

Moving Towards Integrated Management of the Plateau Lakes in Yunnan Province, China

Lessons for Planning and Finance

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Summary

The plateau lake drainage basins in Yunnan Province, due to their geographic, transportation and resources superiority, are often the areas where socio-economic activities are more developed. Higher land utilization rate, low vegetation coverage, intensive and modern farming activities, more industries, and high population density are the common characteristics in the lake basins, as in contrast to the remote mountainous areas where economic are less developed and environmental quality remain relatively unpolluted. Unfortunately, lakes are closed systems with relatively long retention times, which can trap pollutants for extended periods and are particularly vulnerable to a range of anthropogenic stresses. In the process of tackling with the environmental issues and moving towards integrated management of plateau lakes, Yunnan has learnt lessons in planning and financing.

1. Water Systems and Plateau Lakes

Yunnan, the pivotal land that links the Asian hinterland and South Asia sub-continent and Indo-Chinese Peninsular, is a plateau mountainous province in the Southwest China. It has total land area of 394,000 km² with 94% of mountainous area and only 6% of flatland.

On such mountainous area, water system are complicated and there are over 600 rivers, larger or small, widely distributed vertically and horizontally throughout the whole province, belonging to six river systems, namely, Jinsha River (upper reaches of the Yangtze River), Nanpan River (upper reaches of the Pearl River), Lancang River (the upper reaches of the Mekong River), Yuan Jiang (upper reaches of the Red River), Nujiang (the Salween River), and Yinowadi River, the former two are domestic rivers and the later four are international rivers that flow through such Countries as Laos, Myanmar, Thailand, Cambodia and Vietnam, and finally flow into the ocean. Because of locating at the upper stream of rivers, Yunnan is voiced to shoulder higher responsibility of environmental protection.

Yunnan is also one of the Provinces in China with numerous lakes. There are about 40 lakes with water surface area of larger than 1 square kilometres inlaid on such highland area. The total lake surface area in Yunnan Province is

1066 km² with total drainage basin area of about 9000 km². Historically, the socio-economy in Yunnan was developed along the river banks and lake basins. Lakes are vital to the local economic development process. They contain about 30 billion cubic meters of freshwater, (accounting for about 13.5 % of total water resource in Yunnan Province), are critical elements of hydrological system, form vital ecosystems for aquatic biodiversity; and provide livelihood and social, economic and aesthetic benefits that are essential for improving the quality of life of the basin communities. These lakes used for various purposes, including industrial and agricultural water supply, water storage regulation, flood control, aquaculture, climate regulation, navigation and tourism and, even for drinking water.

2. The Nine Big Plateau Lakes, Their Important Roles

The nine big plateau lakes refers to those lakes in Yunnan plateau with water surface area of larger than 30 square kilometers, including Lake Dianchi, Lake Erhai, Lake Fuxian, Lake Chenghai, Lake Lugu, Lake Qilu, Lake Xingyun, Lake Yilong, and Lake Yangzonghai (natural features of the nine plateau lake are shown in table 1). These 9 lakes distribute in 17 counties/cities that belong to 5 prefectures/municipalities (including Kunming, Dali, Yuxi, Lijiang, Honghe).

The nine plateau lakes are the important form of the existence of water resources. They provide physical conditions for people's livelihood and socio-economic development. On the other hand, they are the one of the key elements that constitutes ecosystem and also key factors that cause the changes of ecosystem. The nine plateau lakes and their drainage basins, due to their gentle landform, fertile soil and water resource conditions, have long been the places with intensive socio-economic development.

The nine plateau lakes are the essential momentum for productivity. They are the "mother lakes" of people inhabited in the lake basins. They have long been playing following major great supportive functions in promoting socio-economic development of Yunnan Province:

- Supporting the development of metropolis. Four cities (Kunming, Dali, Yuxi, Lijiang) out of the five key umbi-

licus cities in Yunnan Province rely on lakes and their resources to a great extent.

- Supporting the development of agriculture (particularly intensive and modern farming activities). Lake drainage basins are often the main grain production basis in Yunnan.
- Supporting the development of tourism; Lakes and their drainage basin endowed with the rich resources, beautiful landscape, colourful ethnic culture, historic heritage have high potentiality for tourism development.
- Supporting the development of special local industrial products. About 70% of large and medium sized industries / enterprises are located in the nine lake drainage basins.

These supportive functions and the economy in lake basins hold the balance role in Yunnan's strategic economic development. Total lake drainage basin areas of the nine lakes cover about 8000 km², accounting for 2.1 % of the Province total land area, while population are nearly 4 million, accounting for 9.3% of that of the province, GDP generated in the nine lake drainage basin account for 34% of that of the whole Province. The nine lakes and their drainage basins bear about one third (1/3) of entire provincial impact of socio-economic activities on environment. Environment stress in the nine lakes and their drainage basins are significantly higher than the average level of the province.

3. Main Environmental Stresses of the Nine Plateau Lakes

The irrational exploitation of natural resources, especially land reclamation for farming, over-fishing, over load of pollutants as the result of discharging domestic, industrial, agricultural wastewater, this activities combined with the low awareness towards the environmental protection and lack of interventions in the early stage, increasingly, human activities has been profoundly impacting the lakes' ecological integrity since later last century. Lakes water level

lowered, lakes surface area reduced, water quality seriously polluted, biological resources dramatically reduced, ecological environment of the lake basins deteriorated, lake aging process accelerated, original functions of plateau lakes lost, even in some lake basins resources are nearly exhausted. The situation severely restricted local economic development.

3.1 Water Pollution

Naturally, plateau lakes are often located at lower reaches or near by cities or towns. Before rapid growth population, urbanization and increased modern industrial and agricultural activity, these lakes used to be natural, clean freshwater lakes with high biodiversity. However, with rapid economic and population growth, large amount of untreated urban sewage, industrial wastewater and agricultural runoff discharged into lakes. The accumulation of pollutant in water column resulted in water quality deterioration. In 2000, a total volume of 289 million cubic meters of wastewater were discharged into the nine lakes, accounting for nearly 40% of that of Yunnan Province. Of the nine lakes, eight has been subjected to human being's pollution except for Lugu Lake. Water quality in five lakes was below Class¹ III, four lakes were worse than Class V. Water Quality in about one half of the nine lakes failed to satisfy the designated functions. The polluted lakes also suffer from the serious eutrophication with frequent algae blooming, in some cases, the lake water can't be even used for farming irrigation.

¹ China uses a system of five classes, ranging from Class I (near pristine, head water, natural reserves), class II, (first category of centralized drinking water sources protected zones, rare fish species protection zones, fish & shrimp spawn and provincial protected natural reserves); Class III (second category of centralized drinking water sources protected zones, general fish protected zones and swimming sites); Class IV (general industrial water use and recreational water use, non-contacting with mankind flesh; and to Class V (suitable for agricultural use, and general landscape, but not fishable or swimmable).

Table 1. Features of the Nine Plateau Lake In Yunnan

Name	River system	Location	Drainage Basin area (km ²)	Water inflow (10 ⁸ m ³)	Width (km)		
					Max.	Min.	Average
Dianchi Lake	Jingsha River	Kunming	2920	5.7	12.7	3.6	10.5
Chenghai Lake	Jingsha River	Yongsheng	318.3	1.66	5.0	3.0	4.0
Erhai Lake	Lancang River	Dali	2565	8.3	8.4	3.4	6.3
Yangzhong Lake	Jingsha River	Yiliang	192	0.36	5.6	1.9	2.5
Fuxian Lake	Jingsha River	Chengjiang	614	1.31	11.3	4.0	7.0
Xingyun Lake	Jingsha River	Jiangchuan	383	0.77	5.8	2.3	3.0
Qilu Lake	Jingsha River	Tonghai	354.2	1.1	5.6	0.8	3.1
Yulong Lake	Red River	Shiping	360.4	0.48	3.2	1.2	3.0
Lugu Lake	Jingsha River	Linglang	247.6	0.7			5.2

3.2 Ecological Deterioration

For those polluted lakes, due the swift urbanization, growth of population and economy, industrialization, and irrational resources exploitation, strongly influenced the lakes' environmental ecology. The ecosystem became very vulnerable: In 1998 the maximum percentage of forest cover only amount to 28.6% which is below the average level of Yunnan Province. The percentage of forest cover in Erhai Lake Basin, Chenghai Lake Basin and Qilu Lake Basin is short of 20%. As the result, the water and soil conservation capacity become low: The maximum soil erosion rate was 64.6% of the total basin area. Soil erosion area in Yangzonghai Lake Basin, Yilong Lake Basin, Fuxian lake Basin and Chenghai lake Basin are over 45% of total basin area, and others are over 20%. Increased soil erosion causing siltation of the lake and reservoirs; Eroded soil bring together nutrients to feed into the Lake, forming a type of non-point pollution sources; Perimeter dyke construction and land reclamation destroyed the gentle slop shores shoreline. The loss of shallow water, which included vital wetland, floodplain and littoral zones, have had the most significant adverse impact on the lake's ecology and biodiversity; River flow control by constructing reservoirs and ponds, resulted in the loss of fish spawning sites, the reduction of lake self-cleansing capacity.

3.3 Water Scarcity, Low Storage Capacity and Water Supply short of Demand

Plateau lakes are generally tectonic fault lakes. Most of them are closed or semi-closed lakes. They are no sufficient water from transit rivers to replenish the lakes water. Firstly, in most cases, lake surface evaporations are larger than precipitations and the lake basins are water scarcity areas. Per capita water resources in the nine lakes rang between 98 ~1379 m³/year.person, generally lower than average level of Yunnan Province (5,890 m³/year.person) and national average level (2,480 m³/year). Secondly, the nine lakes have low capacity to store and regulate water. The example is Qilu Lake that often suffers from flooding in the wet years and drought in the dry years. Water balance

has to be kept by the use of storm runoff and the reuse of wastewater and return flows from farmland. Thirdly, lakes' self-purification capacities are week. Lakes' water comes from precipitation runoff. Water retention times of lakes are quite long therefore has very low capacity to self-purify pollution. Furthermore, water withdrawn form the lake serving for socio-economic demand has exceeded the lakes available water. Fresh water inflows to Lakes have been taking away for social and economic development and polluted water keeps flowing into the lake. As a result, the lake's water quality keeps deteriorating. Water quality pollution further exacerbated water scarcity situation. Water crises have occurred in Dianchi Lake, Erhai Lake and Yilong Lake.

3.4 Irrational Economic Development Weakened Lakes' Economic and Ecological Functions

Historically, too much emphasise were made on the development of lake resource with less attention paid to the protection and environmental improvement. The serious soil erosion, land reclamation for farming have led to the siltation of the lake beds, reduction of lake volumes and shrinkage of the lake area and accelerated lakes process towards marsh lands. When it was formed around 3 million years ago, Dianchi Lake was much larger, with an area of about 1,000 km² and a depth of more than 50 m. Although natural changes led to a gradual decrease in area and volume, changes in land-use over the last half century have increased the rate of erosion in the basin. Since the 1950s, the total sedimentation in the lake is more than 50 million m³, with the storage capacity decreasing by 210 million m³. The annual loss of erosion materials averages about 0.377 million tons. Erhai Lake, since the operation of 4 cascade hydropower stations, water level significantly lowered (maximum difference was 2.44 meters) Yilong Lake used to have water surface area of 36 km² in 1950, now decreased to about 30 km² and the water level is still lowering due to land reclamation in 1970s.

Table 1. Features of the Nine Plateau Lake In Yunnan (cont'd)

Max Depth (m)	Average Depth (m)	Water surface area (km ²)	Average water resources (10 ⁸ m ³)	Storage Volume (10 ⁸ m ³)	Surface water Elevation (m)	Population	GDP (million)
10.9	4.4	300	5.7	12.9	1886.5	2,200,000	62,500
35	25.7	75	1.12	19.8	1501.0	40,000	80
20.5	10.5	250	8.3	29.0	1972.5	770,000	5,700
30.0	20.0	32	0.36	6.02	1770.0	60,000	25
157.8	87.0	212	3.5	189.3	1721.0	150,000	1,100
9.5	5.9	34.7	0.68	1.84	1722.0	220,000	1,200
6.7	4.5	37	0.64	1.70	1796.0	250,000	1,600
6.6	2.8	31	0.44	1.1	1412	140,000	550
94.0	40.3	50	0.67	22.5	2690.7	3000	6

4. Actions Taken For Lake Environmental Protection

The Government and people of Yunnan Province have long been attaching great importance on the water pollution prevention and control of the lakes, especially Dianchi Lake. Since early 1990s, ecological protection of the nine plateau lakes was prioritized and put into very important place in the provincial socio-economic development. Series actions have been taken to treat the pollution and conserve ecology of lakes:

4.1 Organisationally, in later 2000, a “nine plateau lakes water pollution control leading group” head by Yunnan provincial governor comprising government agencies concerned was established at provincial level. Leading agencies and management offices were also established in the prefectures/municipalities where the nine plateau lakes are located. Such organization frame provided powerful organisational supports for the lakes environmental protection.

4.2 Each lake developed its “*plan for comprehensive water pollution prevention and control*” once in every five years to guide the investment and actions. Such plans have to be approved by governments at various level, (the plan for Dianchi Lake, one of the lakes prioritized as the “three lakes and three rivers” at national level, has to be approved by the State Council). The plans set up the objectives, indicators and action plans for achieving objectives with estimated budget.

4.3 Input for nine lakes environmental protection was enhanced: a total of 50 million RMB each year from provincial financial revenue plus counterpart funds from prefectural or municipal financial revenues were set up as special funds for the nine lakes environmental protection. During the ninth-five-year (1996-2000) and the tenth-five-year (2001-2005) periods, a total of 2.989 billion RMB and 4.08 billion RMB have been invested

in the lakes environmental improvement respectively. These investment input, including some international loan or grant funds, was used on:

- The control over industrial pollution, through relocating polluting industries outside the lake basin, cease pollution by installing on-site treatment facilities, and the issuance of discharge permits to force industries to be compliance with pollution discharge standards,
- Urban wastewater collection and treatment. A total of 22 sewage treatment plants with total capacity of 795,000 t/d have been established in the 9 plateau lake basins, together with sewage interception and sewer networks.
- Cleansing of rivers flowing into the lake, through interception of waste water from entering into the lakes, cleansing garbage dumped into the river, establishment of wetland land at the river mouths, etc.
- Urban domestic solid waste collection, transfer and disposal. A total of 14 domestic solid waste sanitary disposal sites with disposal capacity of 3818 t/a constructed in the 9 lake basin.
- Rural non-point pollution sources control through such rural sanitation program as the provision of eco-latrines and bio-gas tanks, compost system, rural waste collection and disposal, and balanced application of fertilizers on farmland;
- Ecological conservation and rehabilitation: including reforestation in the lake basins, prohibiting illegal mining activities, returning farmland, fishponds to the lake, re-establishment of wetland along the lake shorelines

Table 2. Water quality of the nine lakes (2008)

Lake	Designated Water Function	Quality assessment	Transparency (m)	Eutrophic index	Main pollutant	Pollution extent
Dianchi — inner lake	V	>V	0.57	79.18	NH ₃ -N, TN, TP	Heavily polluted
Dianchi — outer lake	V	>V	0.51	64.3	TN	Heavily polluted
Yangzonghai	II	>V	3.22	32	As	Heavily polluted
Erhai	II	II	1.63	36.8		Good quality
Fuxian	I	I	4.48	19.49	—	Excellent quality
Xingyun	I	>V	0.62	63.8	TN	Heavily polluted
Jilu	I	>V	0.91	58.93	TN	Heavily polluted
Chenghai	I	III	3.0	29.8	—	Good quality
Lugu	I	II	11.0	4.9	—	Excellent quality
Yilong	I	V	1.08	53.67	TN, COD _{Mr}	Heavily polluted

- Water resources regulation through in the basin or inter-basin water diversion, water saving program to meet the needs of water demand in the lake basins
- Removal of internal pollution sources by means of contaminated sediment dredging.
- Pilot works for testing and popularization of new technology

4.4 Legislatively, formulation of legal system in the lake basins was strengthened. Guided by the national laws and regulations, local ordinances were also developed for the nine plateau lakes. “One ordinance for one lake” becomes one of the important achievements in local legislation in the field of environment and resources in Yunnan Province for the protection of the nine plateau lakes. Supervision/inspection actions were conducted exclusively during the recent four successive years. Illegal environmental behaviours (such as illegal discharging of industrial effluent, fuel-engine boat fishing activities, heavy pollution from aquaculture, illegal building of structures at lakesides) were suppressed.

4.5 Other activities, such as scientific studies, environmental dissemination education, restoration of wetland and freshwater biodiversity, etc. further strengthened.

5. Lessons for Planning

All the actions were taken based on the improved awareness of the importance, complexity, and difficulties of lakes and their environmental management, and improved planning based on the better diagnosis of the lake environmental stresses. Plateau lake basins management in Yunnan has been experiencing through following steps:

5.1 From simple action towards planned action

Before the lake basins environmental degradation, lakes were considered to be free resources granted by nature. Their resources, including the self-purification capacity were irrationally overused. Water companies took water from lakes to meet the demand of urban water supply; water resources agencies build dams, dykes, channels, for the use of lake water resources, farmers reclaimed the lake for farming.

It was not until water pollution and water scarcity were significantly visible, actions to abate pollution were taken. At the early stage of pollution control, industrial polluters were first targeted to treat pollutants in compliance with discharging standards or diverted away from discharging into the lakes under the monitoring and supervision of environmental protection agencies. Wastewater treatment plants were constructed based on urban sewerage sector plan.

5.2 From sector planned action towards integration of sectors planned action by taking the basin as a whole

In the early stage, different sectors set up their plans to release the environmental stress: for instance, environmental protection agency set up its plan to control over industrial pollution, urban master plan set up its water and sewerage sector plan to establish increase water supply facilities and establish wastewater collection and treatment facilities, water resources department set up its plans to optimize the water resources utilization and water diversion program. Without the integration of sectors plans, there was a lack of systematic analysis of the whole lake basin and prioritization of actions, actions planned used to focus more on the lake body with more emphasis on engineering projects, while efforts for ecological conservation or rehabilitation, the environmental rehabilitation of rivers flowing into lakes, rural non-point pollution control, etc. ignored.

Based on the results of a number of research program in the later 1980s, it was recognized that no single action or project can solve the environmental stress of lake basins. There is a need to coordinate among relevant agencies and integration of sector plans. A lake basin-wide *Comprehensive Pollution Over Pollution of Dianchi Lake Basin* was developed first, which integrated all the relevant sectors plans by taking lake basin as a whole, combined, optimized and prioritized efforts from all related agencies to target the common goals set up in the said plan in the early 1990s. Since 1990 when China’s eighth-five-year planning period begins, the nine plateau lakes were priorities as key target for environmental protection. Dianchi Lake were first requested to develop *Five-Year Plan for Water Pollution Prevention and Control in Dianchi Lake Basin* once in every 5 years, which have to be approved by the State Council as it is one the National-level priority program of “Three Rivers” and “Three Lakes”. Such plan was followed by the other eight lake basins later.

5.3 From short-term and mid-term plan towards long-term plan

Through the implementation of a couple of *Five-Year Plans for Water Pollution Prevention and Control in Lake Basins*, evaluation on the performance of the plan implementation was made recently. It was found that the planned actions were not fully completed and the impacts of the actions were not significant as expected, especially for Dianchi Lake due to reasons including the lack of awareness of the importance, complexity, and difficulties of lake basin management and the lack of a long-term plan. While other lakes, for example Erhai Lake where a long-term plan (2003-2020) for lake basin environmental protection and water pollution control were develop performed much better than the others. Now, a *Mid-Term to Long-Term plan for Water Pollution Prevention and Control* and a *Master*

Scheme for Water Pollution Prevention and Control for Dianchi Lake are being developed.

5.4 Future: towards long-term lake basin management master plan balancing environment protection and socio-economic development.

For those lakes which are located nearby the urban area and suffering from serious pollution, and the actions taken did not result significant positive impact is recently recognized as a key development issue resulted from unbalanced socio-economic development and eco-environmental protection. Economic growth and urbanization process in such lake basins exceeded the carrying capacity of a lake. The problems on water shortage and environment degradation will continue to exist in such lake basins for a long run. Above-mentioned Plans for *Water Pollution Prevention and Control in Lake Basins* are only specialized in water pollution control. Drawing the lessons from the previous effort, it is found that: there was an insufficient evaluation of complicated pollution sources and increased pollution loads into the lake resulted from swift socio-economic development and rapid urban expansion. There is a lack of a master plan integrating socio-economic, urban and environment development. Therefore, there is an intention, in the next step, to develop a long-term Lake Basin Master Plan for integrated water and environment management to achieve balanced economic, environmental and social outcomes.

The lake basin master plan: (a) is to be developed prepared on the basis of the sector plans for the balanced development between economic development and environment protection; (b) both point and non-point pollution sources from cities and counties as well as the rural areas of the lakes will have to be addressed under the plan, though the non-point pollution control has a less priority in the government's 11th five-year plan for pollution control; (c) the issues on both water quality and water quantity as well as social and economic activities will have to be addressed and analyzed together in order to have a balanced social, economic and environment outcomes for the Lake Basins; and (d) both engineering measures and demand management measures will be considered, with a focus on demand management measures

6. Lessons for Financing

Integrated lake basin management needs funds support implementing every action planned. Some of the projects/ actions planned in the five-year period for water pollution prevention and control in the plateau lake basins were experienced substantial delay due to the insufficient financing, some of the environmental infrastructures suspended operation due to insufficient revenue to cover operation and maintenance cost. Widening financing channels to create a co-financing mechanism is important.

- In 1980s and early 1990s, the financing channel simple and narrow: (1) industries by practicing "polluter pays principle" to install pollution treatment facility; (2) Central and local governments financial revenue for the establishment of urban environmental infrastructures.
- Since later 1990s, with more policies granted from central and local governments, more financing channels were available. Additional funds include: (1) loan borrowings from World Bank, Asian Development Bank, and bilateral government; (2) loan from the State Development Bank of China or state bonds and commercial banks; (3) donations from State Bonds and from social donations; (4) tariff revenues from charging waste water and domestic waste and water resources.
- Since 2000, Yunnan Government established a special fund of 50 million RMB per annum, which was increased to 60 million per annum since 2006. Central government established special funds for water pollution control since 2006 to which Yunnan can apply for to manage plateau lakes. In the new twenty first century, BOT, BT, were also introduced as well to have attracted more financiers.

To sustain the operation and maintenance of the environmental infrastructure, and the repayment of debt services incurred from the external and internal loans, the Government of Yunnan Province and local government where the plateau lakes are located, under the guidance of the Central Government, have begun to charge a tariff for water resources, centralized water supply, wastewater, and domestic solid waste at a level that could generate revenues to cover at least the operation and maintenance costs since later 1990s, and there are a number of increase of such tariff step by step towards the level that the tariff revenue can even cover the loan interest and principal. The utility companies are asked to make financial projections, based on the audited financial statements. If the financial projections find any substantial deficit that may threaten the financial viability of management activities, the government will consider adjusting the level of tariff or taking actions to reduce costs.

With the widening of financing channels, funds inputs in the plateau lake management are also increased step by step. According to the statistic data, in the ninth-five year period (1996-2000) a total of 2.989 billion, and in the tenth-five year period (2001-2005) a total on 4.08 billion RMB were input in the nine plateau lake basins' management. In the eleventh-five plan period (2006-2010) a total of over 7.0 billion RMB are budgeted in the plan. In the meantime, funds management were strengthened by special auditing program conducted by Yunnan Audit Department in 2007 to safeguard the proper use of all sources of funds for lake basins management.

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