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Part 3: Flood Management

THE ECOLOGICAL CHANGES IN MANWAN RESERVOIR AREA AND ITS CAUSES[1]

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Abstract

The eco-environment of Manwan reservoir is weak and easily deterioration because of its abrupt slope, developed faults, topographic unconformity and concentrated rainfall. Based on site investigation and statistics analysis, this paper elaborates on several aspects of the reservoir's ecological degradation: (1) landscape change. Villages, cropland, terrestrial life formerly in the valley blow the elevation of 994m were inundated; while forest, grassland and grading slope from 1,000m to 1,800m were replaced by newly-reclaimed sloping fields and newly-established concentrated settlements. The eco-environment tends to be frailer, whereas the reservoir's hydrothermal change after impounding provides better conditions for vegetation from 1,000 to 1,300m, hence contributes to its restoration; (2) After 1984, soil erosion in the slope land around the reservoir area have been more serious. The annual sediment concentration in the river flow was increased by 36.6%, and annual sediment flow increased by 37.3%; (3) serious loss of the reservoir's storage capacity. According to the survey in 1998, after 3 years' operating, the loss of the active storage reached at the level that expected after 15 years of operation; (4) the mountain disasters, such as soil erosion, landslide, mudflow, flooding as well as collapses, frequently happen. Through the further analyzing on human factors leading to ecological deterioration, it could be found that: (1) slope reclamation brings about the loss of vegetation and the worsening of soil erosion; (2) filling and releasing of reservoir make the surrounding area less stable and be apt to collapse and landslide; (3) infrastructure development of highway and irrigation projects results in landslide and mudflow; (4) the reservoir's sediment concentration and water pollution are closely related to upstream environmental depression. Finally, to reduce the ecological deterioration's negative effect on local production, life as well as the reservoir's economic life, and to maintain the ecosystem of the reservoir and improve the local farmers' life conditions, five countermeasures have been put forward: (1) to resettle those who reside in the deteriorated area and those who suffer from landslide and mudflow in places beyond the reservoir area. Currently, the affected population is about 1,000, with a resettlement cost of 30 million; (2) regarding small basin as ecological unit, combine reasonable land use, disaster control and community development together to carry out comprehensive regulation, with emphasis on Gonglang River in Nanjian and Heihe River in Fengqing county; (3) strengthen the harnessing of resettlement areas and key disaster-hazard regions; (4) increase maintenance cost for Manwan hydropower station, supporting afforestation engineering, rural resources exploitation and poverty alleviation programme in resettlement areas; (5) harness water-contaminating enterprises in Dali city and Lanping county to improve the inflow quality; (6) along with the construction of Xiaowan's large-scale power station, speed up natural forest engineering and soil-and-water loss control along banks of upper- and mid-Lancang River.

Key words: Manwan reservoir area, ecological change, influencing factors.

BACKGROUND OF THE RESERVOIR'S ENVIRONMENT CHANGE

The exploitation of the Lancang River Basin in Yunnan for electric power commenced 50 years ago. The Tianshengqiao Hydropower Station, with an installed capacity of 400 KW, was completed in 1946. It is situated on the Xier River, a tributary of the Lancang. Since the 1980s, Lancang hydropower development has taken place on the mainstream with a cascade development of eight dams planned (Figure 1 and Figure 2). Manwan

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hydropower station, with an installed capacity of 1500 MW, was completed in 1996 and is in operation. Dachaoshan hydropower station, with an installed capacity of 1350 MW, is nearly completed. Xiaowan hydropower station, with an installed capacity of 4200 MW, is under construction. Two others, Jinghong hydropower station, with an installed capacity of 1500 MW, and Nuzadu hydropower station, with an installed capacity of 5500MW, are at the feasibility study stage and will be started to build in 2006 and 2005 respectively.

Manwan power station is located in the middle reach of Lancang River, with a backwater of 70km. The reservoir belongs to the gorge area with high mountain and steep valley. Most of the mountain peaks nearby the reservoir are highere than 2,200m above sea level, the highest is Heilongtan in Fengqing county (2,863m), the lowest the valley bottom near the dam-site (891m). Within short distance, the peak-valley difference is over 1,900m, and the mainstream-valley gradient ratio is over 15%.

The reservoir enjoys subtropical low-latitude mountain monsoon climate, with an annual average temperature of 19℃ in the valley, and about 10℃ in the mountainous area on the top of the slope.

Precipitation increases along with the rising of elevation. The annual mean precipitation in the past years is 900~1,700mm in the reservoir, 900~1,100mm in the valley, and climbs to 1,600~1,700mm in the mountainous area above the valley sides. The difference between dry and wet season is distinct, and precipitation is uneven throughout the year. There is plenty of rain during the wet season from May to October (accounting for 85% of the whole year), especially in the three months from June to August when concentrated rainfall occurs (accounting for 57% of the year). June to August is also the period which witnesses concentrated storm and continuous precipitation lasting 15~25 days. Whereas there is scarce precipitation in the dry season from November to the following April (less than 15% of the year), particularly in January to March when the longest non-precipitation period lasts one month. In the valley, the normal evaporation is 900~1,200mm and the annual mean dryness 0.80~1.20, hence aridity is evident.

The valley's morphosturcture is different at various elevations. In the valley tract below 1,100m, V-shaped, deeply dissected valleys are found; terraces and flood plains develop along the banks are not large in scale, and the cropland is scarce. Only in places where the tributaries meets mainstream or the rock stratum is rather weak, can multi-terrace be found, in which the primary concentrated settlements develop, such as Tianba, Jiangbian and Mangshuai village. Most of these areas are inundated by the reservoir. In elevation 1,100~1,200m, 1,400~1,500m above the valley, there are secondary denudation planes primarily shaped by intermittent lifting ever since the Quaternary period. Featured by topographic unconformity and meagre land, it is the major settlement area for the displaced people. In 1,500m above sea level, mostly highland and high-and-cold mountains will be found.

In summary, the encompassing feature of the reservoir's eco-environment lies in its frailness, particularly in slopes where the environment is unstable and apt to deterioration, which finds expression in the following aspects: (1) fault development is found and active geotectonic results in topographic unconformity; (2) heat is sufficient, but there is occasional occurrence of abnormal coldness in spring; (3) precipitation is moderate, yet unevenly distributed throughout the year. Storm often occurs whereas aridity is evident; (4) there is much steep slopes and less flat lands, and the condition for settlement is rather bad; (5) the social and economic standard is too low to withstand natural disasters.

Figure 1. The Hydropower Projects Distribution along the Mainstream of Lancang River

Figure 2. The Map of Lancang-Mekong River Basin and Its Upstream Cascade Dams' Distribution

THE ENVIRONMENTAL EVOLUTION

Landscape Change

After the filling of the reservoir, the water level rises from 891m to 994m. Between the dam-sites of Manwan and Xiaowan, the 70km-long mainstream valley and 2km-long tributary valley were submerged, and the previous valley landscape disappeared as well. The reservoir's surface area reaches 23.6km^2, increased by 280% over the natural one; and the average surface width of the reservoir is 337.1m, increased by 300% as compared to the former status. Villages, cropland, terrestrial animals and plants formerly in the valley tract blow 994m were inundated; while forest, grassland and grading slope in the valley sides from 1,000 to 1,800m were replaced by newly-reclaimed sloping fields and newly-established concentrated settlements. The eco-environment tends to be frailer, whereas the reservoir's hydrothermal change after impounding provides better conditions for vegetation from 1,000 to 1,300m, hence contributes to its restoration.

Sediment Change

According to "Primary Design on Manwan Power Station" (1984), in the 30 years from1953 to1983, the long-term average flow at Manwan dam-site reads 1,230m^3/s, the annual runoff volume 388×10^{8}m^3, the normal annual sediment concentration 1.21kg/m^3, and the annual sediment runoff 4,704×10^{4}t/y (bed load about 150×10^{4}t/y). The sediment runoff from June to October constitutes 95% of the whole year, among which solid ore accounts for 44% of the total.

Table 1. The Annual Mean Distribution of Flow and Sediment at Gajiu Hydrologic Station (1953~1991)

Item	whole year	Flood season (Jun.~ Oct.)	Wet season (Nov.~ next May)
discharge (m^3/s)	1,240	2,130	596
total runoff volume (10^{8}m^3)	391	282	109
percentage in annual total runoff volume (%)	100	72.1	27.9
sediment delivery ratio(kg/s)	1,599	3,661	113
sediment discharge (10^{4}t)	5,047	4,840	207
percentage in annual sediment discharge (%)	100	95.9	4.1
sediment concentration (kg/m^3)	1.29	1.72	0.19

Source: Kunming Institute of Survey and Design, Department of Power and Industry, "Technological design of Manwan Hydropower Station : the Second Section - Hydrology".

According to "Technological design of Manwan Hydropower Station: the Second Section-Hydrology", in the 39 years from 1953 to1991, the annual mean discharge at Gajiu hydrological station (15km down-stream of the dam-site) is 1,240m^3/s, the total annual runoff 391×10^{8}m^3, with sediment concentration of 1.29kg/m^3 and annual sediment runoff of 5,047×10^{4}t (Table 1 and Figure 3).Compared the above-mentioned two results of 30 and 39-year, it is clear that the variation of long-term annual runoff is relatively slight, merely increased by 0.81%; while the sediment concentration increased by 36.6%, and annual sediment runoff by 37.3%. Those figures show that surface soil-and-water loss has become more serious in the reservoir area and upper reaches after 1984. Such trend is more obvious in Figure 2 which shows longitudinally the difference of three periods.

Damage to the Reservoir's Storage Capacity

According to the result analysis on underwater topographic survey conducted at Manwan hydropower station in June, 1996, after 3 years operation, the silting rate has reached 18.1%, almost equal to 20.95% assumed for the 5th year; the silting rate of the active storage has amounted to 4.9%, exceeding 4.2% as expected for the 15th year; the silting-up height has reached 913.8m, exceeding 900m as designed for the 10th year; and the annual mean sediment entering the reservoir accounted for 12.7% of 6000×10^{4}t. In June, 1993, the first unit was put into stream. As dynamic conditions changed after impounding, sediment from the upstream concentrated in the reservoir, resulting in the rising of the reservoir's bottom, especially its tail. Up to June, 1996, after 3 years operation, the bottom height of reservoir has reached 913.8m, 30m higher than it was formerly constructed.

According to the survey in 1998, after 3 years operation, the silting rate has reached that assumed for the 5th year, and the loss of the active storage reached that expected after 15 years of operation. Owing to the rapid

concentration of sediment, the silting area further extends to the upstream and leads to increasing loss of beddings and bays.

Mountain Disasters

Major mountain disasters endangering Manwan station include soil-and-water loss, landslide, mudflow, torrential flood and collapse as well, which frequently occur in areas surrounding the reservoir, and resettlements on the valley sides. The primary reasons accounting for the frequent occurrence of disasters read as the following: (1) the filling and releasing of reservoir break the hydrodynamic balance of the surrounding area; (2) the slope's hydrodynamic condition is changed by slope reclamation, highway and building construction, and earth-rock piling up; (3) occasionally, storms in the mountainous areas may induce disasters; (4) the reservoir's operation may cause its stress field to change, and bring about earthquake, although this has not be proved yet. Up to the end of 1988, reservoir filling has caused over 40 landslides, of which the ones occurred in the opposite bank of Akudi Village (upstream of the mouth of Gonglang River), and Wanzi Village in Nanjian county were the most serious. In these two cases, the earth-rock volume amounted to $40\times10^4m^3$ and $200\times10^4m^3$ respectively.

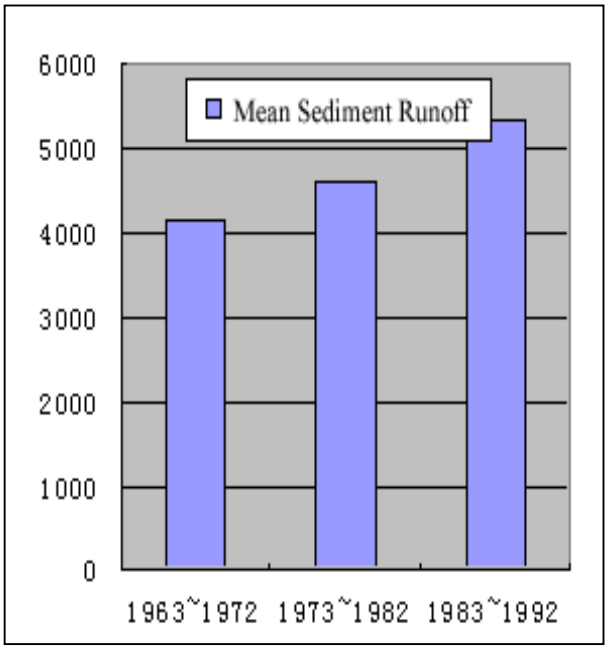

Figure 3. Annual mean sediment runoff variation of Gajiu hydro-station during different periods from 1963 to 1992.

Source: Kunming Institute of Survey and Design, Department of Power and Industry, "Analysis on sediment issue of Manwan Hydropower station in Yunnan Province"

ANALYSIS ON HUMAN FACTORS IN ECOLOGICAL EVOLUTION

Besides the reservoir's own frailness, human activity accounts primarily for the eco-environmental evolution.

Slope Reclamation

Most of landslides and mudflows, caused by slope reclamation and highway construction, take place on the mountain sides. As the displaced people are resettled upward and backward, moving from the better valley to the steeper, leaner mountain sides, previous sloping land are reclaimed as terraces. Consequently, vegetation coverage declines dramatically, soil-and-water loss turns more serious, and environmental deterioration becomes worse. As slopes continue to be reclaimed regardless of water-deficient irrigation and cropland shortage, the slope environment is further deteriorating.

Currently, soil-and-water loss turns to be increasingly serious in the 8 townships relevant to resettlement (with an eroding modulus of $2000t/km^2 \cdot Y$). Due to forest denudation and gully development, seriously eroding land is stretching, constituting 1/3~1/2 of the total area in some townships, while landslide, mudflow and torrential flood become the big hazard.

Landslide Caused by Filling and Releasing of the Reservoir

After the reservoir's filling, the bank sides tend to be less stable because of age-long soakage, hence being apt to collapse and landslide. According to the monitoring of the 2nd Gajiu hydrological station, the daily average water level fluctuation below Manwan dam is 3~4m, occasionally 4~5m, and the highest reaches 6.5m (1998). Such big fluctuation exerts great influence on the reservoir area and lower reaches as well. Since 1993, there have been over 100 collapses or landslides directly resulted from the reservoir's filling and releasing. A typical example was in mid-March, 1995, during Manwan's desilting operation, the water level shortly dropped from 991m to 940m and brought about slides or bank failures in the surrounding area, among which Jingdong county witnessed 51 bank failures within a week. It also caused large-scale slide in Wuli village, where the mountain has kept down

sliding. There were frequent occurrences of continuous slide in wet seasons, and some of the residents have to move to other places, while some others cannot sleep at night.

Disasters Caused by Highway and Irrigation Projects' Construction

In Dapingzhang and Lannitan village of Yunxian county, besides 18 households moving out because of landslide, aqueduct construction also led to slides. In particular, the large-scale slide in Dapingzhang village damaged the gully built with over 200,000 yuan investment and impaired the diversion irrigation of several relating villages. Another example is that, in March ~ April, 2000, to ensure the material transportation to Dachaoshan station, Dachaoshan Liability Corporation rebuilt the sinking highway at distance post 2527, and bulks of earth-and-rock was piled up on the slope under the highway. On 13, July, 2000, an unexpected storm made the mudflow rush into the lower reaches of Longshu river, and brought great damage to the farms along the banks.

Impact of Outer Environment's Change on the Reservoir's Eco-environment

In recent 30 years, the occurrence frequency, effecting population and direct economic loss of global natural disasters have been climbing up rapidly. According to the statistics of Wang Jing with Yunnan Disaster Prevention Association, disaster loss has been increasing since the 90s, and the occurrence frequency of natural disasters increased by 3.2 times as compared to that of 25 years ago. For instance, the provincial sediment runoff, eroding modulus and eroding rate have increased from 336.84million ton/year, 884ton/km^2•Y, 0.71mm/year in the 60s to 462.99million ton/year, 1.209ton/ km^2•Y, 0.97mm/year in the 80s respectively, with an annual growth rate of 1.58%. Manwan reservoir area and the relevant counties in its upper reaches are places where frequent occurrences of landslide, mudflow and soil-and-water loss are witnessed.

Therefore, the ecological evolution of Manwan reservoir is closely related to the change of outer ecological environment. In term of water quality, for instance, as the water bodies of Heihui River and Bi River are polluted by numbers of paper-making factories, synthetic fibre factories, Erbin paper-making factory as well as Lanping lead-zinc ore, the quality of Manwan reservoir turns worse and excessive concentration of heavy metal is found on its bottom.

Soil-and-water loss in the upper reaches attributes greatly to Manwan reservoir's sediment concentration. Within its catchment, the annual volume of soil-and-water loss is about $4{,}200\times10^4$t, among which 56.25% is from upstream, that is $2{,}359\times10^4$t; 15.48% from the four surrounding counties (Yunxian county, Jingdong county, Lanjian county and Fengqing county); and only 0.25% from the resettlements within the reservoir area, that is about 10.5×10^4t.

COUNTERMEASURES FOR THE HARNESSING AND MAINTENANCE OF THE ECOLOGICAL

Environments in the Reservoir Area

Ecological deterioration is harmful for local production and life. Currently, Manwan town of Jingdong county is the most serious disaster-hazard area. From 1993 to 1996, due to landslide and collapse, 319.1mu cropland and forest were damaged, and 161 persons from 32 households and 3 villages were displaced, with an extra resettlement cost of 600,000 yuan. According to the disaster survey in 2000, 953 farmers from 222 households need resettling, and 510 houses with 2,426 rooms were destroyed or damaged. During the wet season in 2000, in Wuli resettlement area, continuous heavy rain caused torrential flood and large-scale landslide, which made 460 persons from 107 households homeless, and 322.21mu cropland damaged, among which dry farm 145.65mu and irrigated land 176.56mu. Owing to mountain disasters and environmental deterioration, about 500 persons in Yunxian county needed to be re-displaced. Up to 1998, at the reservoir area in Nanjian county, 88 mu cropland and 116.63 mu irrigated land were devastated as the result of landslides and bank failures; 610mu forests were ruined, 5.15km farm ditch and 9.89km tractor trail were damaged; 5,830m^2 houses were rebuilt, and 2,780 bearing economic trees were destroyed. Meanwhile, the reservoir itself suffered from mountain disasters and environmental degradation. On 7, January, 1989 when Manwan dam was under construction, excavation caused the mountain on the left to slide, with an earth-and-rock volume of $10.6\times10^4m^3$. The harnessing cost amounted to 120 million yuan, and the whole project was delayed for one year, with a total loss of 1 billion RMB. In 1990, a mudflow attacked the sand yard of Manwan station, 14 persons dead and 33 injured.

Active measures must to be taken to regulate and maintain the reservoir's eco-environment:

1) resettle those who reside in the severely deteriorated area and those who suffer from landslide and mudflow to places beyond the reservoir. Currently, the affected population is about 1,000, with a resettlement cost of 30 million;
2) regarding small basin as ecological unit, combine reasonable land use, disaster control and community development together to carry out comprehensive harnessing, with emphasis on Gonglang River in Nanjian and Heihe River in Fengqing county;
3) strengthen the harnessing of resettlement areas and key disaster-hazard regions;
4) increase maintenance cost for Manwan power plant to support afforestation engineering, rural resources exploitation and poverty alleviation programme in resettlement areas;
5) harness water-contaminating enterprises in Dali city and Lanping county to improve the inflow quality;
6) along with the construction of Xiaowan's large-scale power station, speed up natural forest engineering and soil-and-water loss control along banks of upper-and mid-Lancang River.

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