing problems is necessary for effective environmental management and planning. Because of the possibility of continual changes in system components with time, this necessity should lead to the development of a "real-time" decision support system. This means that the analytical results should be composed not only of a set of firm decision alternatives (presented as research reports) but also of a controllable management system through which the alternatives can be implemented (presented as computer software packages). Decision-makers can then input information for the future periods and generate updated solutions using the modelling software, allowing "new" planning alternatives to be developed. This "real-time" feature will improve the effectiveness of environmental planning in the basin.

In the basin many environmental protection, socio-economic development, and resource management objectives exist. Many of these have competing objectives which are of concern to a number of decision-makers and stakeholders having differing interests. These decision-makers and stakeholder interact with each other in various ways depending on the particular issue being analyzed. All decision-makers and stakeholders within the study area have the potential of limiting or promoting each of the other decision-makers and stakeholders. Thus, the systems analysis methods must be sensitive to trade-offs and/or compromises between the interests of different stakeholders in order to maximize overall benefits throughout the entire system (i.e., the entire basin during the entire planning time horizon).

Many system components and parameters, as well as their inter-relationships, are difficult to identify, analyze and quantify within an analytical framework. From the modelling point of view, such difficulties are analyzed as uncertainties in the study system. Such uncertainties are poorly conveyed using mean or median values to represent uncertain information, leading to loss of information and/or mistakes in the interpretation of the result. In the Lake Erhai and Xi'er River system, many activities are uncertain. For example, it is hard to calculate a deterministic value for the loading capacity of tourists at a specific tourism site. Instead, only some uncertain information can be obtained to represent it. If this information is simply presented as a mean or median value, the reliability of the result used in making planning decisions may be adversely affected. Consequently, development of systems analysis methods that can effectively reflect uncertainties is important for generating reliable and realistic planning alternatives.

Based upon the analysis set forth above, the resolution of the complex relationships identified as existing within the Lake Erhai and Xi'er River basin requires that a nested set of dynamic mathematical models be used to forecast likely outcomes of a given set of proposed actions. Recent advances in programming have resulted in a number of compatible methodologies to be developed (Figure 6). These methodologies include the Inexact Fuzzy Multi-objective Programming model (IFMOP), the Systems Dynamic model (SD), the Environmental Support Capacity Assessment model (ESCA), and the Object-Oriented Programming model (OOP). The assumptions inherent within these techniques can be applied in combination to guarantee the rationality, applicability, and flexibility demanded when undertaking a task as complex as the environmentally-sound planning of a large watershed.

Policies approaches. The Tourism Sector as an example.
With regard to the development of a tourism policy, consideration was given to the adoption of policies and principles as a basis for sustainable tourism development in the Lake Erhai basin:

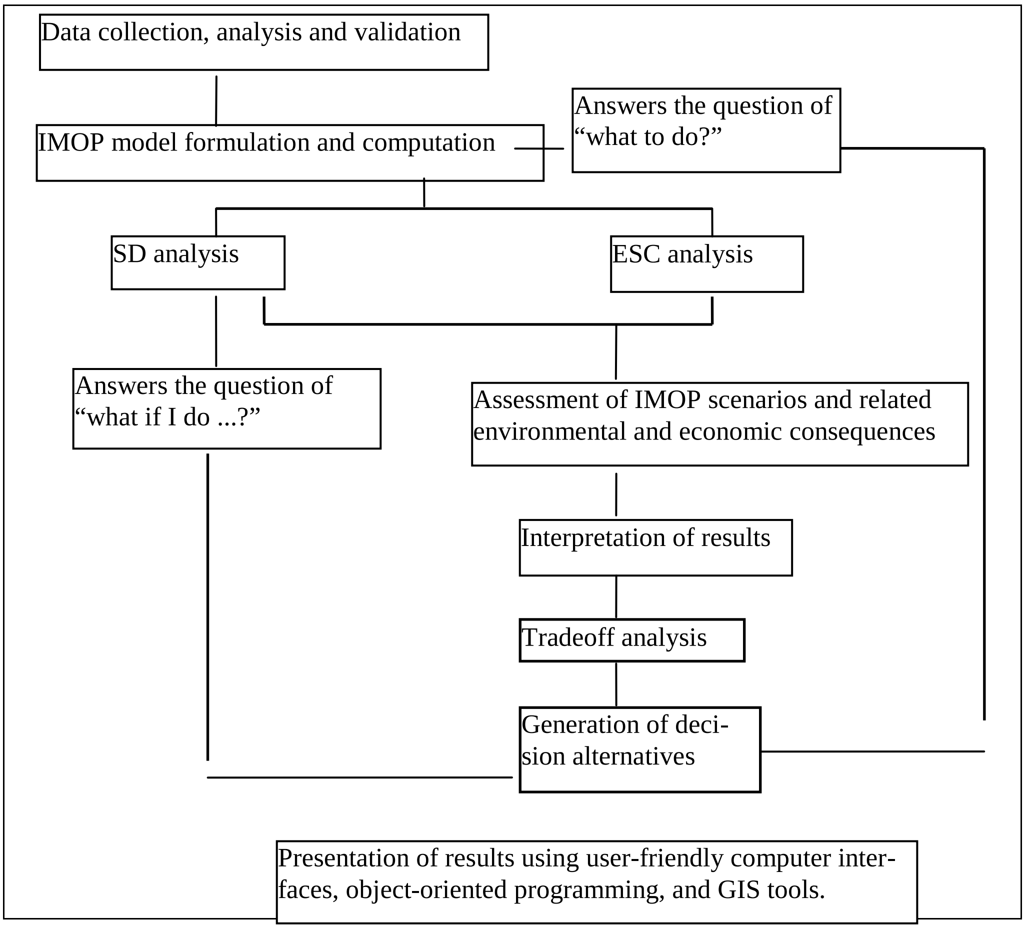

Figure 6. Generalized flow chart of the modelling approach.

tourism development shall be undertaken with a view to creating equitable economic rewards for all inhabitants and economic units in the region;

an high level of visitor satisfaction shall be assured in order to encourage visitors to extend their stay in the region;

provision of visitor facilities shall be based on comprehensive market research in the source markets to identify a range of tourist profiles as a prerequisite for increasing the total number of visitors to the region;

natural and cultural resources shall be developed and utilized on a sustainable basis;

quality of life shall be enhanced through the integration of tourism into social structure and economic activity of the community;

development of tourism facilities shall be balanced and integrated with both their host communities and the surrounding environment, both in terms of their physical design and their ongoing operation;

development of visitor facilities, in scenic and nature areas as well as in villages and towns, shall be based upon demand with due consideration given to the carrying capacities of the local sites;

tourism facilities shall be developed in a manner consistent with the preservation of historic and cultural buildings and environments, as these are vitally important elements of the tourism product;

village-based tourism shall be encouraged and supported;

development of tourism opportunities shall be undertaken on the basis of practical and practicable enabling strategies, with provision for the dynamic adaptation of opportunities in response to actual events and experiences.

These policies and principles also will form a sound basis for the process of successfully enhancing the economy and improving the quality of life in the Lake Erhai basin, while preserving its unique character and environment.

Many other aspects are considered in the present management plan of the basin which includes Environmental Technologies, Eutrophication Control Technologies, Cleaner Production Methodologies , Regulation and Monitoring, Biodiversity and Conservation, Water Quantity and Quality Monitoring, Administration and Human Resources, and Capacity Building amongst others and well developed in the publication.