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Inner Mongolia Lake Restoration Project
Lake Wuliangsuhai Comprehensive Study Extension

Management and Control Plan

Norwegian Institute for Water Research

– an institute in the Environmental Research Alliance of Norway

REPORT

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Abstract

Lake Wuliangsuhai is the 8th largest lake in China and only 170 km^2 of 300 km^2 is at present considered as open waters due to widespread reed vegetation. The massive pollution loads from domestic, industrial and agricultural sources threats the existence of the lake. A collaboration project was implemented to study the lake status, trends and threats and to propose Management and Control Plans to secure the lakes existence as a lake. This report provides an overview and results from one of the sub-projects.

The report presents a series of potential actions to rehabilitate and restore sound environmental conditions in the lake while facilitating the related livelihoods of the people surrounding it. The potential actions were initially proposed during a stakeholder workshop (LFA). These were further elaborated, and preliminarily prioritised according to their cost-benefit considerations by a group of specialists and stakeholders from China, Sweden and Norway.

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Inner Mongolia Lake Restoration Project

Sub-Project 9:

Management and Control Plan

Preface

This is one in a series of reports of the development co-operation project called Inner Mongolia Lake Restoration Project, Main Study Step 2. The implementing institution, Inner Mongolia Environmental Science Institute (IMESI), has through the Inner Mongolia Science and Technology Committee and the State Science and Technology Commission a contract with Sida and NORAD. The Contract is for financial support to carry out a five years' restoration project in Lake Wuliangsuhai in Inner Mongolia, the Peoples Republic of China. Swedish Environmental Research Institute (IVL) and Norwegian Institute for Water Research (NIVA) are acting as consultants in the project.

The long-term goal of the Project is to keep Lake Wuliangsuhai as a lake, and at the same time develop it into a productive resource for future sustainable development of the Hetao area. A prerequisite is therefor to facilitate the establishment of sustainable water usage in the Hetao. The main delivery of the Project is thus a proposed management and control plan. This plan addresses how to manage the conflicting interests that affect the eutrophication process of Lake Wuliangsuhai and to suggest actions to keep the lake as a productive resource. This plan is complemented with a maintainable knowledge base on the natural and societal processes affecting the water quality and quantity. Furthermore, the Project has qualified Chinese personnel in relevant topics and skills.

The Project is divided into nine sub-projects as follows:

1. Economic Indicators
2. Pollution Sources Inventory
3. Water Quality Monitoring System
4. Historical Development
5. Basic Processes
6. Training and Dissemination
7. Quality Assurance
8. Water Quality Management System
9. Management and Control Plan

Summary

The overall aim of the project is to assist the exploitation, management, protection, and restoration of the natural resources of the Lake Wuliangsuhai, while keeping it as a lake; a functional wetland with high biodiversity. The XI^{th} 5-year plan of the People's Republic of China defines the restoration of the Lake Wuliangsuahi as a priority. The various sub-reports presented in this report pertain to the required activities of the project. The project realizes that Lakes' management issues are addressed by many institutions, and is complex.

The Lake Wuliangsuhai serves as a source of income for several local stakeholder groups who have rights to harvest fish, reed and other natural resources. These groups together with local authorities have implemented some management measures to regulate their harvest, restore, and enhance natural resources. Pollution from various sources including agriculture, urban sewerage and industry is a problem. Thus, loading of nutrients (phosphates and nitrogen), dissolved organic matter and mineral salts to the lake is an important issue to be addressed, as it affects a number of different sectors, and have many side- or secondary effects.

Overall, exploitation, management, protection, and restoration of Lake Wuliangsuhai pose unique challenges. One of the challenges is to balance the competing demands of the lakes' resources involving various stakeholders. This involves the need to satisfy the various user interests while at the same time sustain or restore both the water quality and the biodiversity in the lake. Scientific challenges include questions concerning the applicability of site-specific data to understand natural resource problems at the sub-basin, basin, or whole lake levels. Other challenges are the lack of long-term data collection programs and the use and compatibility of data from various sources and time periods to understand ecosystem health trend analyses.

The Lake Wuliangsuhai Lake Restoration Project is a complex programme, and the potential measures were identified during a stakeholder workshop in 2003. These measures were further elaborated and grouped into 10 management and control measures (MCP). These include: 1.Urban Sewage Treatment; 2. Industrial Waste Water Treatment; 3. Increasing Depth by Dredging; 4. Harvesting Submerged Vegetation and Utilization; 5. Reed Bed Control and Utilization of Mud; 6. Keeping Water Level High; 7.Natural Pre-Treatment and Moving Inlet Pont; 8. Erosion Control; 9. Agricultural Pollution Management; and 10. Improvement of Internal Circulation. These various MCPs simultaneously address the most important issues to better understand and rehabilitate the lake ecosystem.

Most part of the lake has water qualities belonging to the Class IV and V of the Chinese classification system. The intention is to improve the status at least to the Class III. In order to achieve this, reductions of 47% of organic matter (8750 t/a), 72% of phosphorous (76 t/a) and 52% of nitrogen (873 t/a) are required. The analysis show that the proposed domestic and industrial wastewater treatment plants can reduce the pollution loads to by far to the above required levels. The phosphates need to be reduced further by 13 t/a or 12% and nitrogen by 254 t/a or 15%. Both these targets are easily achievable with a well functioning wetland, which is proposed. Both these targets are easily achievable with a well functioning wetland, which is also proposed. With these actions, together with the other actions proposed, the lake is anticipated to be rehabilitated along the environmental, economical, sociological and institutional aspects.

This report provides the most important details of the study undertaken and the results making specific findings and recommendations. A Multi-Criteria Analysis (MCA) has been performed to rank the preference of the stakeholders to prioritize the environmental, economic, social and institutional goals. A ranking of actions according to cost-benefit rations are also suggested.

The fact that the restoration of the lake is proposed as a specific issue in the next 5-year plan is a significant acknowledgement. However, most of these funds need to be secured externally through bi- or multi lateral loans. Considering the ownership of the action, it is recommended the following financing structure:

- Industries should bear 100% of the investment costs
- Municipal WWTP: 30% from the local government and the enterprises
- Other costs and measures: loan and investments from the Inner Mongolia government central governments as well as donors

The proposed actions totals to an investment of 800 millions RMB, excluding the abatement actions in agriculture pollution reduction. Total estimate for the latter is about 3 billion RMB, but it is anticipated that few prioritised actions could be considered as the immediate measures within the allocation of the XIth 5-year plan. For the domestic wastewater treatment plants, the total is about 310 million RMB, indicating a need of over 200 million RMB as loans. The industries have a relatively lower investment burden of 10 million RMB, provided the Haojiang paper mill will remain closed. Otherwise, heavy investments will be required.

The ranking of the proposed actions can be carried out using various approaches. A logical approach would be to:

- actions to reduce the pollution loads to the lake
- actions within the lake which reduces pollution
- actions to secure sufficient quantities of water to control vegetation, provide favourable dilution and to improve biodiversity, etc
- actions to sustainable utilisation of the lake's resources

Such an approach is widely utilised by internationally and in China, and agree among the Chinese, Swedish and Norwegian specialists. The following ranking was identified as rational according to this approach.

1	Industrial wastewater treatment (all)
2	Wuyuan wastewater treatment
2	Linhe wastewater treatment
2	Hanghou wastewater treatment
3	Yellow River water supply and lake level increase
4	Moving of inlet and wetland construction
5	Harvesting submerged vegetation and utilisation
6	Reed bed control
7	Erosion control
8	Agricultural pollution abatement
9	Improvement of internal circulation
10	Dredging (all)

Implementation of study recommendations will enable careful management of the living resources of the lake, ensuring maximum public benefit and guaranteeing perpetuation of these resources. Agreed-upon goals and objectives will be realized as the health of fish resources improves. When viable and productive stocks of native and other desired fish species are available, birds successfully visit the lake and reproduce in high species numbers. At the same time, chemical and other stress-induced deformities in fish and wildlife will be eliminated. Then the fish can be consumed with little or no risk to human health and growth of reed etc. will provide the local communities with employment and income. When all of these achieve, we can be satisfied that, the restoration goals for the lake will have been met.

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1 INTRODUCTION

The Government of Inner Mongolia recognises the need for restoration of the lake Wuliangsuhai, the eight largest freshwater lakes in China, whose existence as a lake is now threatened due to various reasons. The restoration of the lake is recommended to be defined as a specific action in the XI^{th} 5-year plan.

Inner Mongolia Environmental Science Institute (IMESI), with the auspicious of Inner Mongolia Science and Technology Committee and the State Science and Technology Commission (SSTC) and the financial contribution of the governments of Sweden (Sida) and Norway (NORAD) has launched a project to scientifically elaborate the status, problem and actions. The project had a financial frame of about 40 million RMB over a 10-year period.

The project is completed in 2005 and the findings are documented in a series of Project Reports, together with various working documents. This is one of the Project Reports, addressing the Preparation of a Management and Control Plan for the restoration of the lake.

1.1 Aims of this subproject

The lake Wuliangsuhai faces with the following major challenges today:

- Reed gradually occupies a larger part of the surface area of this shallow lake
- Severe water pollution from agriculture, industry and domestic sources and resulting deterioration of lake water quality
- Salt accumulation due to the combination of the irrigation technique and climatic factors
- Erosion in the local catchment
- Conflicting interests between users of lake resources
- Decreased inflow due to restricted volume of irrigation water to be diverted in the future.

The pollution loads to the lake today is estimated to be about 18750 t/y of COD or 2350 t/a of BOD as organic matter, 106 t-P/a of phosphates and 1673 t-N/a of nitrates. These nutrients contribute to the current state of the lake. Most parts of the lake can be categorised to be in the Class-IV or V of the water quality. An immediate and comprehensive action plan is required to keep the lake as a lake with the benefits it provides to the nature and the humans surrounding it. Scientists believe that it is necessary to reduce the present pollution loads by 50-70%, together with other measures, to improve the water quality to the Class III and better levels.

The purpose of this subproject, “Management and Control Plans for rehabilitation of the Lake Wuliangsuhai”, **is to present a series of potential actions to rehabilitate and restore sound environmental conditions in the lake while facilitating the related livelihoods of the people surrounding it.** The potential actions were initially proposed during a stakeholder workshop (LFA). These were further elaborated, and preliminarily prioritised according to their cost-benefit considerations by a group of specialists and stakeholders from China, Sweden and Norway.

Using the knowledge, methods and tools developed in the project, this subproject intends to produce a feasible management and control proposal that addresses how to manage the conflicting interests that affect the eutrophication process of Lake Wuliangsuhai and keep the lake as a productive resource.

The material presented here is developed by a group of Chinese specialists and stakeholders in collaboration with the Swedish and Norwegian consultants. The basis for the presented material are separately organised as a series of internal working documents, available with IMESI.

2 Characteristics of the Lake Wuliangsuhai

2.1 General description

The large and shallow Lake Wuliangsuhai, situated in the Autonomous Province of Inner Mongolia, P.R. of China, is the largest internal lake in the northwest China, and no. 8 in surface area in China. It is an important and unique ecosystem in the vast semiarid grassland region and has multiple functions of climate buffering, bird refuge, irrigation/drainage water adjustment, primary production of harvestable plants, tourism, etc.

Lake Wuliangsuhai is situated in Urad Front Banner of the Bayannaoer Prefecture of Inner Mongolia Autonomous Region. It is linked to Hetao Irrigation Catchment in the west, to Wula Mountains in the east, and located at the east tip of the Hetao Plain. The lake is 35 to 40km long (N-S) and 5 to 10km wide (E-W), with an area of about 293 km^2. The average elevation of the lake over the years is 1018.5m, steered by an outlet dam, and with a capacity of 250-300 million m^3. It has a maximum depth of less than 4m, while the average depth is only about 1.0 m. Annual average temperature in the area is 7.3 °C, annual sunshine 3184.5 h, average annual rainfall 224 mm, potential average annual evaporation 1502mm. The lake is normally covered by ice from November to March, and only 152 days per year are frost-free.

Figure 1. Map over the Great Bend of Yellow River with Hetao and the irrigation system. Red lines are irrigation canals and blue dashed lines are drainage canals. Yellow lines are roads and black dashed lines are administrative borders. Along the main drainage canal at the northern border of the area are the numbers of the major drainage canals noted (BaMeng Hydrological Bureau, 1980).

Lake Wuliangsuhai is an important part of Hetao agriculture irrigation and drainage system. Yellow River is the main irrigation water resource of this area. Sanshenggong branch dam is the intake of Yellow River. About 6.0 billion m^3/y water are introduced to Hetao each year. The area of 6900 km^2 plowland is in the irrigation areas, and it is planed to add to 7300 km^2.There is a main irrigation channel and a sub-division into about 20,000 branch irrigation channels that composes the irrigation system in Hetao. The drainage system consists of 22,000 branch drainage channels, which head for the main drainage channel together and finally into Lake Wuliangsuhai. The pumping stations lift 0.7-0.9 billion m^3 water from the drainage canals into Lake Wuliangsuhai. Once the surface level of the lake is higher than 1018 m above sea level, or in the low water period of Yellow River, Lake Wuliangsuhai will be drained to supply Yellow River. The output volume is about 2 billion m^3 every year, with a supply of 20 m^3/s water to the Yellow River. The lake retention time is 160-200 days.

The eutrophication of the lake is a result of large loading of nutrients from the Hetao area, which is an intensively cultivated agricultural plain entirely dependent on irrigation water from the Yellow River. At present, one conspicuous problem with Lake Wuliangsuhai is that the lake surface is giving way for reed beds that today cover roughly half of the lake.

2.2 Geological history and context of Lake Wuliangsuhai

Lake Wuliangsuhai in a geological and historical perspective
The climate of the Ordos Plateau, of which the lake Wuliangsuhai is a NE part, has undergone dramatic changes since Tertiary. With the Pliocene collision of India into the Asian continent, the resulting uplift of the Himalayas created a barrier to the monsoon rains, and shifted the climate from humid to arid, from subtropical to cool, and from forest to steppe (and the occasional deserts) (Li et al, 1990).

The trend has continued through Pleistocene and Holocene and explains some of the problems encountered in the lake area today. During late Pleistocene, the Ordos Plateau became extremely cold and dry, with moving sands covering much of the area.

Archaeological evidence shows that the Ordos Plateu was inhabitated some 60.000 years ago (Shi et al, 1991). Early written records exist for the last 2.000 years. Whereas climatic changes in the Pleistocene (3 million to 10.000 years before present) can be attributed solely to geological changes, the more recent Holocene shifts can be attributed to human intervention such as grazing, farming practices, etc.

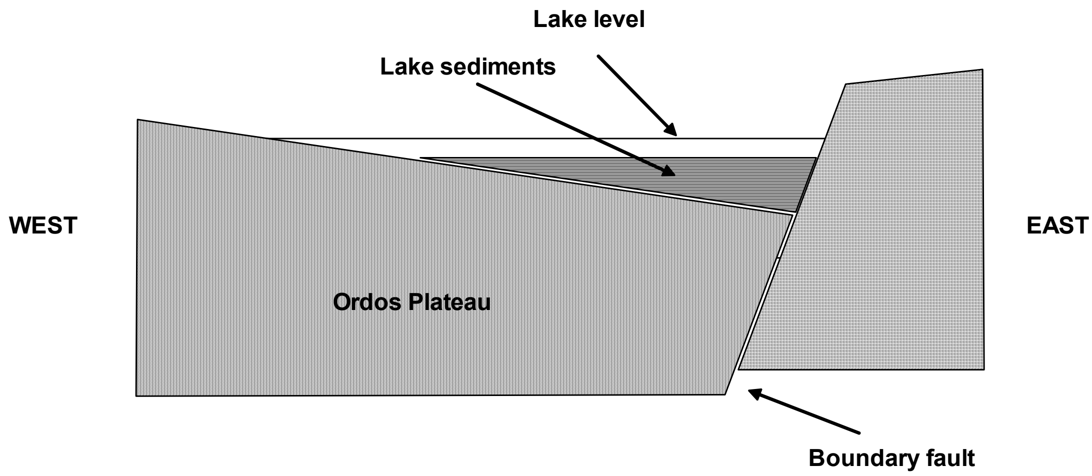


Figure 2. Lake Wuliangsuhai was created by a slight tilting of the Ordos block. The lake is dammed against the northern and eastern fault scarps, which form the main confinements of the present lake.

Factors controlling water depth and size of Lake Wuliangsuhai
From a geological perspective, the Lake Wuliangsuhai is situated at the very depo-center of the tectonically active Hetao Fault Basin of the Ordos Plateau. The lake is bounded to the south and east by active tectonic escarpments.

The very reason for the Yellow River taking its famous easterly detour (the Great Bend) is due to tilting and subsidence of the SE corner of the Ordos Plateau. In other words, natural sedimentation and block subsidence have diverted the river and have controlled the presence and size of the lake since the early Pleistocene, some 3 million years ago. The lake has expanded and contracted over much of the Hetao area countless times during this period.

Consequently, several thousand meters of alluvial, lacustrine and eolian sediments have accumulated under the present Lake Wuliangsuhai. As the rate of subsidence has not always kept up with the rate of sedimentation over the past few hundred years, the lake is presently being filled in and is consequently steadily shrinking, essentially from natural causes. The deterioration of the climate (colder and drier) during the past 1000 years has also contributed to less water and more sediment due to eolian transportation of loess, dust and sand.

In addition, man-made factors are controlling the lake level and depth. The most important factor is presently the artificial replenishment of water, which is drained from the intensely irrigated Hetao plain and pumped into the lake. At present, the lake's area is 293 km^2. While the lake water level is being controlled by the outlet weir, organic and inorganic sedimentation of the Lake Wuliangsuhai is slowly but steadily filling up the basin, at the expense of the water quality as well as the volume of water stored in the lake. Since the water level is not being adjusted correspondingly upwards to compensate for the increasing elevation of the bottom level, the inevitable consequences of the sedimentation are less available water and an increasingly shallow lake.

With increased populations, economic development, better living standards and consequent water demands downstream, the pressure on the available water resources of the Yellow River is mounting. The amount of water that eventually will be allowed to replenish Lake Wuliangsuhai will no doubt determine the lake's future.

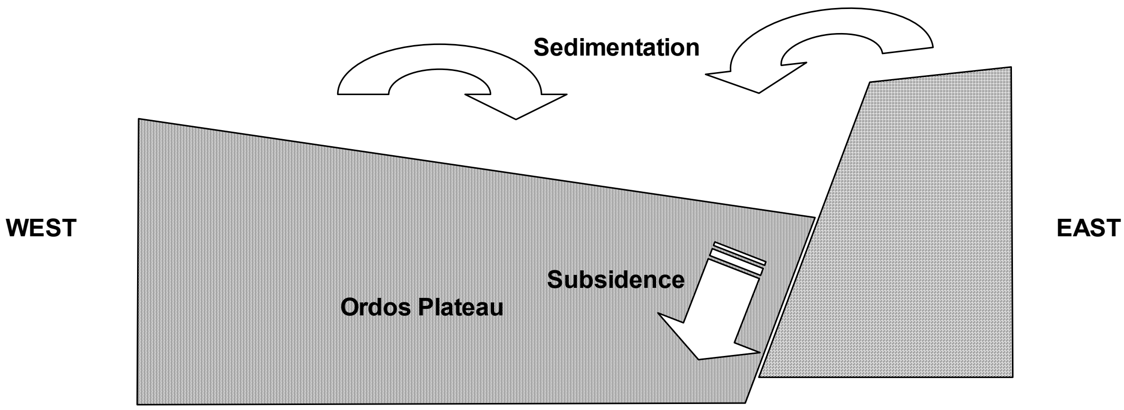


Figure 3. Competing rates of sedimentation and subsidence determines the size and depth of Lake Wuliangsuhai at any point in time. The age of the faulting (and the subsidence) is predominantly Pliocene until Recent, i.e. the system is still active.

The above situation is nicely illustrated by the flow situation in the present day Lake Wuliangsuhai. The very presence of the lake is totally dependent upon the rate of subsidence exceeding the rate of sedimentation. When simulating water flow during a summer day, the bulk of water is seen to prefer the eastern flank of the lake, a legacy of the tilting situation as explained above, in addition to the mosaic pattern of reed and 'open water'.

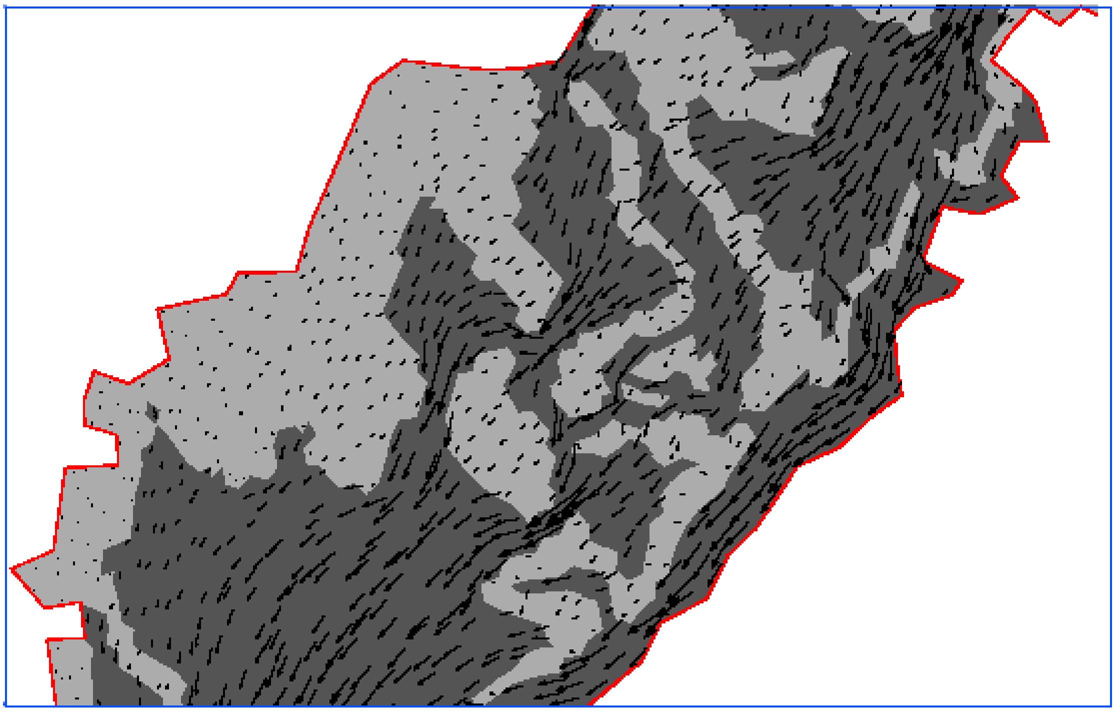


Figure 4. The preferential region of water flow, as seen from model simulations, coincides with the deepest (eastern, left) part of Lake Wuliangsuhai. This situation is a legacy of still active tectonism (subsidence).

2.3 Lake area, coverage and water volumes

Since the cut-off from the Yellow River during a major flood at ca. 1850, the main lake basin including dense reed areas has gradually diminished to the present size of ca. 300 km^2 due to a combination of natural processes and the establishment of Hetao Irrigation Area.

Lake Wuliangsuhai is a very shallow lake. The maximum depth found during the three field studies in 2001 and 2002 was 3.3 m situated in the southern part of the lake, probably part of an old riverbed. Most parts of the lake have depths less than 1.0 m and the mean depth of open water' is approximately 1.0 m. Other information claim that the deepest point of the lake is somewhat deeper (up to 4 m), but it has not been possible to verify this during the project work. Despite some inaccuracies (especially in the northern part, north of the crossing road) due to limited resources, the depth contour (Fig. 5) probably gives a fairly good framework for most relevant problems to be addressed in this project. The depth contour map below is super-imposed a satellite image from 2002, and shows the lake with reed belts in yellow and open water in different shades of blue and violet depending on depth.

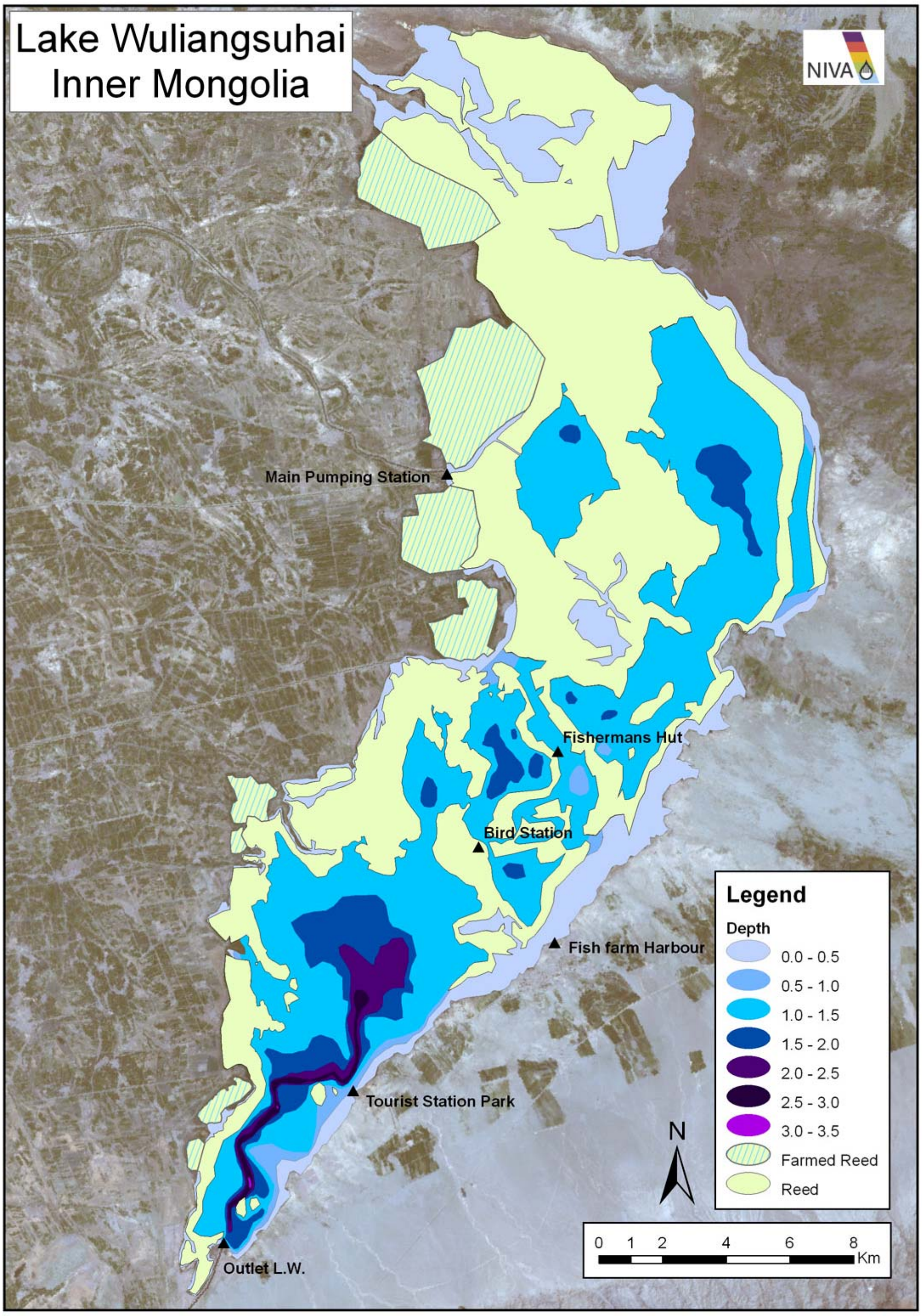


Figure 5. Depth contour map of Lake Wuliangsuhai constructed from a large number of depth measurements during this project.

The volumes and areas of open water are estimated from the above map are presented in Fig 6-7.

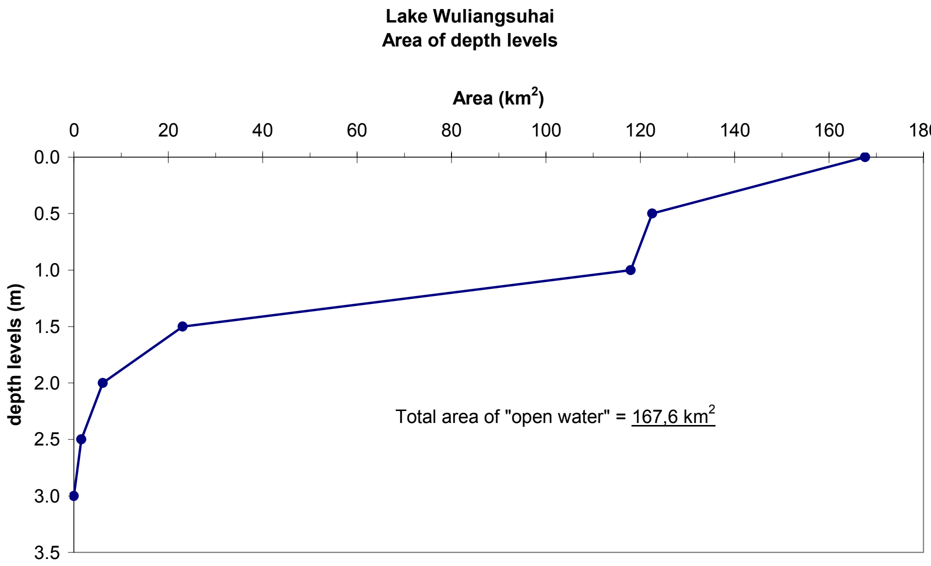


Figure 6. Areas of 'open water' calculated from the depth contour map.

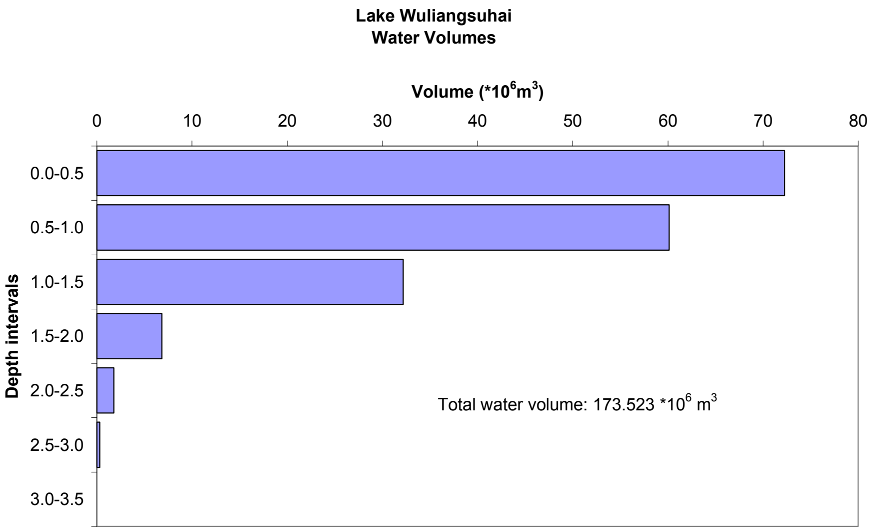


Figure 7. Water volumes of 0.5 m depth-levels of 'open water' in Lake Wuliangsuhai.

As it is shown in the Fig 6, the total area of 'open water (without reed) is calculated from satellite images to be 167 km^2, whereas reed covered an additional 178 km^2. Thirty two km^2 of the present reed area is defined as' farmed reed' as it grows on former agriculture land on the western side of the lake. The satellite images as Fig 8 were used to estimate the reed coverage area.

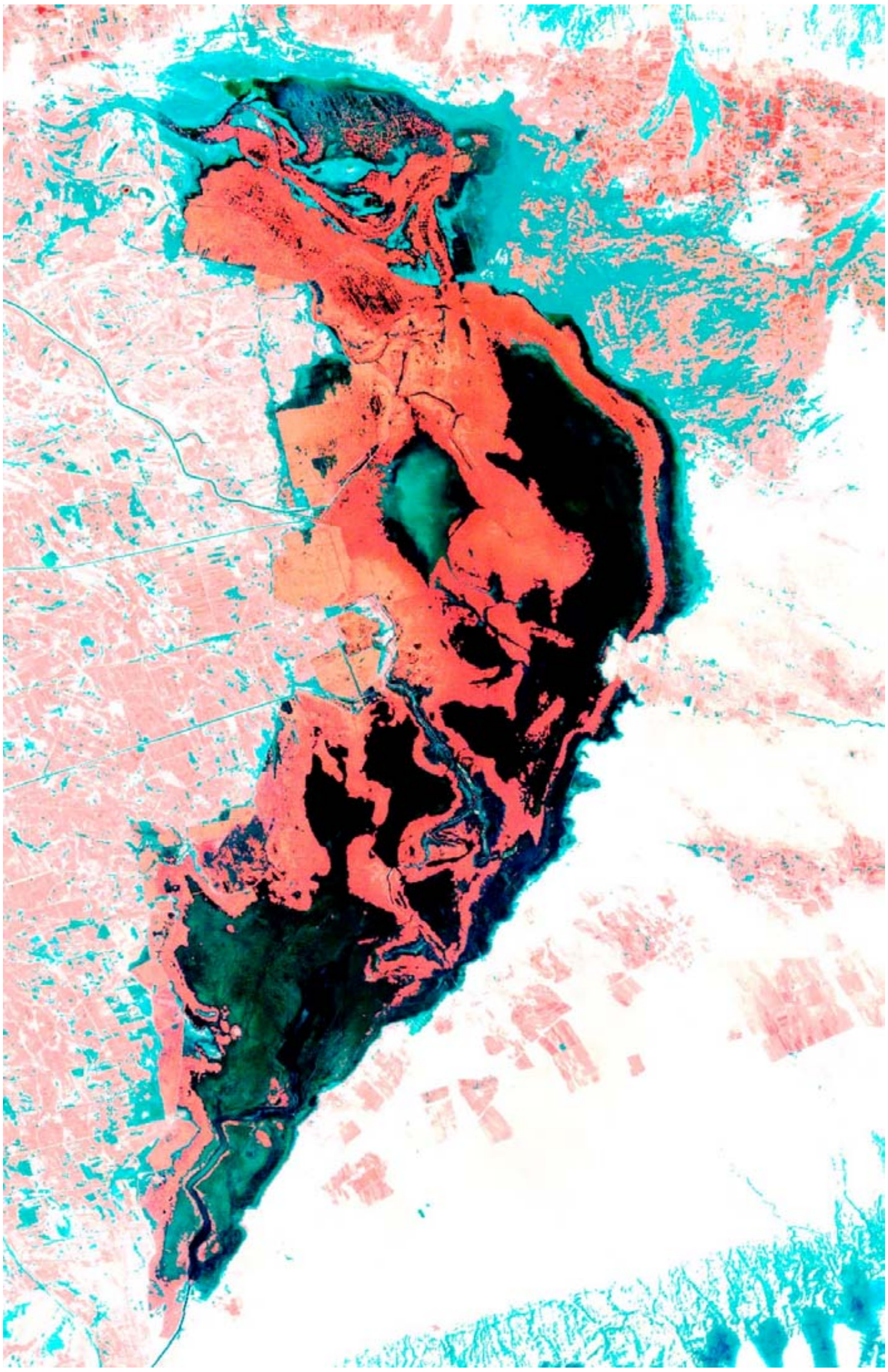


Figure 8. Satellite image from 20 July 1999. Red colour is vegetation, the dark red is mainly reed in the lake while lighter red is farmland on terrestrial areas. Close to 50 % of the lake surface area is covered with reed today. Shallow areas in the lake and turbid water in Xidatian basin, as well as wet mud on terrestrial areas are green.

2.4 Hydrological aspects

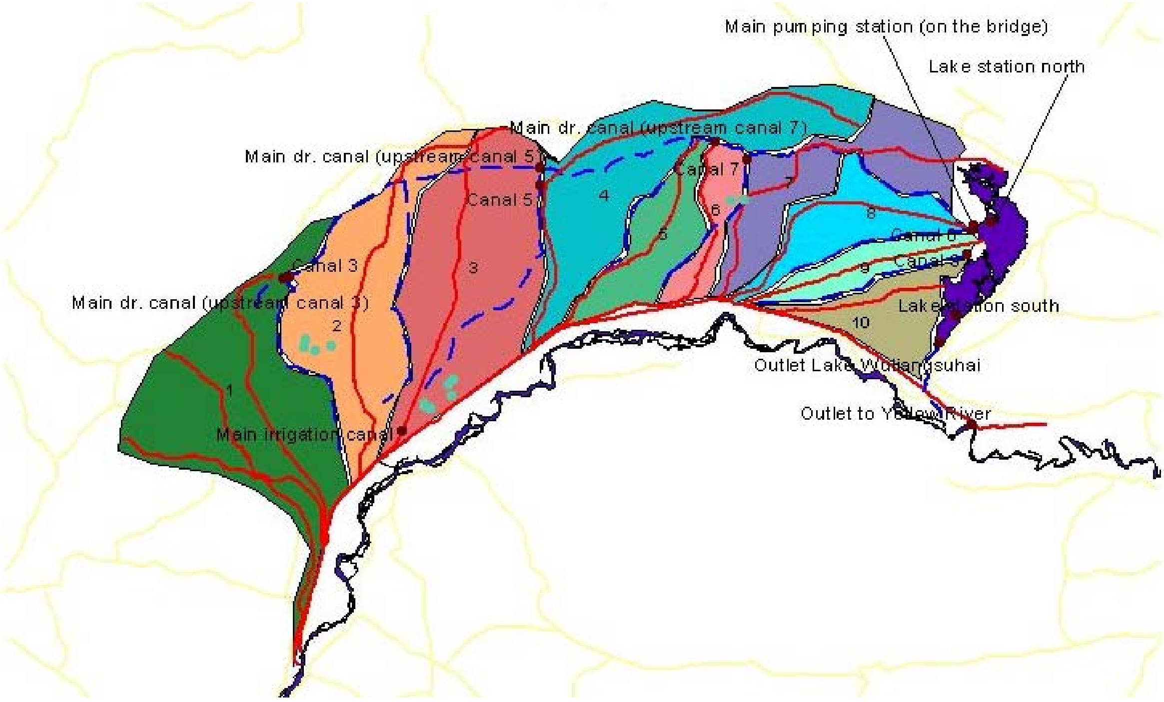


Figure 9. Drainage (red) and irrigation (blue) canals in the Hetao area. Local catchments to irrigation canals nos. 1-10 are presented in different colours.

The Lake Wuliangsuhai receives its water from the Yellow River, via the Main Irrigation Canal (Fig. 9). The gate in Yellow River at Sanshenggong is open during the irrigation period, i.e. mid April to late October. During this period, half of the water flow of Yellow River at this point is diverted into Hetao for irrigation purposes.

The total Hetao Irrigation Area uses the irrigation water diverted from the main canal by gravity flow. The canal system of the Hetao Irrigation System consists of seven levels of canals. On the downstream side of the farmland, the drainage canal system also consists of seven levels. After irrigation of the farm fields, the drainage water enters the Main Drainage Canal, which runs parallel to the Main Irrigation canal about 200 km further to the north, and finally into Lake Wuliangsuhai through the Main Pumping Station. Only drainage water from Drainage canals 8 and 9 is pumped directly into the lake via separate pumping stations.

The water in Lake Wuliangsuhai discharges into Yellow River by gravity flow. A dam regulates the water level of Lake Wuliangsuhai according to the need for flood protection, a stable water level through the winter etc. The lake occasionally receives backwash water from Yellow River via the outflow canal. In this way, the lake may serve as a flood protection reservoir for the lower parts of Yellow River.

A hydrological simulation of the current situation was carried out (see next chapter for details), and the results are depicted in Fig. 10. The water enters to the lake from the mid-left and discharged through the southernmost point. It is well evident from the simulations that there is an obvious stagnation of water in the northernmost 1/3 of the lake, as well as many other areas.

The reed coverage, entering and discharging points, flows and internal barriers (roads) have created the current hydraulic conditions.

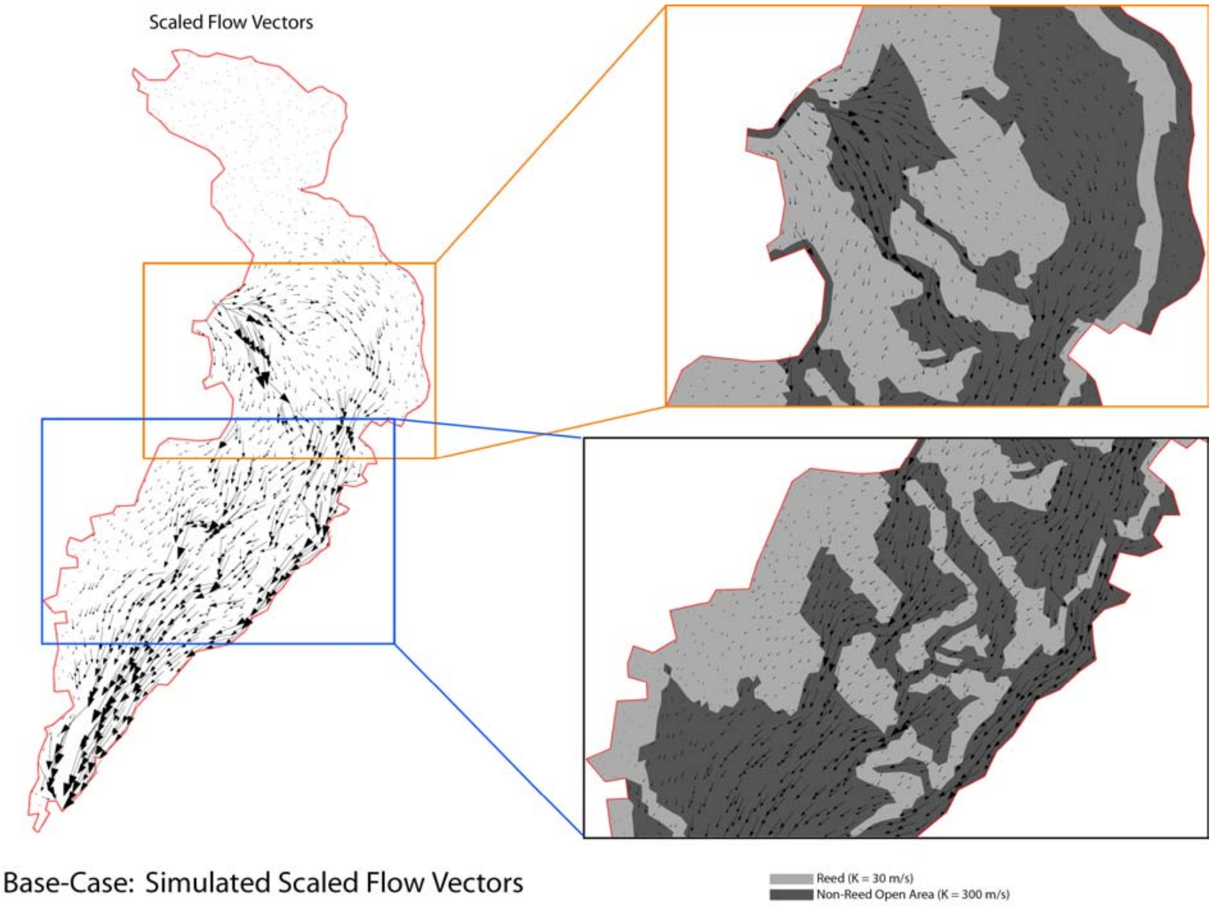


Figure 10. Simulation of hydraulic conditions of the lake. Length and direction of the arrows indicate the hydraulic condition.

2.5 Water quality

The discharge of organic matter into the lake from the Hetao area is so large that the water quality for these variables are beyond the classification standard (exceed class V), when measured as BOD_5 and COD. Only in the Erdiar during summer, the organic content is within the limits off class V. For nitrogen, the water quality class is beyond class V at both lake stations, except at Erdiar during winter. A large part of the Total nitrogen was present at ammonium. Total P was in class V the whole year around in the southern basin, while the Xidatian was beyond class V in winter.

Table 1. *The Chinese water quality standard classes for surface water (GB 3838-2002) for the most relevant variables in lakes with upper concentration limits for the different variables.*

	BOD5 mg/L	COD mg/L	CODmn mg/L	NH4-N mg/L	NO2-N mg/L	NO3-N mg/L	PO4-P mg/L	total N mg/L	total P mg/L
Chinese Standard (Lake)									
class 3	4	20	6	1		10		1	0,05
class 4	6	30	10	1,5				1,5	0,1
class 5	10	40	15	2				2	0,2

Exceed class5

The water quality was generally better in the southern part of the lake (Erdiar) than in the northern basin close to the Main Pumping Station (Xidatian), for nitrogen (Total N, NH_4, NO_2 and NO_3), but not for Total P and organic substances (BOD_5 and COD). However, during the non-irrigation period the Total P concentration was also markedly higher at Xidatian than at Erdiar. These evaluations are based on average values for all sampling years (1987-2002).

The water quality tends to be better in the irrigation period compared to the non-irrigation period at both lake stations. The table below show both the average concentrations (with numbers) and the water quality class (colour according to standard classes to the left on the preceding table).

Table 2. Comparison of water quality classes in irrigation and non-irrigation periods. Numbers in this table refer to the average seasonal concentration while the colour is the water quality standard class for surface water.

Non-Irrigation Period, Lake	BOD5 mg/L	COD mg/L	CODmn mg/L	NH4-N mg/L	NO2-N mg/L	NO3-N mg/L	PO4-P mg/L	total N mg/L	total P mg/L
Lake station, North	12,83	91,63	11,56	9,47	0,03	0,43		25,15	0,51
Lake station South	16,23	127,23	7,49	0,41	0,01	0,11		1,89	0,15

Irrigation Period, Lake	BOD5 mg/L	COD mg/L	CODmn mg/L	NH4-N mg/L	NO2-N mg/L	NO3-N mg/L	PO4-P mg/L	total N mg/L	total P mg/L
Lake station, North	10,86	50,48	7,55	2,00	0,18	0,28		6,91	0,13
Lake station South	6,69	67,90	10,24	0,32	0,04	0,13		3,13	0,17

Today the lake is characterized by severe plant-type eutrophication including high concentrations of plant-nutrients (P and N), dissolved organic substances and mineral salts, causing a dense growth of reed and submerged vegetation, winterkills of fish and a markedly reduced biodiversity of many groups of plants and animals. An analysis of the lake sediment has documented the development from a former situation with much 'healthier conditions' with cleaner water and less plant production during the first ca. 100 years of the lake's life span after the diversion ca. 1850.

Despite this negative development, the lake is still a large, valuable and rare wetland ecosystem of the dry northern plains in China. Its high value depends both on the production of valuable resources for the local people and its environmental significance; not the least as a bird habitat.

However, the average depth of the 'open water' part of the lake is only about 1 m today. It is clear that the lake will inevitably become shallower at a high speed due to the pollution and its high biological productivity. Unless efficient steps are taken to counteract the present development, it is predicted that the lake will develop into dry land during the next 30-100 years.

2.6 Biodiversity

To sustain or increase the biodiversity in Lake Wuliangsuhai is one of the goals of this project. A detailed description of biodiversity of the lake is given in the Sub-project report on Basic Processes (Sub-project Report no. 5). This chapter only presents highlights and main concerns.

A shallow lake like Lake Wuliangsuhai consists of parts with different characteristic environmental qualities. These environments have pronounced differences in productivity, plant and animal biomass, species diversity, vulnerability to human impacts etc. In the following, five different environments relevant to Lake Wuliangsuhai are described. A simplified description of plant and animal species diversity is suggested.

In general, lake environments are characterised by much lower biodiversity than terrestrial ones. This is both attributed to their low structural heterogeneity and to the 'young' age of most lakes, with short time to both species invasion and evolution of new species.

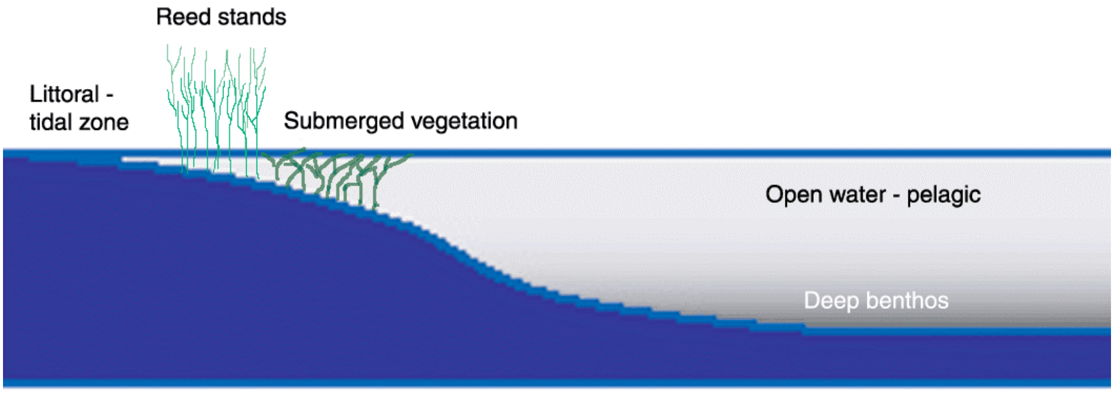


Figure 11. Division of a shallow lake into five different habitats. For Lake Wuliangsuhai, additional habitats like islands or marshy forest could be added.

Deep benthos
There are bottom areas in the lake too deep to be inhabited by green plants, due to lack of light. Such areas are dominated by animals living on and in the sediment relying on the organic content and the micro-organisms of the sediment or the deep water as their main source of food. Examples of such animals are insect larvae, mussels and sponges.

Actually, no water depths larger than 3,2m have been measured in the lake lately. For the purpose of the systematic of this presentation we choose to call this environment 'Deep pelagic', to distinguish it from benthic communities within the reed and submerged vegetation. Even though such areas have limited distribution in Lake Wuliangsuhai, their inhabitants may play an important role as food for fish and birds. To our knowledge, no investigation has been carried out on benthic animals in the lake.

Normally, deep benthic communities are stable compared to those in pelagic environments, due to more stable physical and chemical environment. However, pollution or extreme climatic events may considerable affect these environments. In Wuliangsuhai, the organic pollution and the high plant production cause oxygen depletion near the sediment during winter, which have a dramatic impact on the biota in this environment every year.

Table 3. A rough evaluation of diversity of the most typical plant and animal groups in deep benthos habitats in Lake Wuliangsuhai.

	low diversity	medium diversity	high diversity
insects		□	
zoobenthos		□	
phytobenthos	□		
phytoplankton		□	
zooplankton		□	
fish	□		

Open water - pelagic
The pelagic part of the lake is the water above the deep benthos. In these parts the phytoplankton, zooplankton and pelagic fish dominate. The only primary producers in this environment are the phytoplankton that converts light energy from the sun to biomass by means of chlorophyll, like other plants. The main difference with other plants is that phytoplankton

consists of microscopic, free-floating algae with no cell differentiation to form roots, stems, branches and leaves. Phytoplankton constitutes, together with pelagic bacteria and organic particles, food for filter-feeding zooplankton. In addition, some zooplankton species are predators on smaller zooplankton. Zooplankton may be important food for many fish species.

The relative more importance of pelagic food chains in shallow lakes than in deep ones is caused by the high plant production in the reed and submerged parts of the lake, and that the pelagic constitutes a restricted part of the lake.

The pelagic environment is vulnerable to pollution events and extreme climatic conditions. Due to short generation times of phytoplankton, the pelagic food chains may rapidly change in species distribution, diversity and productivity.

Table 4. A rough evaluation of diversity of the most typical plant and animal groups in open water – pelagic habitats in Lake Wuliangsuhai.

	low diversity	medium diversity	high diversity
insects	□		
phytoplankton			□
zooplankton			□
fish	□		
birds			□

Submerged vegetation

In a large part of the lake shallow enough for plant growth, submerged vegetation has established. These are vascular plants (with roots, stems, branches and leaves). The submerged plants are connected to the sediment by roots, which collect a certain part of the nutrients they need. During summer, the stems normally grow long enough to reach the surface of the lake. Many submerged plants start growing in the spring from seeds, or from small wintering shoots on the sediments, so-called tubers. Other species may survive the winter as intact plants.

The dominant submerged plant in Lake Wuliangsuhai, sago pondweed *Potamogeton pectinatus*, seems to a large degree able to survive the winter as intact whole plants. Another species observed in the lake, which may form winter shoots is hornwort, *Ceratophyllum* sp. The dense cover of submerged plants make a physical environment well fit for a rich flora and fauna. In addition, *Potamogeton* has a low content of cellullose, a fact that makes it a feasible food item for plant-eating birds and fish. When the *Potamogeton* reaches the surface during early summer, the floating mass of plants is a suitable surface for insects, attached algae and birds.

This type of submerged plant environment is known to be resistant to most disturbances in a lake. Once established this species will normally persist for ages.

Table 5a. A rough evaluation of diversity of the most typical plant and animal groups in submerged vegetation habitats in Lake Wuliangsuhai.

	low diversity	medium diversity	high diversity
insects			□
zoobenthos			□
phytobenthos			□
phytoplankton	□		
macrophytes	□	□	
zooplankton			□
fish		□	
birds			□

Reed stands

The most prominent feature of Lake Wuliangsuhai is the widespread reed stands covering ca. 50% of the lake surface. The by far most dominant is common reed, *Phragmites australis*, a species distributed worldwide in temperate lakes and marshes. The sub-dominant is a bulrush, *Typha* sp. These species grow in water depths down to ca. 0,7m. The reed marsh is the habitat of a high number of birds and insects. Under water in such areas a rich community of microorganisms, attached algae, insect larvae and other invertebrates may also be found. However, these communities have not been the targets of the present investigation.

Typical of a reed marsh is waterlogged conditions and anaerobic soils. The reed is expected to be a very stable environment of the lake, resistant to most normally-occurring disturbances.

Table 5b. A rough evaluation of diversity of the most typical plant and animal groups in reed habitat in Lake Wuliangsuhai.

	low diversity	medium diversity	high diversity
insects			□
zoobenthos			□
phytobenthos			□
phytoplankton	□		
macrophytes	□		
zooplankton			□
fish	□		
birds	□		

Littoral zone

In Wuliangsuhai, restricted areas of the lakeshore without or with sparse plant cover are found. These areas are very different from those with reed or submerged vegetation. One feature of such areas is that their plant and animal communities are much more vulnerable to changing water levels than those protected with plants. A moderate to high level of disturbances (humidity, temperature, erosion etc.) may cause rapid seasonal successions and high competition, predation and competitive exclusion of species in these areas. Terrestrial run-off and water movements continuously replenish nutrients and suspended organic particles, and growth rates and competition are therefore often quite high.

Table 6. A rough evaluation of diversity of the most typical plant and animal groups in littoral habitats in Lake Wuliangsuhai.

	low diversity	medium diversity	high diversity
insects			□
zoobenthos			□
phytobenthos			□
phytoplankton		□	
macrophytes	□		
zooplankton			□
fish			□
birds			□

To further increase the biodiversity of Lake Wuliangsuhai, the area of some of the rare habitat types could be increased (e.g. Deep benthos and Littoral zone) and some additional habitats could be introduced (e.g. Islands and Wet Shore Forest).

2.7 Function Analysis

During a stakeholder workshop (LFA- Logical Framework Approach) in 2002, the following issues were identified and concluded as the main issues.

Functions in the past

- ecosystem function of wetland

- containing irrigation water
- improving water quality before water input to Yellow River
- supplement water to Yellow River in low water periods
- tourism
- fishery
- reed harvesting
- climate adjustment

Functions at present

- ecosystem function of wetland
- containing irrigation water
- improving water quality before water input to Yellow River
- supplement water in low water period
- tourism
- fishery (very limited)
- reed and submerged vegetation harvesting
- climate adjustment

Planning Functions in the future

- ecosystem function of wetland
- utilize of water resource
- containing irrigation water
- improving water quality before water input to Yellow River
- supplement water in low water period
- prevention flood
- tourism
- fishery
- reed and submerged vegetation harvesting
- climate adjustment

2.8 Socio-economic issues

Lake Wuliangsuhai is considered a dynamically fragile ecosystem that is relatively resistant to minor changes with which it has co-evolved. However, at the same time it is vulnerable to major perturbations such as resource overexploitation and pollution from various sources. The lake has a high biodiversity, of which fisheries is a major resource for the riparian communities. During the last two decades, the lake has encountered numerous problems, which have constrained its productivity resulting in the decline of biodiversity in general, and fisheries in particular.

Since the 1950s, the lake has undergone successive dramatic changes. External changes in the drainage basin vegetation, industrialization, agricultural developments and the introduction and invasion of exotic species are among the factors that have led to the destruction of the native and endemic components of the lake. These changes have been followed by a progressive build-up of physical and chemical changes in the lake. In addition, the socio-economic and institutional changes have led to overuse of the lake's resources. A proper understanding of the society-nature interactions is necessary to provide a better understanding of the current problems and possible solutions for better management of the lake ecosystem.

In the case of Lake Wuliangsuhai, socio-economic analysis is needed to get more information about the resource dependency of the local communities on the lake. This could be used to improve the management of the lake resources with the help of local communities and other stakeholders that could increase their benefits from the lake resources. Stakeholders in the lake area include farm workers, fish farm villages, state-owned agriculture farms, city of Wulateqianqi and its local government and the relevant departments (agriculture, industry and environment), regional government, Bayannaoer League, especially three sectors: agriculture (fertilizer pollution water into Lake Wuliangsuhai), industry (polluted water) and the Yellow River Management Bureau introducing water from Yellow River, who control the water quantity being diverted into the lake. These stakeholders have competing interests over the lake's natural resources, which keep changing with changes in socio-economic setting.

Stakeholders choose their strategy and behave according to the incentives they receive from the surrounding ecosystem. The incentives they derive from the lake depend on the profession and the status in the whole social-economical setting. A change in the environmental setting influences the types of incentives they receive. Socio-economic analysis helps to study the existing patterns of behavioural changes, norms or values; and community participation, which is essential for sustainability; to gain more knowledge on local needs, problems, constraints and solutions.

A proper assessment of the positive and negative socio-economic impacts of the development initiative is needed to show the local stakeholders and ensure their commitment for the conservation of lake's resources.

The assumption is that the proposed project measures may not have a major impact on the social system, since they are mostly technical based. On the other hand, some of the proposed interventions will depend on local institutions being able to change the awareness and the production systems around the lake. This will require an analysis of the institutional capacity and possible programme for institutional strengthening as part of project implementation.

The present situation in Inner Mongolia is comparatively difficult for agriculture. Hetao area, due to Yellow River water's irrigation function, is known as an oasis in completely dry, desert-surrounding Inner Mongolia area. Hetao irrigation area is an old alluvial flood plain created by Yellow River. Today, irrigated agriculture is still the biggest GDP producer, accompanied by a rapid increase of industry and service sectors. Socio-economic development is putting more and more pressure on local environmental and ecological habitats. Water resource problem is prominent among all environment problems. Lake pollution comes from wastewater produced by local agriculture, industry and municipal and flowing into the lake through canals. Pollution is seriously hazarding the Lake Wuliangsuhai.

From the time it was established in 1960s, Wuliangsuhai Fish Farm has supported livelihoods of 2-3 generations. Fish is an important source of income and diet to the local people and the many people are engaged in reed harvesting. In the Fish Farms, seasonal workers do not get wages. Their income mainly depends on their production, especially linked with surplus over production quota.

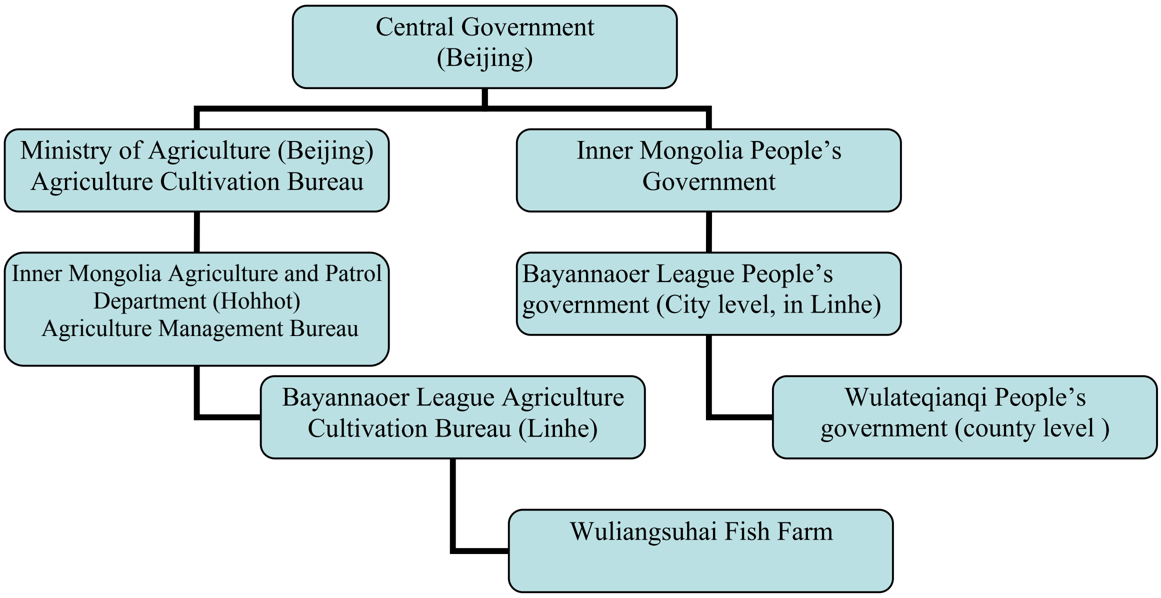


Figure 12. Fish Farm Lake Wuliangsuhai's institutional set-up

The figure shows a top-down approach of the institutional set-up. The recent institutional changes in the study area are an example of people's interests in participating in the lake management. This is practical for people to solve the various conflicts between the sectors, and tackling the pollution problems, which are posing a serious threat to the lake ecosystem. The poor conditions of the workers in the Fish Farm are the results of the conflicts and they bear the costs of these social losses of institutional disadvantage.

Production quotas increase pressure on natural environment and resource of the lake. The increasing population, declining fish stocks, increasing pollution of lake and the reed expansion, all have their toll on the lake ecosystem. In order to decrease the pressure from the increasing human activities it is necessary to take some remedial measures.

2.9 Economical considerations

The resources of the lake represent important livelihoods for the population in its surroundings. A detailed analysis of economic values of the alternative use of water resources is presented in a separate sub-project report.

Based on available data, primary data collected in the field, and the assumptions in the sub-project report, the average economic values per unit area of reed and open water are calculated as following, and are low-end estimates.

The *average* value of return flow from the Hetao Irrigation Area for uses in Lake Wuliangsuhai is around 0.10-0.11 RMB/m^3 depending on whether 2001 or 1998 is used as a base year. This estimate is based on the lower bound estimate of recreational value (97.5% confidence) based on the travel cost method (TCM), not including willingness to pay (CVM) estimates for a lake with improved water quality. If we include willingness to pay estimates and use mean welfare estimates from the travel cost study, the average value of return flow is 0.11-0.14 RMB/m^3. These average values represent the hypothetical opportunity cost of losing all return flow to the lake, and with it, all lake uses.

Despite a lack of detailed modelling of hydrological, water quality and plant succession, a rough attempt was made to evaluate the *marginal* opportunity cost of a partial loss of the lake of 0.5

meters in lake level. For drops in lake water level there is a possible trade-off between visitation and reed production if assumed aggressive reed colonisation. Given conservative assumptions, the value of additional water to the lake to avoid a 0.5 meter drop in water level - equivalent to losing 211 million m^3/year - is between 0.04-0.06 RMB/m^3. This is higher than the 0.0274 RMB/m^3 the lakeside Fish Farm company paid for about 78 million m^3 in 2004. Therefore, it is concluded that the Fish Farm's purchase of Yellow River water at the 2004 terms had net benefits from an social economic point of view. From a short-term financial point of view of the Fish Farm the benefits are less obvious, as reed area may even increase with a drop in lake level and current (2001) income from tourism was very low. Almost all value comes from consumer surplus to visitors.

However, one should keep in mind that potential future lake uses, such as use of aquatic plants for production of animal feed, mud for fertiliser production and international ecotourism based on bird watching, etc. might influence the economic considerations. Lake Wuliangsuhai is a Bird Protection Area on the autonomous region level. Combining bird counts in spring 2000 and autumn 2004 revealed an estimated 128 different bird species and as many as 42 000 individuals. Lake Wuliangsuhai is the only freshwater lake within several hundred kilometres and of such an importance to migratory bird species that it fulfils the criteria for designation as a RAMSAR wetland of international importance (Subproject on monitoring). Future revisions of this report should include transferring estimated economic benefits of bird conservation for international tourism from similar RAMSAR wetlands to Lake Wuliangsuhai.

The conservative assumptions for recreational values were used based on data collected in the visitors' survey. Currently the main reasons for visiting the lake among the mainly Chinese one-day visitors are for boating and lakeside viewing, with bird watching coming 3rd. However, a lake with improved habitat for birds has a potential to attract multi-day visitors for bird-watching and ecotourism, a potential use values which has not been explored further in this study.

For fisheries the lake has a considerably larger economic potential than the present subsistence fishery, both through increasing stocks of more valuable fish species, and though larger individuals which fetch better prices by weight. The potential value of such a 'healthy' fishery in the lake along the lines of anecdotal evidence from the 1950s has not been estimated mainly due to lack of any historical fisheries effort data, catch statistics only as far back as 1980, and only a few years of water quality monitoring. Such data would be required to identify the relative importance of pollution and over-fishing for the decline in fish stocks.

Furthermore, no value is assigned to water stored in Lake Wuliangsuahi and released to the Yellow River during the dry season. In 2001 this was 366 000 m^3. Returns to downstream water uses in the Yellow River were given at 0.3-0.5 RMB/m^3 in available studies. At these values, the current (2001) value of the reservoir services provided by Lake Wuliangsuhai to Yellow River would be small. We have in no way pretended to evaluate the economic potential of such reservoir services given the poor resolution of topographical data from the lakeshore. However, it would seem to be limited and inferior to economic impacts of large seasonal changes in water level on reed harvesting and especially visitation.

Putting Lake Wuliangsuhai and Hetao Basin in a wider context it is possible to make some simple comparisons on the value of water allocation (Fig. 13). If irrigation water losses are excluded from calculations (0% loss), the values of water in irrigated water in Hetao are considerably higher than values with irrigation losses observed in 1989. Increase in the water value of economically marginal crops such as wheat may be as much as 0.5 RMB/m^3. This is more than the most conservative marginal value of water for lake uses observed. Based on this logic, water savings in wheat should be pursued aggressively assuming that the increased value to wheat production would be greater than the (albeit conservatively) estimated losses to downstream lake uses.

This is however, a theoretical value given that water transportation will always entail some loss before reaching the field. Wheat is a water-demanding crop consuming an estimated 670 million m^3 /year in Hetao, including irrigation loss proportional to its cultivation area. Depending on which year is used as a basis, the average residual value of water to irrigated wheat varies between 0.05 RMB/m^3 (1999) – 0.39 RMB/m^3 (2003). Even with the very conservative estimates of the marginal value of lake water uses, the report shows that a good economic case could also be made for reallocating water from the least productive areas under wheat to the maintenance or increase of water level in Lake Wuliangsuhai.

From the perspective of downstream uses in the lower half of Yellow River, even the very conservative estimates of opportunity costs to downstream water uses (0.3-0.5 RMB/m^3) make a good case for reallocating at least some of the water from marginal crops, such as wheat (670 million m^3 /year), maize (574 million m^3/year) and interplanting of wheat-maize (2088 million m^3/year) to downstream uses. Based on the agricultural production data we have available for 1999-2003, this conclusion would also be true even after eliminating all irrigation losses in agriculture. Part of such reallocated water could be passed through Lake Wuliangsuhai in March /April in order to achieve a somewhat higher flow back into the Yellow River in May when irrigation demands are at their highest.

Based on even the slim data available in this study, the potential economic value of ecosystem services - such as flow attenuation - that are and can be provided in Lake Wuliangsuhai are likely to surpass the economic value of direct uses. 'Keeping the lake as a lake' would seem to have an economic rationale, if added that this requires better allocation of water in the Hetao basin in addition to the pollution abatement measures upstream, and restoration measures in the lake itself that have been the main focus of the Lake Wuliangsuhai Project.

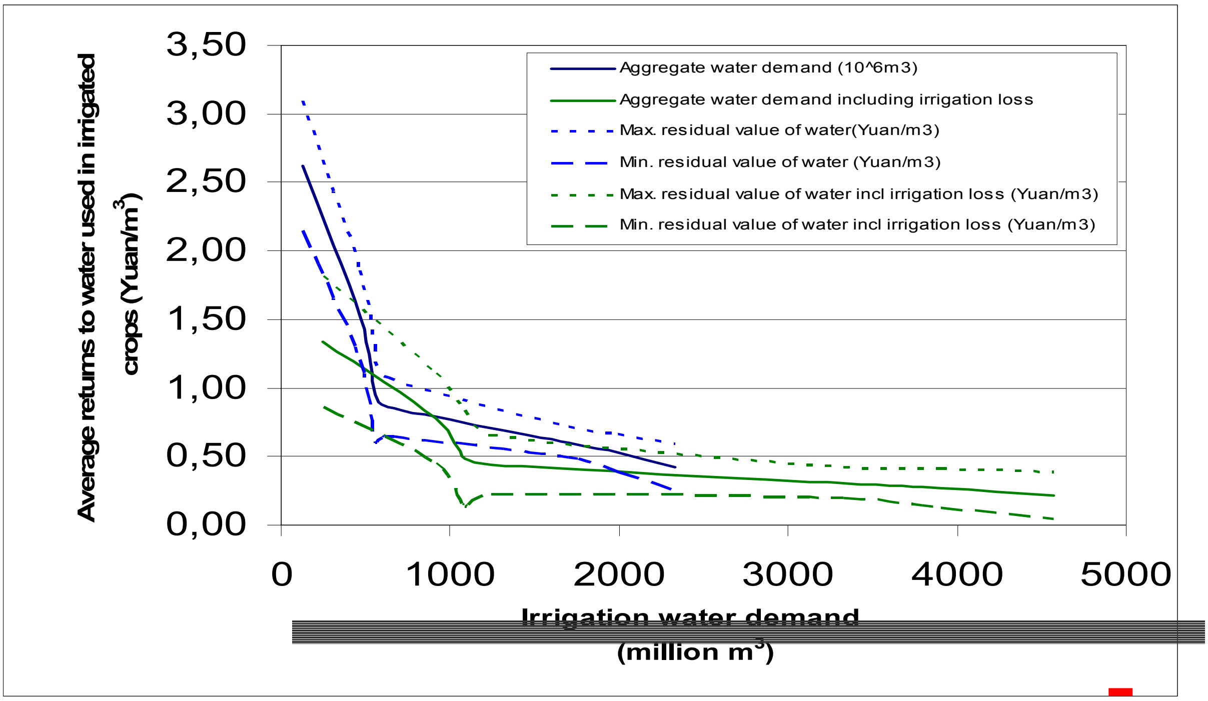


Figure 13. Returns to use of water in agriculture (1999-2003), average opportunity cost in Yellow River (grey line), estimated value of return flow for lake water uses (short red line lower right hand corner). Note: (1) Estimated value of return flow for lake water uses depends on which assumption regarding water loss to lake is used: 0.11-0.14 RMB/m^3 (638 million m^3 = 1998 return flow); 0.10-0.11 RMB/m^3 (440 million m^3 = 2001 return flow) and 0.04-0.06 RMB//m^3 (211 million m^3= hypothetical drop of 0.5 meters in lake level.
(2) The lower bound for the value of water in marginal crops (wheat) is below conservative estimates of the value of water in lake uses. The lower bound for the value of water in crops such as wheat – even disregarding irrigation losses - is also lower than a conservative estimate of opportunity costs of water in the lower Yellow River. Both comparisons argue for a reallocation of water from marginal crops in Hetao to downstream uses in Lake Wuliangsuhai and the Yellow River.

2.10 Critical pollution loads and need for pollution reduction

2.10.1 Approches for critical pollution loads estiamtion

The estimation of the maximum tolerance loading (critical loads) a very complicated task, which involves nutrient release from the sediments, absorbability and accumulation of various nutrients, chemistry and natural process as well as other activities influencing the accumulation, release and degradation of pollutants. The impact of submerged vegetation on the release, absorbability and accumulation by sediments needs not only lengthy and extensive research, but also relavant technology. On the other hand, harvesting of reed will remove significant amounts of nutrients from the lake, which will affect the conditions.

We can use three approaches to estimate the critical pollution loads to the lake:

<u>1) Estimation according to standards</u>
Let us assum that the lake does not degrade and accumulate the pollutants if the lake water quality achives the Class III of the "State surface water environmental quality standards" GB3838-2002. This refers to the concentrations of T-P = 0.05 mg/l, T-N= 1.0mg/l and COD= 20mg/l. Assuming that the annual average water volume in the lake is about 460 million m^3, the critical laoding will be: T-P=23t/a; T-N = 460t/a; COD = 9600t/a.

2) Estimation by modeling

The critcal loads in the lake according to the Dillon formula estimates to be T-P= 25.83t/a, and T-P = 34.1 t/a according to the R.R. Vollenweider formula (Inner Mongolia Lake Eutrophication Investigation and Research, May, 1990, 150p). Although these formula are valid for large deep lakes, they could be used as a conservative figures for a shallow lake like Wuliangsuhai.

3) Estimation by monitoring

In 1987, the T-P concentration in the monitoring points in the center of the lake was 0.0677mg/l. It was estimated that the total input of T-P from the main drainage channel to the lake to be 55.5t/a at that time.

The critical load can be estimated as the ratio between the concentrations according to the water quality standards (TP=0.05, TN=1, COD= 20mg/l) to the observed water quality, multiplied by the observed loading. This has resulted in critical loads in 1987 as T-P = 41 t/a and T-N = 31 t/a. Following the same concept, the present critical loads can be estimated as given in Table 6, using the monitoring results from 2001.

Table 6. Critical loads estaimated based on monitoring results

	1987			2001		
	Concentration, mg/l	Load, t/a	Critical load, t/a	Concentration, mg/l	Load, t/a	Critical load, t/a
TP	0.0677	55.5	41	0.187	116	31
TN	1.788	820	459	2.789	2200	789
COD				107.6	25000	4647

2.10.2 Estimation of the critical load

With reference to the above estimates, the critical pollution loads to Lake Wuliangsuhai are estimated to be TP= 28-41t/a, TN=460-800t/a and COD=4600-9600t/a. Considering the assimilation of phosphates by the dense submerged vegetation, it may be assumed that the critical phosphate loading should be higher than 30 t/a. For the purpose of further analysis, we suggest to select TP=30 t/a, TN=800 t/a and COD=10000t/a as the recommended maximum loading of nutrients to the lake.

However, this must be considered a low estimate when the ecological functioning of shallow lakes, and the principle of the “two alternate stable states”, are taken into consideration. 30 t/a of T-P will ensure a low concentration of phytoplankton in the lake water even if the submerged vegetation should be removed or considerably reduced. If the submerged vegetation is protected from damage and removal, a higher loading of T-P, ca. 50 t/a T-P, could be acceptable. This does not apply to the estimate of T_N loading to the same degree as that of T-P.

2.11 Summary of lake status and goals

	STATUS	GOALS
Environmental	• Poor water quality • Problem of pollution loading into lake from various sources • Reduced lake area • Lake biodiversity under stress • Unsustainable use of lakes resources	• To improve water quality suitable for various uses • To treat and reduce the pollution loads into the lake • Increasing lake depth by various measures • To sustain or increase the biodiversity in Lake • To achieve environmental sustainability
Economic	• The lake provides income to various stakeholder groups	• To protect lake resources with an objective to sustain the income of the local groups • Selection and implementation of the most cost-effective measures for pollution management and control measures • Efficient allocation of water between competing uses within the Hetao Basin
Social	• Several stakeholder groups have user rights to lake resources • Competing demands and conflicts over access to the resources • The reduced water quality has an impact on the health of the local people using the lake	• Identify key stakeholders and establish an appropriate framework for their participation in the lake restoration and management • Balancing the competing demands by rehabilitating the lake resources • Assess the social impact of investment projects • Conflict resolution • Improved health of the local groups

3 HYDRODYNAMIC SIMULATIONS OF LAKE WULIANGSUHAI

3.1 Introduction

In order to understand both present, and hopefully the future hydrodynamic characteristics of Lake Wuliangsuhai, a numerical groundwater flow was suggested and implemented. By using a numerical Finite Element Model (FEM) originally designed to handle flow within porous media (of aquifers), the Lake Wuliangsuhai has consequently been subjected to various modelling scenarios, which will be presented and briefly discussed in this chapter.

It is important to note that due to practical constraints, the full power of hydrodynamic simulations can only be unleashed with practical use, implying a process of interaction between users, relevant lake observations, changing scenarios and a continued process of calibrations. In other words, the value of a numerical model depends on a process of maturation, both conceptually as well as in practical terms.

It is a known phenomenon that working with mathematical models of this type stimulates systematic thinking and deepens the understanding of the object under observation; in this case the dynamic response to varying flow regimes. In other words, using a computer model both stimulates further thinking and understanding, as well as providing clues towards new solutions.

The more obvious advantage of using a mathematical model is that experimenting with solutions, i.e. the process of trial and error, is considerably less expensive on a computer screen than in the field. Of equal importance can be the predictive power of the tool, for example to provide documentation on impacts resulting from future stress conditions such as drought, limited water influx, etc.

3.2 The FEM model

Originally, the simulations were intended to be done on a Finite Difference Model (FDM), but a more sophisticated approach was finally chosen and the following simulations have been carried out (Moe and Ruden, 2004), using the Dynflow (www.dynaflow.com) FEM model environment. More details on the theory and application of FEM can be found at this website. The application and calibration of the model used in a single layer, shallow and moving water body context is supported by Wdowinski (2004) on a similar case in Florida.

Two main parameters (objectives) are simulated in the following scenarios:

- Flow
- Head

Flow, in dimensional terms, is defined as *velocity multiplied with depth* at any point in the lake. The arrows used to illustrate flow in the following maps are proportional, and relative. In other words, the vector arrows can be used for comparison and do not represent absolute values. The latter can be derived by dedicated field observations.

Head is the build-up of water as the function of flow resistance, gradient and flux. Provided these assumptions are correct, the maps depicting simulated heads will indicate the water level as the function of stress such as influx of water, etc. Due to the principle of equivalence, the model would benefit from a long-term calibration process.

All simulations discussed in this report have been run in a *steady state* mode. This implies that there is no change of (water) volume within the system during the model runs.

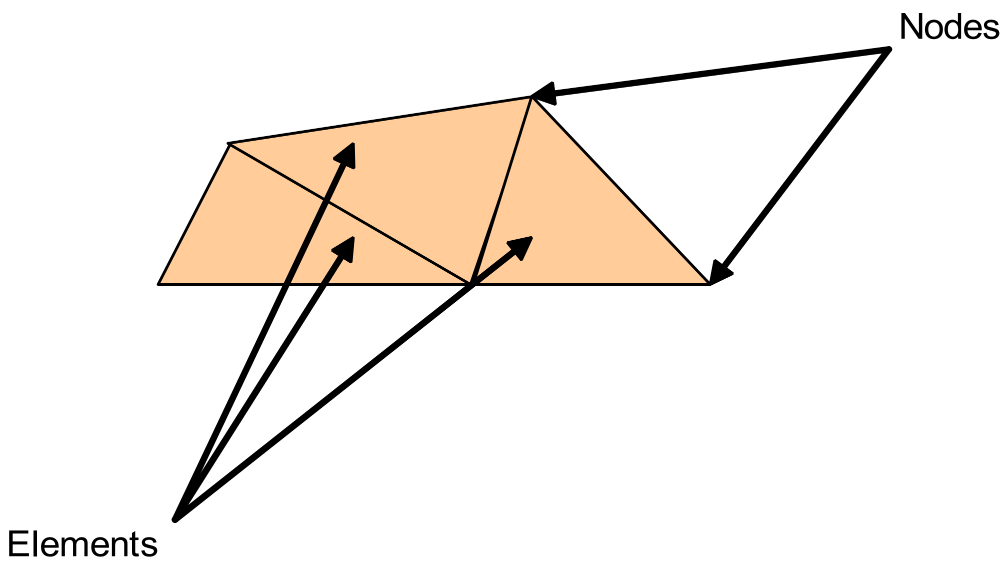


Figure 14. The FEM grid (coloured triangles) is flexible, and can accommodate complex geometric forms, such as the lake. The corners of the triangles are termed nodes; the triangles themselves are elements. The Lake Wuliangsuhai model is comprised of 6074 such nodes, and 11546 elements.

3.3 Model specifications, FEM

1. Model Used
- DYNFLOW (see www.dynsystem.com) – finite element based numerical ground water flow model.
- Simulates steady-state and transient flow
- Multiple aquifer layers
- Variable grid density
- Can integrate 3-D, 2-D, and 1-D elements
- Automatic transition between dry, unconfined and confined conditions
- Variety of boundary conditions representing interaction with surface water and adjoining aquifers
- Algorithms to represent wells pumping from multiple aquifer layers

2. Numerical Grid
- 6074 nodes, 11546 elements
- Nodal spacing about 200-250 m
- Lake simulated in 2-D (single layer model)

3. Boundary Conditions
- No-flow along lake margins

- Specified flux at major inflow locations: Main Pumping Station, Canal 8, Canal 9
- Fixed head at lake outlet location

4. Elevations

- Lake bottom elevation set according to depth map provided by NIVA and sent as ESRI shape files

5. Hydraulic Conductivity Distributions

- Separated reed areas from non-reed (open areas)
- Reed areas: K = 30 m/s (calibrated) and based on Wdowinski, 2004.
- Non-reed areas: K = 300 m/s (calibrated)
- E-W road across lake to north: K = 0.000001 m/s (element-width averaged)

6. Fluxes

- Main Pumping Station (MPS): average inflow 1992-2002 = 12.384 m^3/s
- Canal 8: average inflow 1992-2002 = 1.30 m^3/s
- Canal 9: average inflow 1992-2002 = 0.784 m^3/s
- Recharge (from rainfall): 0.1 m/yr
- Note – inflow from MPS and Canal 8 combined at single flux location in model

3.4 Overview of model calibration and assumptions

3.4.1 Calibration

1) Based on Wdowinski, 2004 (Space Based Measurements of Sheet-Flow Characteristics in the Everglades Wetland, Florida).

2) Assumed gradient N-S of approximately 0.4 m – i.e., matched simulated heads against a natural gradient of 0.4 m from north to South.
3) Steady-state conditions prevail

4) NOTE: actual lake water level distribution is not exactly known

5) Model is not rigorously ‘calibrated’ *per se* - hydraulic conductivities (K) were varied and selected in the expected range provided in Wdowinski, 2004 (Space Based Measurements of Sheet-Flow Characteristics in the Everglades Wetland, Florida).

3.4.2 Other Assumptions

1) Assumed gradient N-S across lake of approximately 0.4 m, per NIVA assumptions – therefore, matched simulated heads are against a gradient of 0.4 m from North to South. Simulated combination of K values gave head rise equal to target gradient.

2) Culvert in road at the northern of the lake is simulated by changing hydraulic conductivities only. The model does not account for any convergent or divergent turbulent head losses. Note: This could affect actual head rise to the north of the road for scenarios 2–5.

3) Modelled scenarios are representative of summer seasons only and do not apply when the lake freezes over during the winter season.

4) Influx figures are averaged.

3.5 Overview of model simulations – Scenarios

3.5.1 General

The following pages contain a total of 12 map illustrations from flow and head simulation of Lake Wuliangsuhai. These describe basic assumptions, materials properties, head distribution and flow vectors for a total of 5 scenarios.

The following presumptions and scenarios are presented graphically in the following:

Description of scenario:

Base case: Main Pumping Station (MPS): average inflow 1992-2002 = 12.384 m^3/s
Canal 8: average inflow 1992-2002 = 1.30 m^3/s
Canal 9: average inflow 1992-2002 = 0.784 m^3/s

Scenario 1: Same as base-case, but with additional 253 Million m^3/yr (8.02 m^3/s) inflow at Main Pumping Station.

Scenario 2: Same as base-case, but with additional 253 Million m^3/yr (8.02 m^3/s) inflow at Yi He Canal at very northern end of lake

Scenario 3: Same as Scenario 2, but with levee (barrier, marked in red)) built into the lake, running NE-SW to the south of the MPS inlet location

Scenario 4: Same as Scenario 2, but with levee (barrier) built into the lake, along and just south of the MPS inlet location.

Scenario 5: Same as Scenario 2, but with levee (barrier) built into the lake, running E-W from the eastern end of the lake

Simulations:

1) Simulated Distribution of hydraulic conductivity, Base-Case and Scenarios 1-3
2) Simulated Distribution of hydraulic conductivity, Base-Case and Scenarios 4-5
3) Simulated Scaled flow vectors, Base Case
4) Simulated Scaled flow vectors, Scenario 1
5) Simulated Scaled flow vectors, Scenario 2a (central part of the lake)
6) Simulated Scaled flow vectors, Scenario 2b (northern part of the lake)
7) Simulated Scaled flow vectors, Scenario 3 (central part of the lake)
8) Simulated Scaled flow vectors, Scenario 4 (central part of the lake)
9) Simulated Scaled flow vectors, Scenario 5 (central part of the lake)
10) Simulated heads, Base Case and Scenario 1
11) Simulated heads, Base Case and Scenario 2 and 3
12) Simulated heads, Base Case and Scenario 4 and 5

Figure 15. Map of canals and water inlet points referred to in the text.

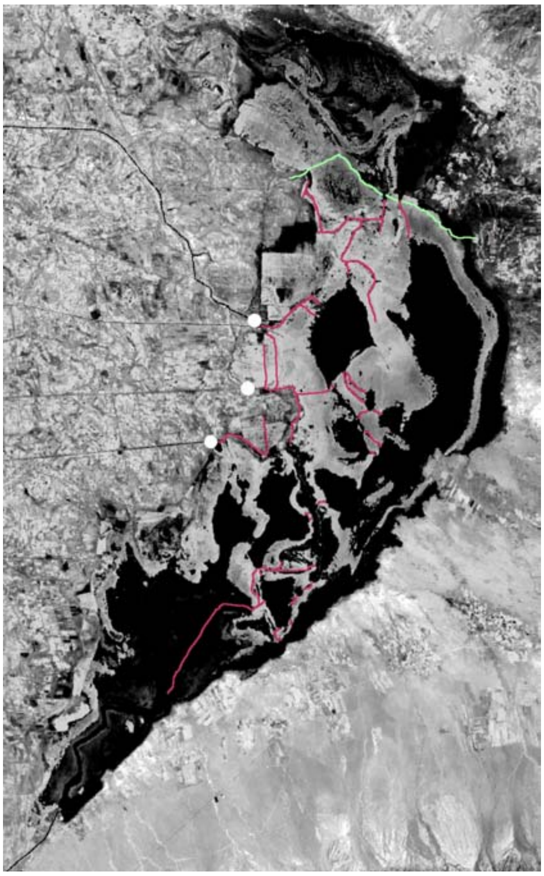


Figure 16. Overview of existing water inlets (white dots) as illustrated in the foregoing map. Presumed existing navigation canals are in red. The road crossing the lake in the northern section is inferred, (green).

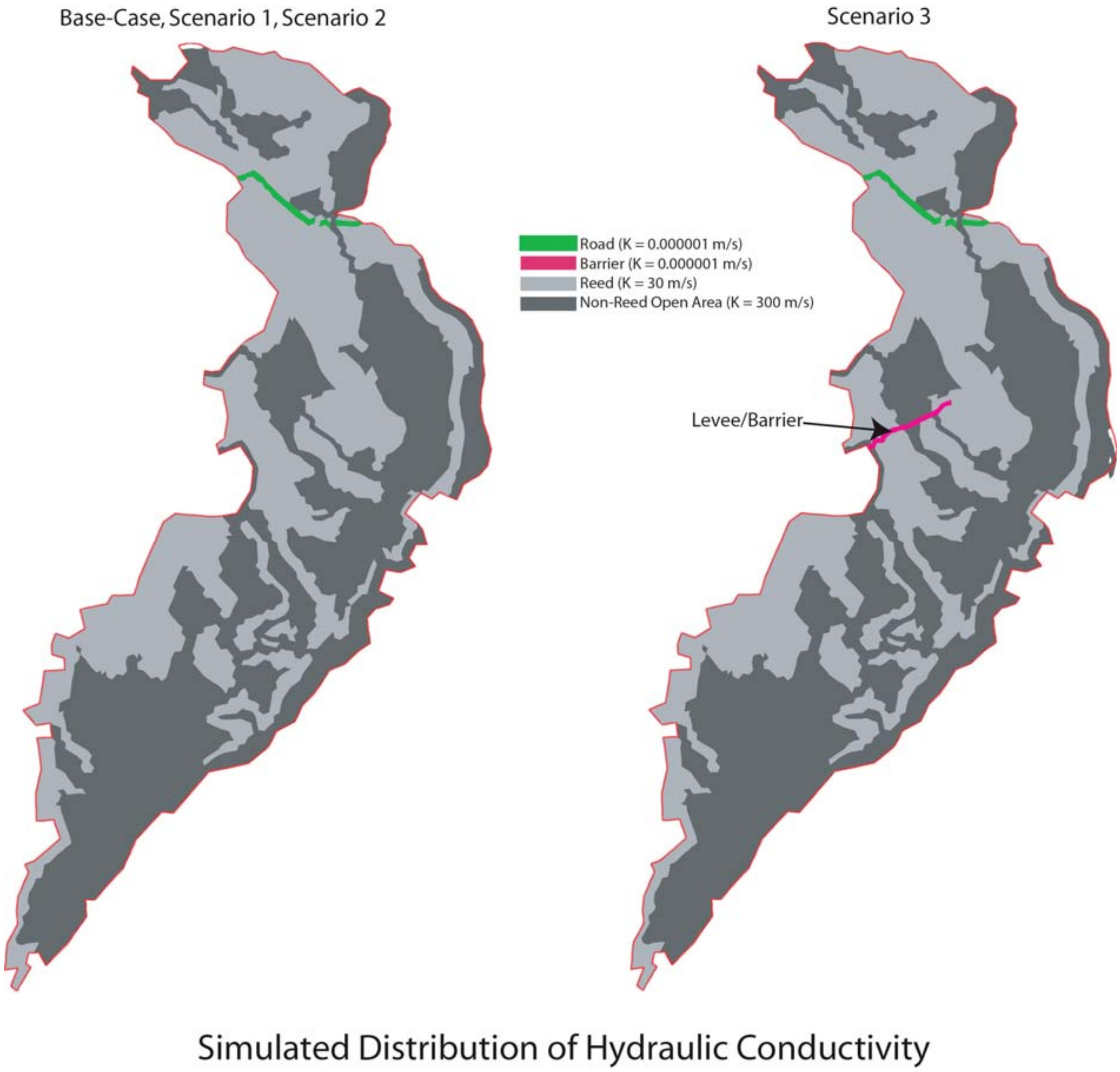


Figure 17. The above maps illustrate the distribution of hydraulic presumptions behind the following model simulations:

- Base Case
- Scenario 1
- Scenario 2

are outlined above, where K is the hydraulic conductivity. Note the approximate position of the crossing road in the northern part of the lake (green), which forms a barrier except for two assumed culverts.

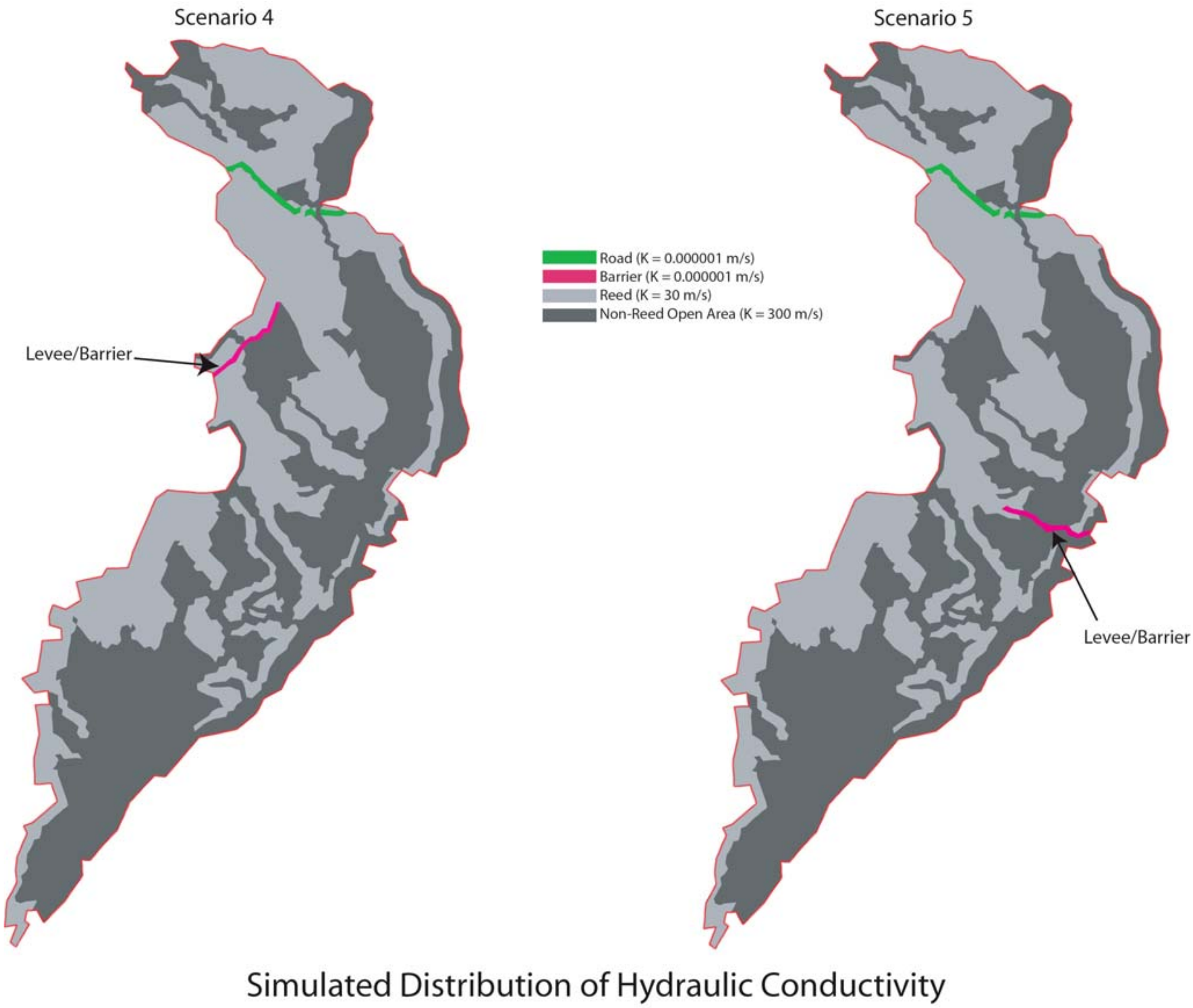


Figure 18. The above maps illustrate the distribution of hydraulic presumptions behind the following model simulations:

- Scenario 4
- Scenario 5

are outlined above, where K is the hydraulic conductivity.

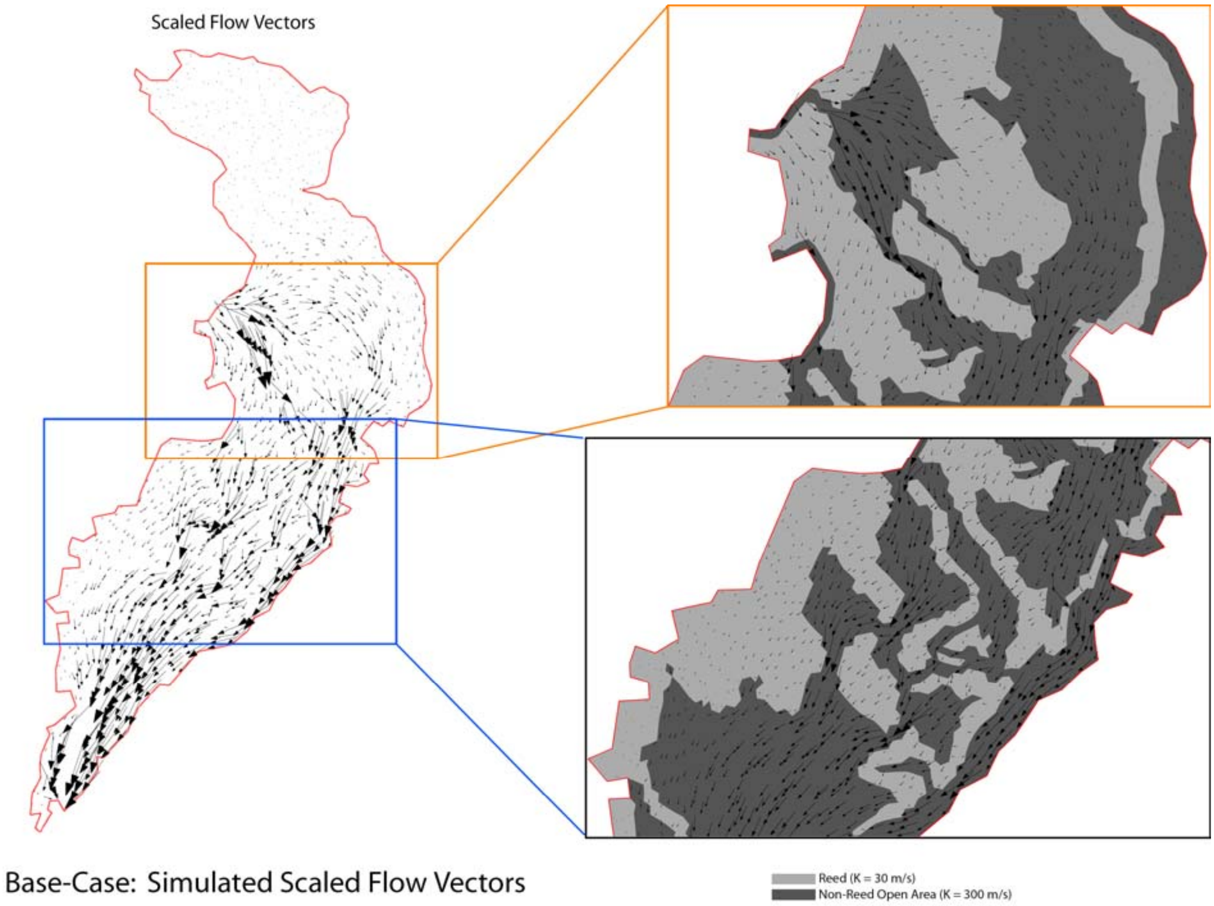


Figure 19. Base Case Scenario. *Hydraulic parameters are as described above.*

The influx figures are:

- Main Pumping Station (MPS): average inflow 1992-2002 = 12.384 m^3/s
- Canal 8: average inflow 1992-2002 = 1.30 m^3/s
- Canal 9: average inflow 1992-2002 = 0.784 m^3/s

Model result summary:

- Significant channelling of flow.
- Majority of water flows quickly through preferential pathways.
- Distribution of flow to northern 1/3 of lake is very limited.
- Stagnation zones apparent in N and SW

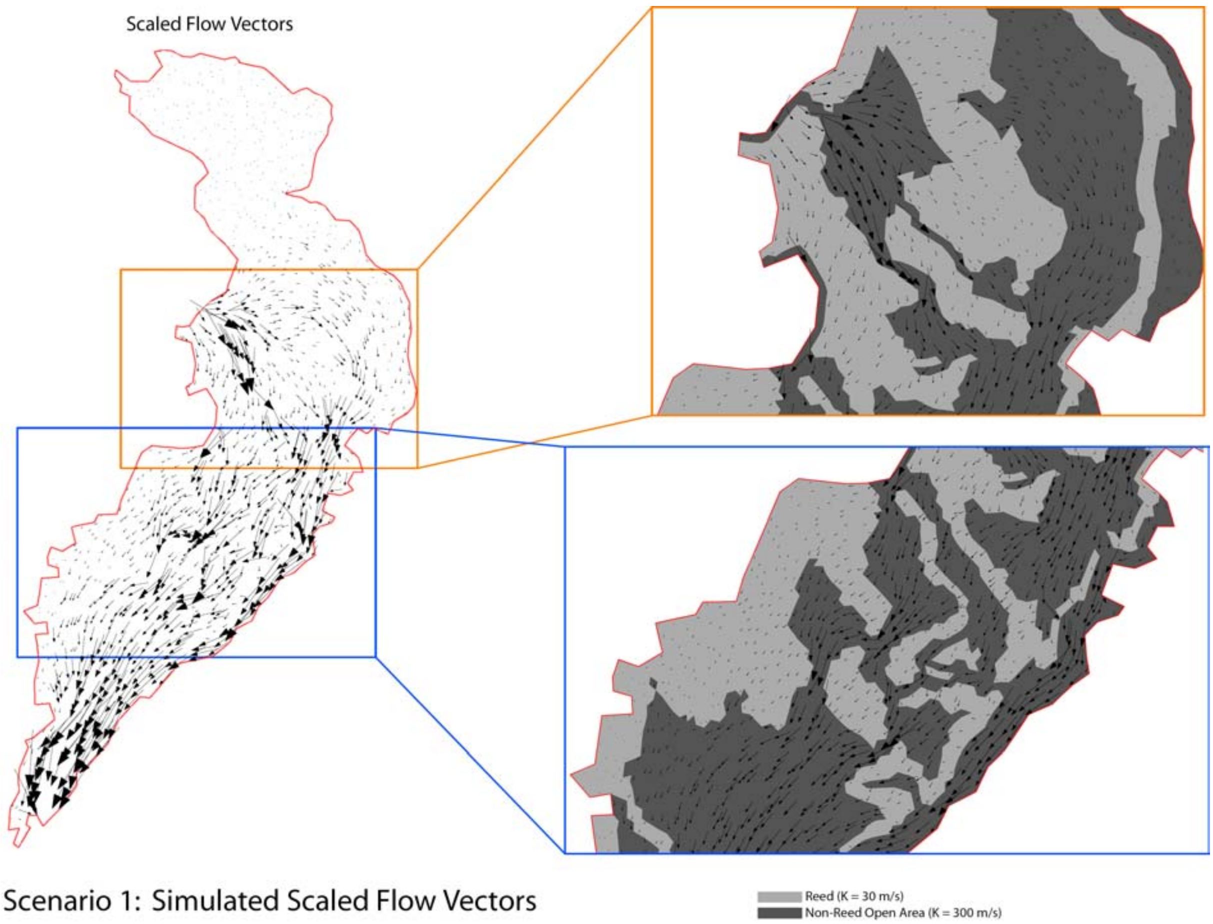


Figure 20. Scenario 1. *Same as base-case, but with additional 253 Million m^3/yr (8.02 m^3/s) inflow at Main Pumping Station.*

Model result summary:

- Addition of water to MPS has limited influence on flow patterns.
- Flow gradients and velocities increase, but flow remains preferential along existing channels.
- Increase in water levels in northern part of lake (>0.5 m)

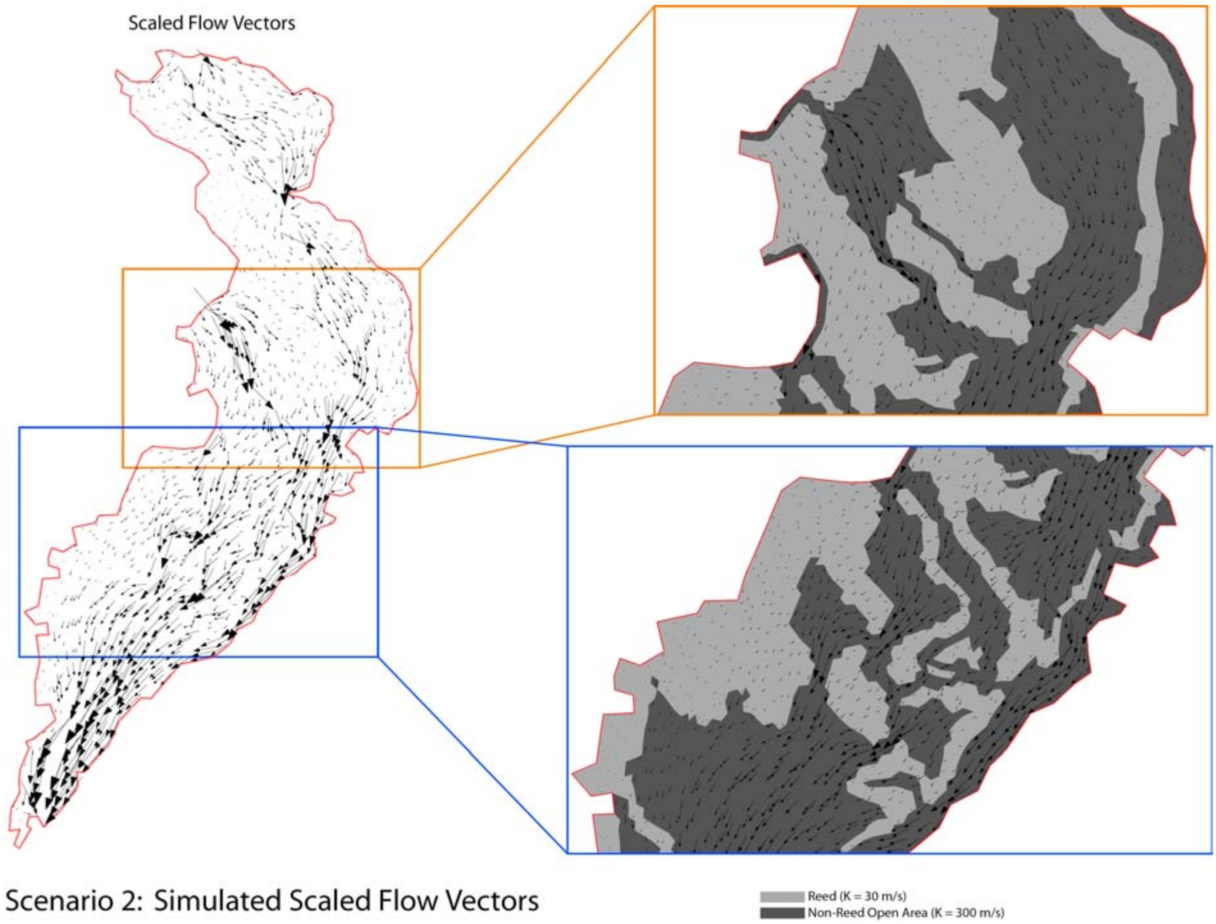


Figure 21. Scenario 2: *Same as base-case, but with additional 253 million m^3/yr (8.02 m^3/s) inflow at Yi He Canal at very northern end of lake. This map focuses on conditions in the central part of the lake.*

Model result summary:

- Addition of water to lake from Yi He Canal has significant impact to northern part of lake, north of E-W road. Water levels rise by > 0.5 m.
- Inflow from Yi He Canal flows quickly and preferentially through non-reed areas and is channelled through eastern culvert across E-W road. Flow then continues southward and preferentially along the eastern margin of lake to outlet location.
- Limited/no benefit to W and SW part of lake.
- Flow out from MPS similar/identical to base-case scenario.

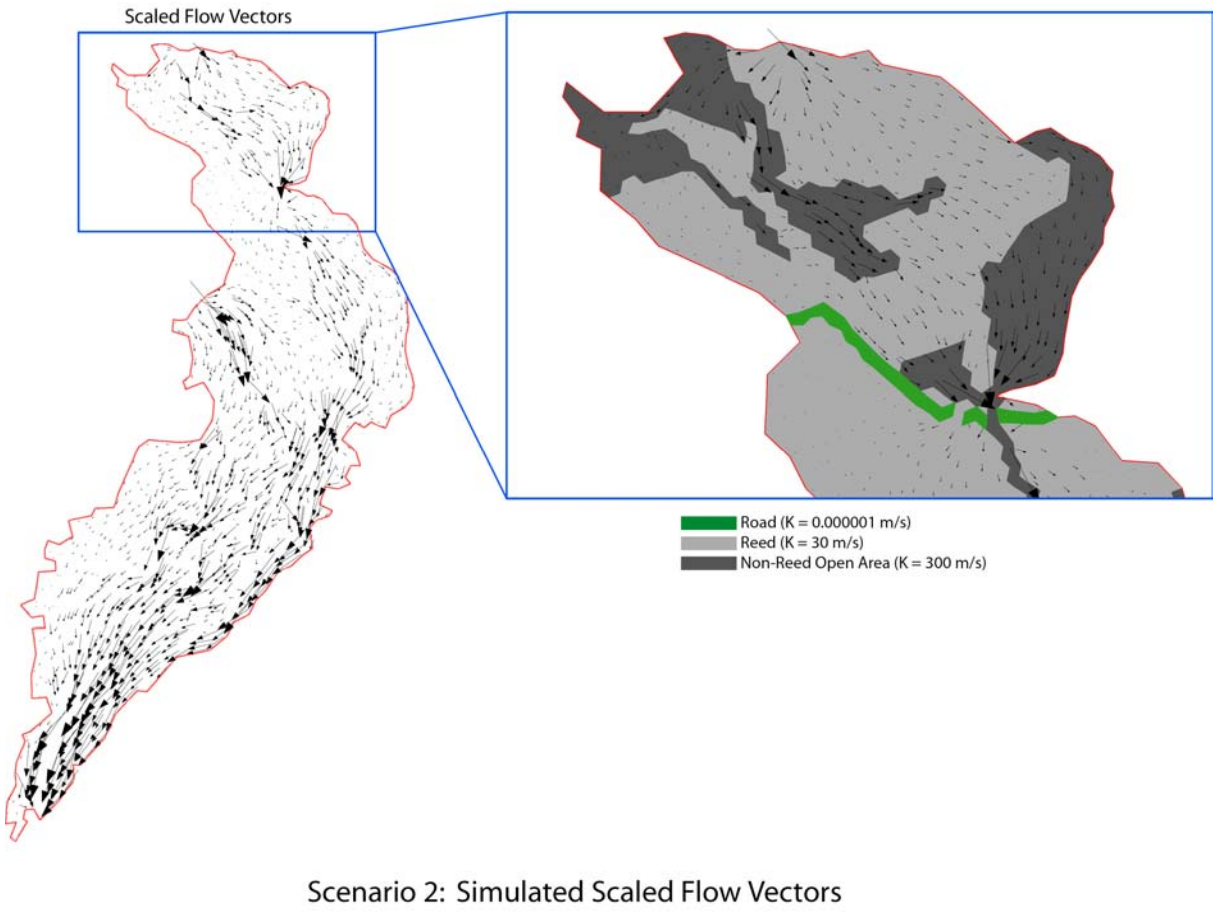


Figure 22. Scenario 2*: Same as base-case, but with additional 253 Million m^3/yr (8.02 m^3/s) inflow at Yi He Canal at very northern end of lake.*

Model result summary:

- Addition of water to lake from Yi He Canal has significant impact to northern part of lake, north of E-W road. Water levels rise by > 0.5 m.
- Inflow from Yi He Canal flows quickly and preferentially through non-reed areas and is channelled through eastern culvert across E-W road. Flow then continues southward and preferentially along the eastern margin of lake to outlet location.
- Limited/no benefit to W and SW part of lake.
- Flow out from MPS similar/identical to base-case scenario.

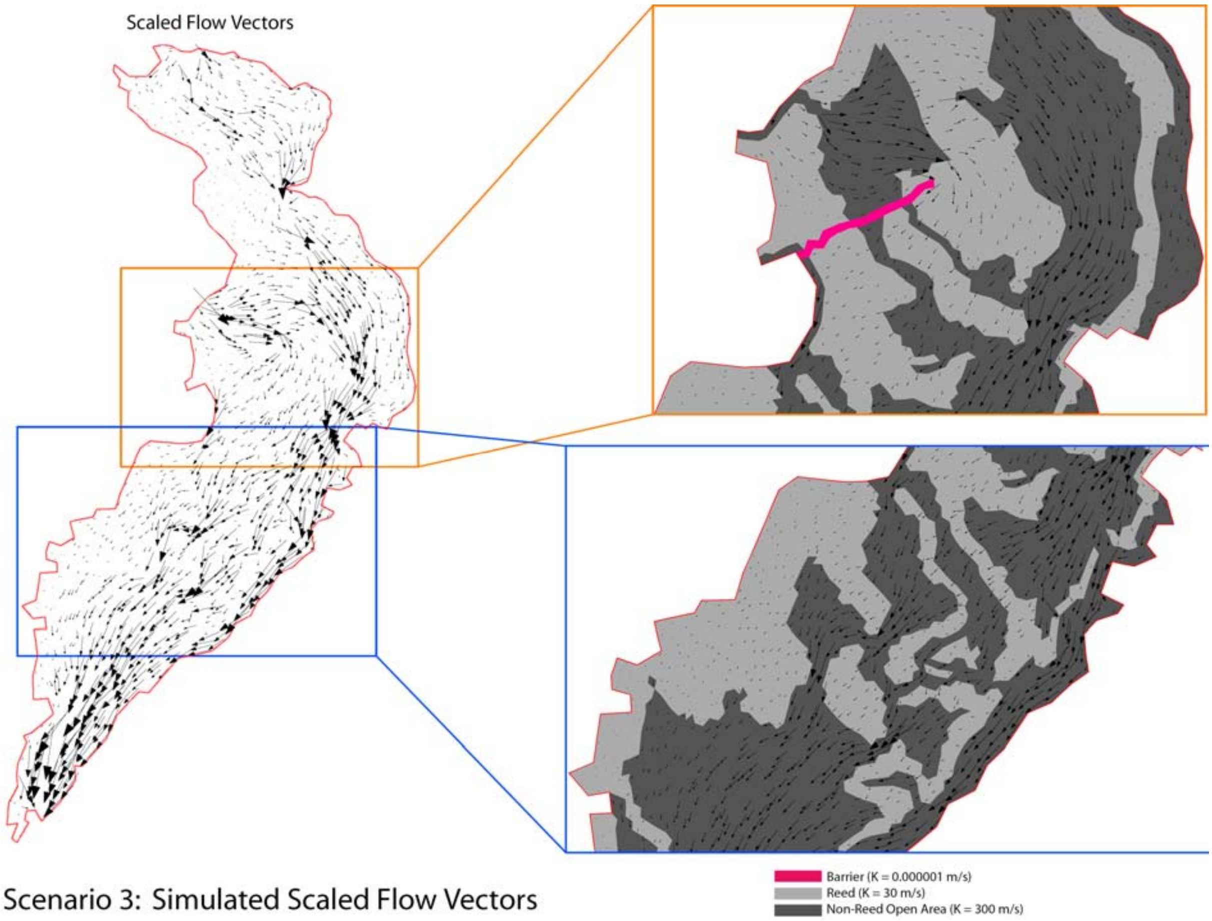


Figure 23. Scenario 3: *Same as Scenario 2, but with levee (barrier, marked in red)) built into the lake, running NE-SW to the south of the MPS inlet location. Levee is intended to intercept and divert the channel flow south of the MPS, in order to spread inflow further to the north and east. It will be noted that the position and simulation of the above levee is mainly for demonstration purposes; possibly better solutions may easily be arrived at by trial and error by stakeholders.*

Model result summary:

- Simulated levee has significant local impact on water levels and flow distribution in vicinity of the MPS location, however, flow tends to revert around the levee and continue its path south along existing channel network.
- No benefit to S and SW parts of lake.
- No benefit to northern part of lake.

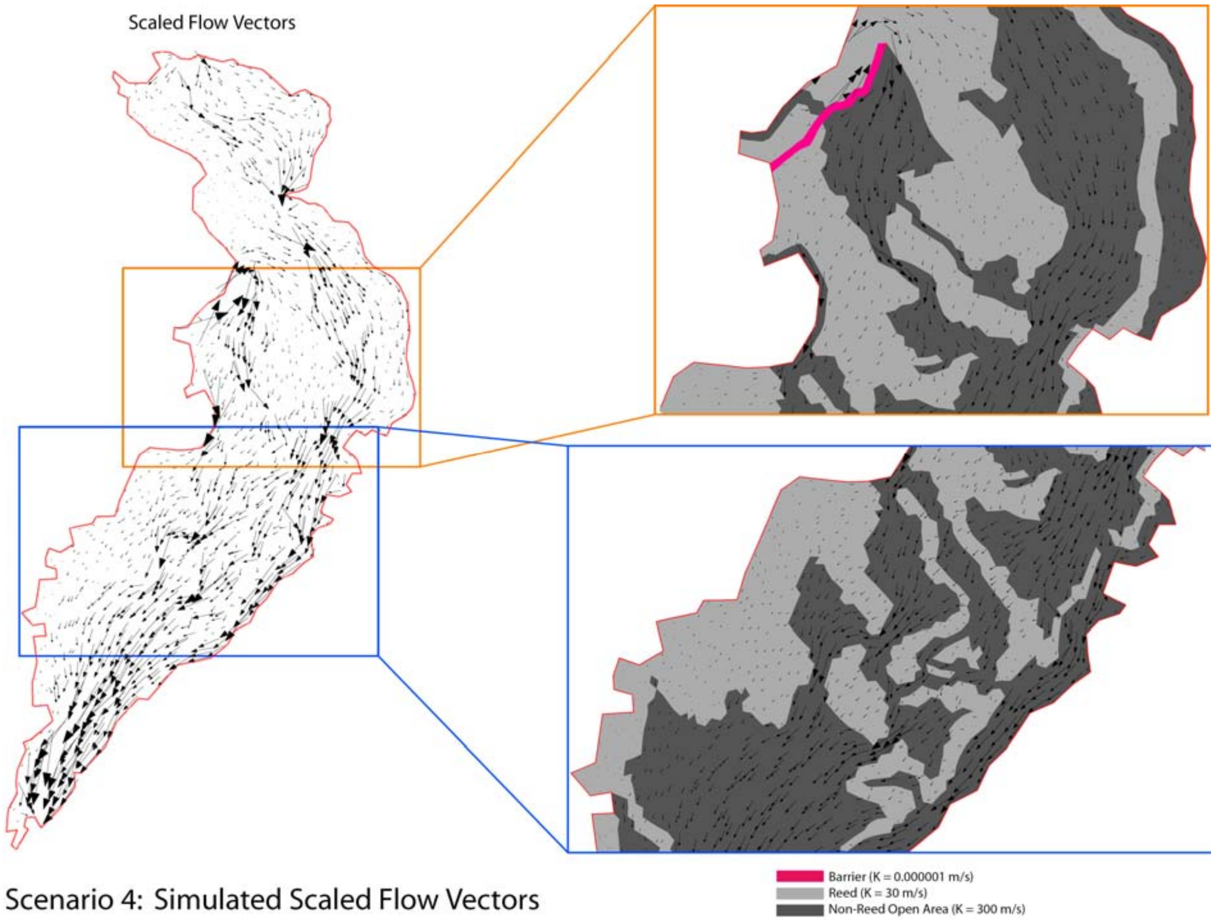


Figure 24. Scenario 4: *Same as Scenario 2, but with levee (barrier) built into the lake, along and just south of the MPS inlet location. Levee intended to carry the inflow from the MPS further to the NE, in order to avoid significant and immediate channelling of water to the south.*

Model result summary:

- Significant head build-up between the lake margin and simulated levee – influx directed into reed area, where it meets increased resistance to flow.
- Redirection of flow to north, added benefit.
- Simulated build-up would result in backflow from MPS back into the inflow/drainage channels. Scenario probably infeasible without remedial measures to open up reed areas to the NE of the MPS.

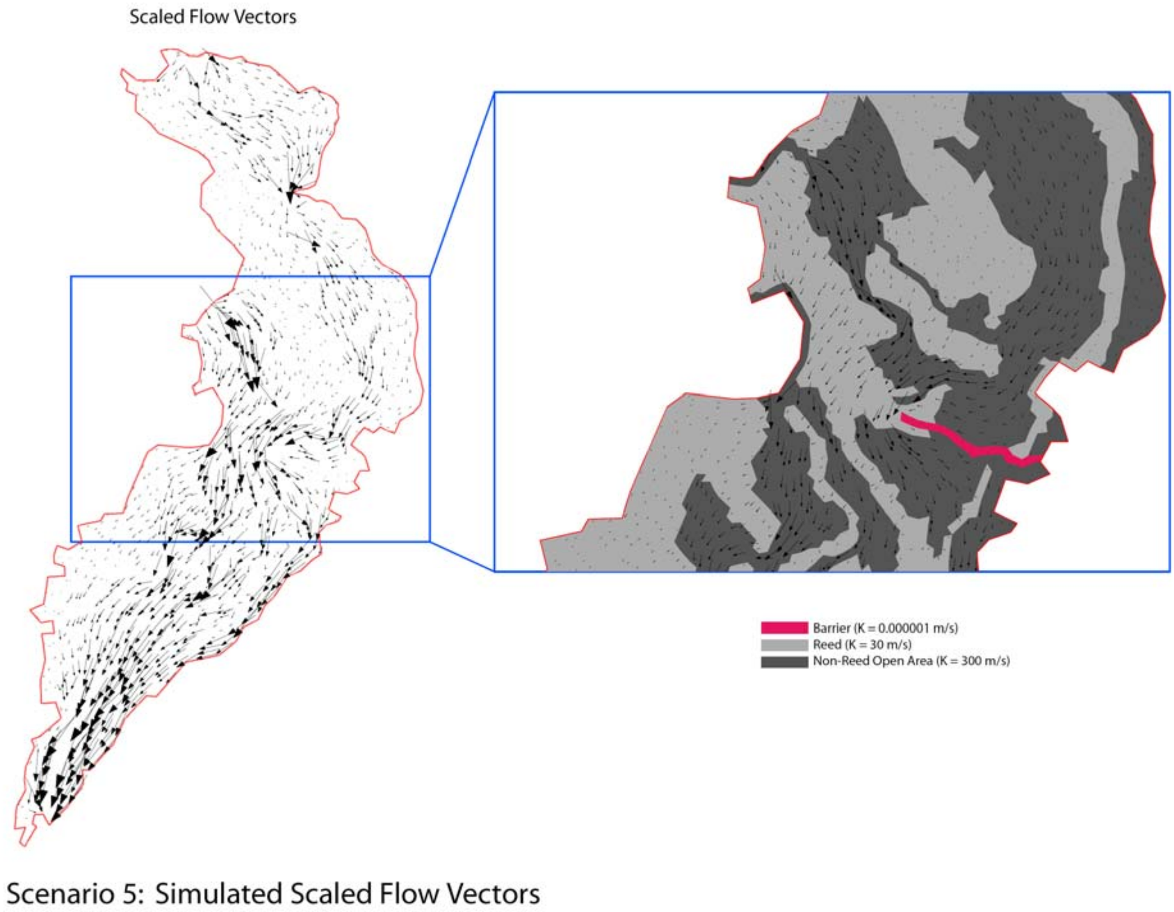


Figure 25. Scenario 5: *Same as Scenario 2, but with levee (barrier) built into the lake, running E-W from the eastern end of the lake, to intercept significant N-S throughflow, in an attempt to 'spread' the flow distribution better across the southern half of the lake.*

Model result summary:

- Considerable re-direction of flow to the west around the simulated levee.
- Past the levee, flow reverts to base-case patterns of preferential flow along existing channel network.
- Benefit (improved circulation pattern) in central part of lake.
- Creates small but new stagnation zone immediately south (downgradient) of levee.
- No benefit to S and SW parts of lake.

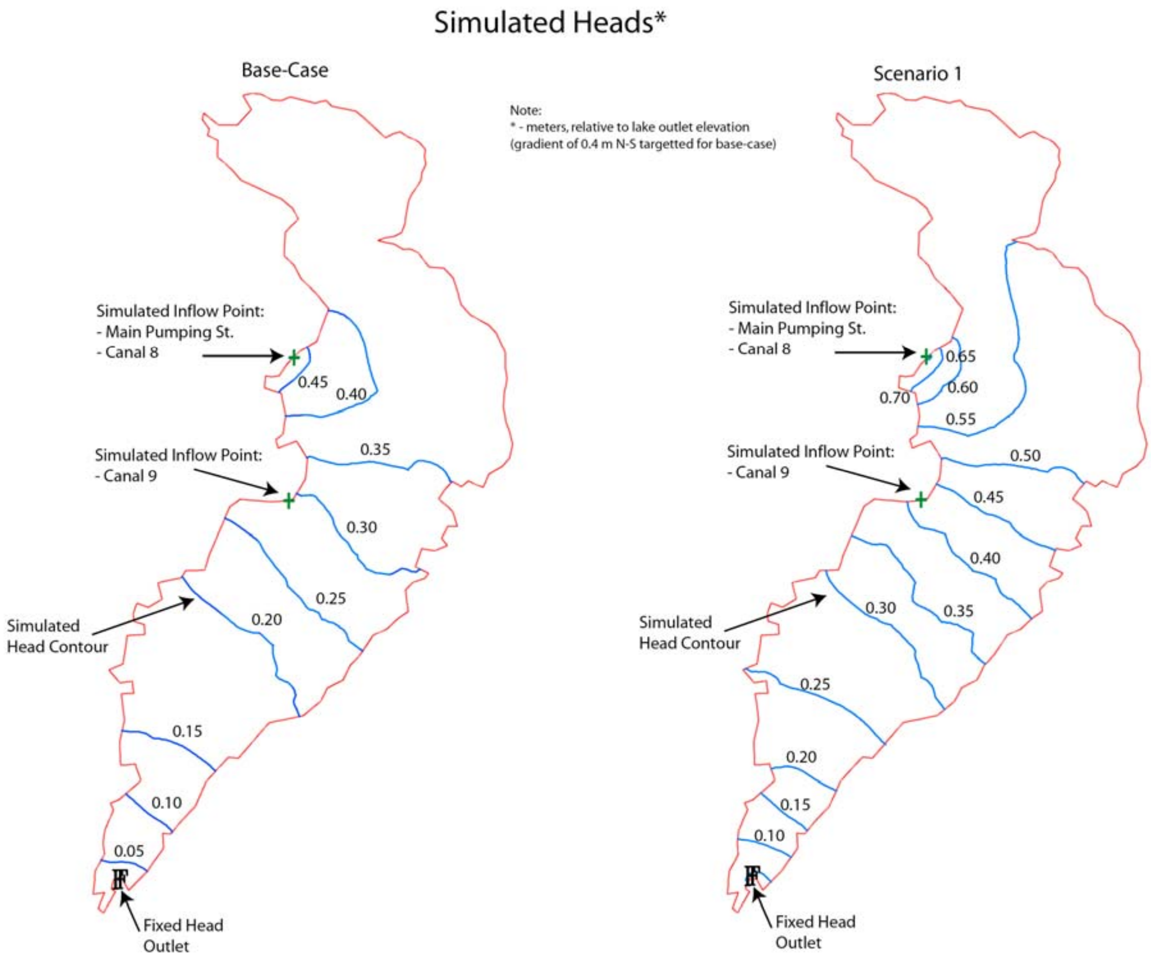


Figure 26. Simulated heads, Base Case and Scenario 1.

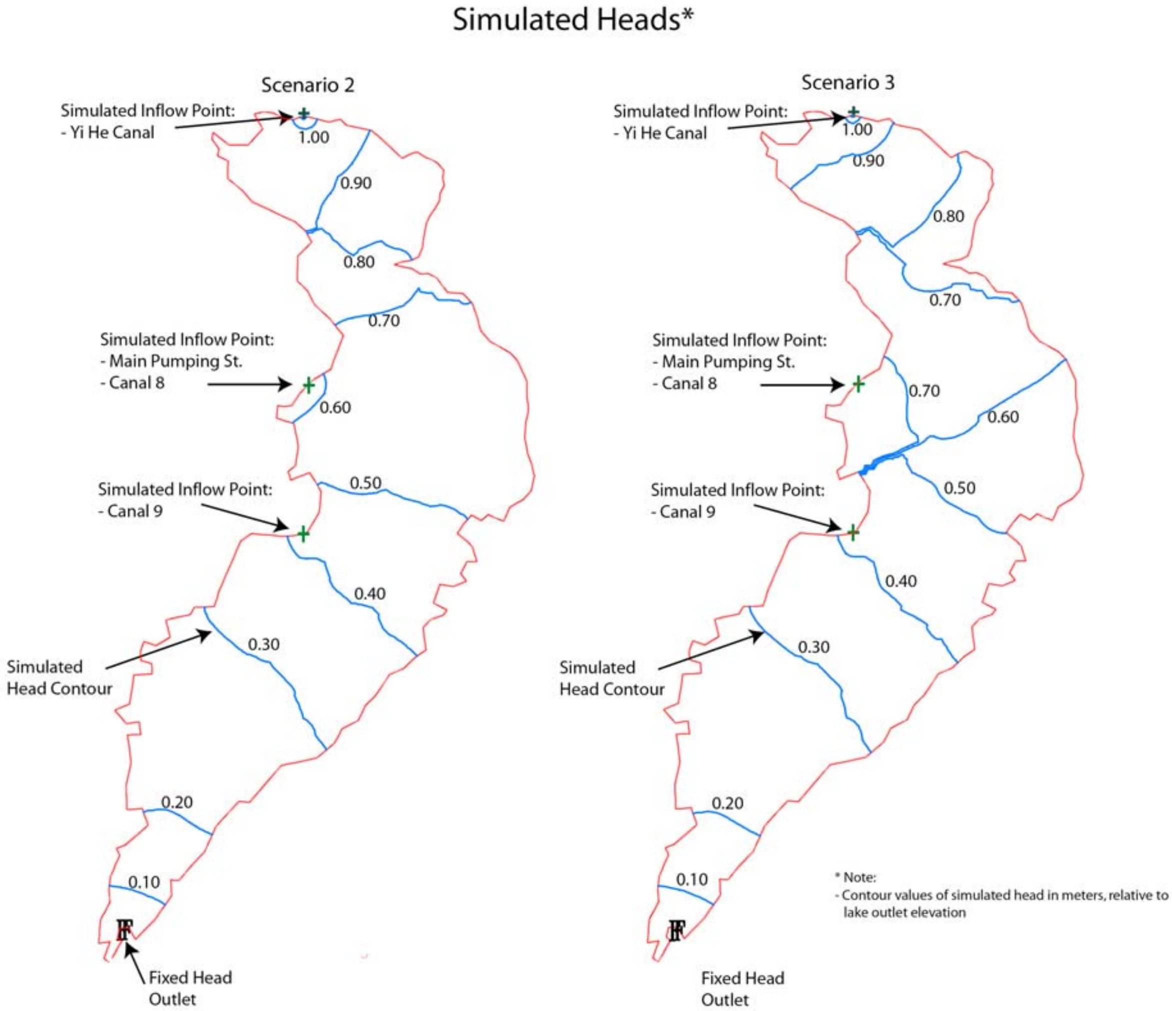


Figure 27. Simulated heads, Scenarios 2 and 3.

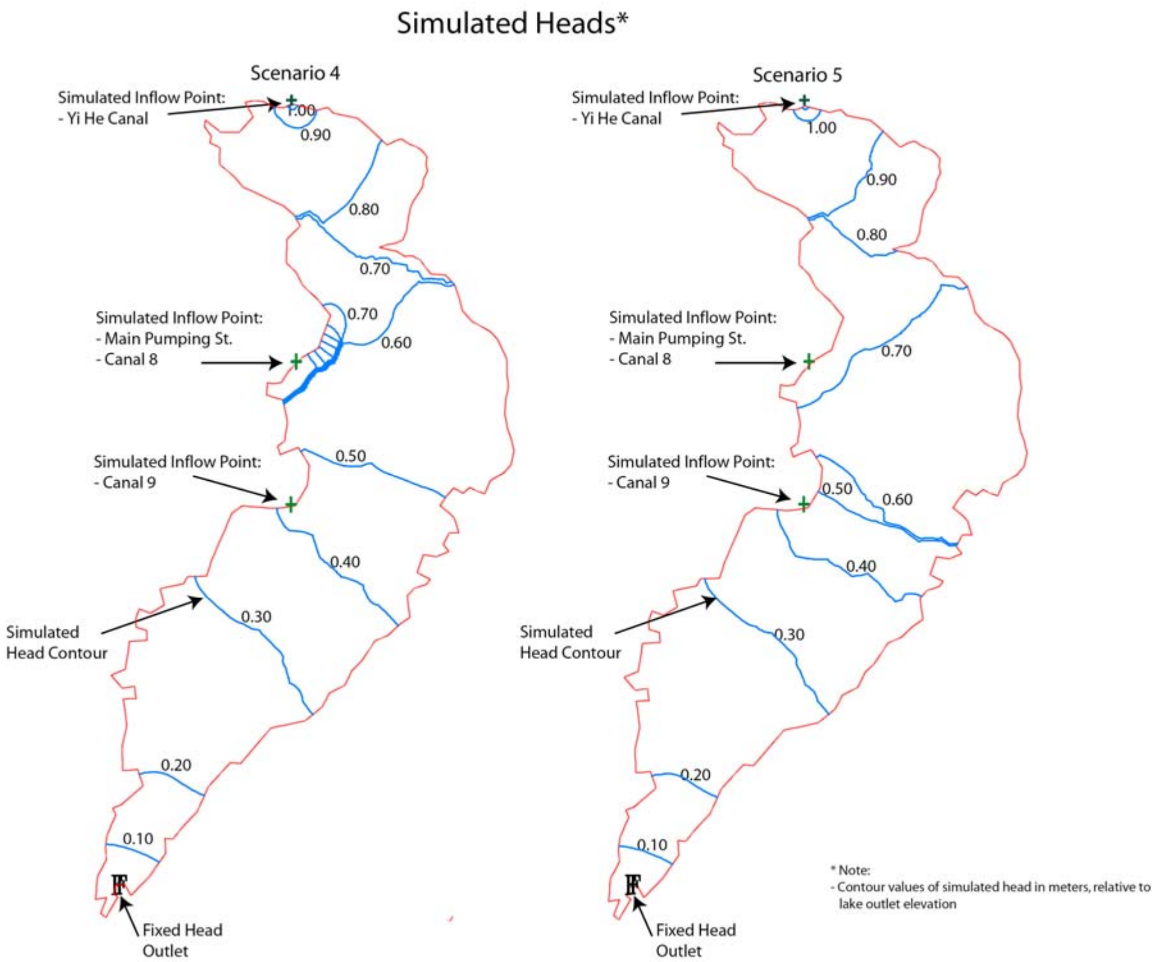


Figure 28. Simulated heads, Scenarios 4 and 5.

3.6 Simulation summary

3.6.1 Base-Case:

- Significant channelling of flow.
- Majority of water flows quickly through preferential pathways, i.e. channels and gaps.
- Distribution of flow to northern 1/3 of lake is very limited (stagnant).
- Stagnation zones apparent in N and SW.

3.6.2 Scenario 1:

- Addition of water to MPS has limited influence on flow patterns.
- Flow gradients and velocities increase, but flow remains preferential along existing channels.
- Increase in water levels in northern part of lake (>0.5 m)

3.6.3 Scenario 2:

- Addition of water to lake from Yi He Canal has significant impact to northern part of lake, north of E-W road. Water levels rise by > 0.5 m.
- Inflow from Yi He Canal flows quickly and preferentially through non-reed areas and is channelled through eastern culvert across E-W road. Flow then continues southward and preferentially along the eastern margin of lake to outlet location.
- Limited/no benefit to W and SW part of lake.
- Flow out from MPS similar/identical to base-case scenario.

3.6.4 Scenario 3:

- Simulated levee has significant local impact on water levels and flow distribution in vicinity of the MPS location, however, flow tends to revert around the levee and continue its path south along existing channel network.
- No benefit to S and SW parts of lake.
- No benefit to northern part of lake.

3.6.5 Scenario 4:

- Significant head build-up between the lake margin and simulated levee – influx directed into reed area, where it meets increased resistance to flow.
- Redirection of flow to north, added benefit.
- Simulated build-up would result in backflow from MPS back into the inflow/drainage channels. Scenario probably infeasible without remedial measures to open up reed areas to the NE of the MPS.

3.6.6 Scenario 5:

- Considerable re-direction of flow to the west around the simulated levee.
- Past the levee, flow reverts to base-case patterns of preferential flow along existing channel network.
- Benefit (improved circulation pattern) in central part of lake.
- Creates small but new stagnation zone immediately south (downgradient) of levee.
- No benefit to S and SW parts of lake.

4 Presentation of potential actions

During a stakeholder workshop (LFA- Logical Framework Approach) in 2002, fifteen potential actions were identified. These were further elaborated and integrated to 10 actions as presented in Table 8.

Table 7. Management and Control Measures.

No.	Description of measure	Main purpose
1	Domestic wastewater treatment for cities	Reduction of pollution loads
2	Industrial wastewater treatment	Reduction of pollution loads
3	Increase of water depth in selected areas by dredging	Ensure fish survival during the winter and improve fish production; increase water storage capacity and improve biodiversity
4	Harvesting of submerged vegetation	Increase the open water area
5	Reed bed control	To reduce the potential of the lake becoming a reed marsh land
6	Introduce water from Yellow river and increase water level	Reduction of nutrient concentration, increase water level, improve water circulation
7	Moving of the main inlet and to construct a wetland	Improve water circulation and to reduce nutrient loading
8	Erosion reduction	Reduce water loss and sedimentation
9	Reducing diffuse pollution from agriculture	Reduce pollution load
10	Improvement of internal water circulation	Reduce stagnation and improve self-purification

4.7 URBAN SEWAGE TREATMENT

4.7.1 Purpose

The present condition of the urban sewage situation in Lake Wuliangsuhai's catchment has been thoroughly investigated. On this basis, a number of proposals have been formulated concerning comprehensive treatment of the sewage from all cities in the catchment area.

The purpose with this measure is to:

- substantially decrease the pollution discharge from point sources in the catchment,
- make the sewage water comply with national standards,
- reduce the pollution load on Lake Wuliangsuhai,
- lay a good foundation for the whole of Inner Mongolia Lake Restoration Project, and
- make Lake Wuliangsuhai's water quality comply with '*environmental quality standard of ground water (GB3838—2002)*'.

4.7.2 Background

Introduction of Lake Wuliangsuhai catchment

Parts of the Hetao Irrigation Area have been irrigated for centuries. The downstream part of the current system consists of a number of drainage canals (numbered 1 to 7) entering the Main Drainage Canal and finally Lake Wuliangsuhai. In the lake's catchment, there are three towns (See table below). Urban sewage, along with industrial wastewater from the towns, is discharged into drainage canals 3, 5 and 7 respectively. The canals are also draining agricultural runoff and rainstorm runoff from the Langshan Mountain to the north. Smaller villages in the catchment are lacking sewer systems and are thus not directly contributing to the load on the lake. Two more towns, Dengkou and Wulateqianqi, are situated close to the lake, but are excluded from this study, since they discharge their sewage directly to Yellow River, and not to the lake.

Table 8. Overview of the cities in Lake Wuliangsuhai's catchment. Data refer to the situation in 2002

Town	Banner	Co-ordinates	Population	Gross industrial output (RMB)
Shanba	Hangjinhouqi	E 107°08′ N 40°53′	85,749	0.889 billion
Linhe City	Linhe	E 107°23′ N 40°46′	216,759	2.067 billion
Longxingchang	Wuyuan	E 107°25′ N 41°01′	85,469	0.445 billion
Xishanzui	Wulateqianqi	E 108°45′ N 40°40′	90,289	1.274 billion

**Hanghou, Linhe and Wuyuan are commonly used instead of the actual city names in all project reports.*

Figure 29. Map over Hetao and the irrigation system. Red lines are irrigation canals and blue dashed lines are drainage canals. Yellow lines are roads and black dashed lines are administrative borders. Along the main drainage canal at the northern border of the area are the numbers of the major drainage canals noted (BaMeng Hydrological Bureau, 1980).

Present condition of sewerage system

As presented in the table below both Hanghou and Wuyuan are currently lacking municipal wastewater treatment. Linhe has primary treatment with aerated lagoons, but will have to improve the efficiency.

Table 9. *State of municipal treatment plants in Lake Wuliangsuhai's catchment in 2004*

	Current status	Future plans	Financing
Hanghou	No treatment	To be constructed 2005 – 2008	Allocated 30 % from local funds, need rest from central government (5-year plan)
Linhe	Aerated lagoons, 2004	Needs improvement, no decision made. BaMeng EPB has made a proposal.	No
Wuyuan	No treatment	To be constructed 2005 – 2008	Allocated 30 % from local funds, need rest from central government (5-year plan)

The construction of urban sewage network in Hanghou was initiated in 1987 and the primary project was finished in 1999. The coverage in 2003 was about 5 km^2 and the total network length is 30 km. The coverage rate was thus 60 %. The sewer system enters Drainage Canal 3 from two pump stations, East Pump Station and West Pump Station. A schematic overview of the sewer system is given in the figure below.

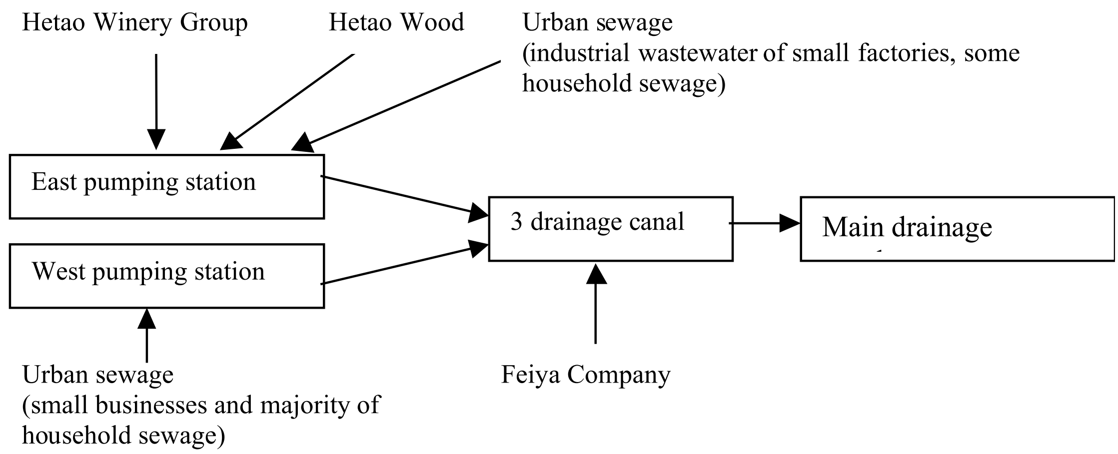


Figure 30. Flow direction chart of urban sewage and industrial wastewater of Hanghou.

The first construction phase of urban sewer network at Linhe took place between 1984 and 1994. The total length is about 30 km and it ends in Hongxinghaizi, a north-eastern suburb where it enters the Linhe municipal treatment plant, which is in operation since 2004. However, the effluent quality does not meet the required treatment standards due to the chosen process configuration. Thus, an upgrade to increase efficiency of nitrogen and phosphorus removal is planned. The treated sewage is discharged into Drainage Canal 5. A schematic overview of the sewer system is illustrated below.

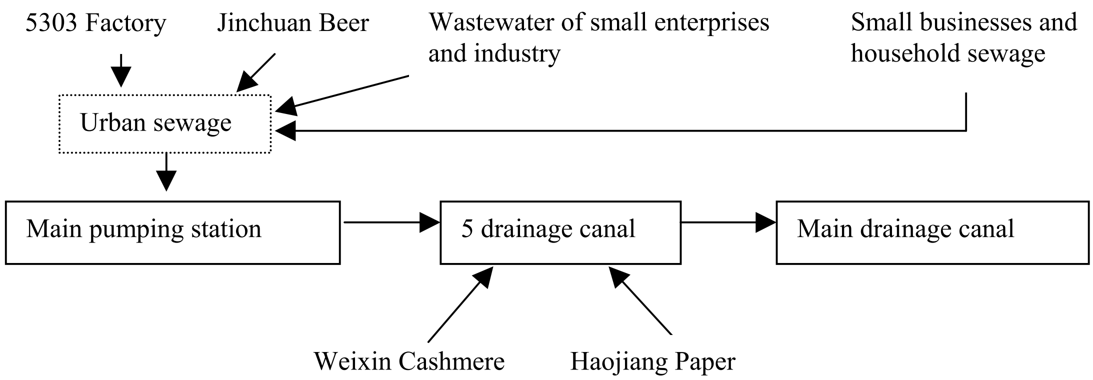


Figure 31. Flow direction chart of urban sewage and industrial wastewater of Linhe City in 2002.

In Wuyuan, the sewer system was constructed between 1989 and 1997. More than 20 km of pipes, resulting in a coverage area of 5 km^2 ends with a pressurised pump at Xidaqiao Bridge in the north-western part of the town, and is discharged into Drainage Canal 7. A schematic overview of the sewer system is presented below.

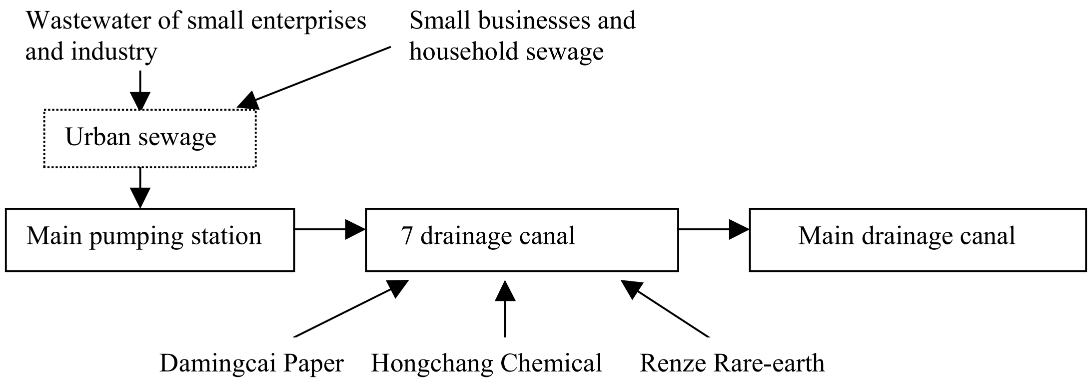


Figure 32. Flow direction chart of urban sewage and industrial wastewater of Wuyuan.

4.7.3 Present pollution situation in Lake Wuliangsuhai's catchment area

The pollution situation in Lake Wuliangsuhai's catchment is comprehensively studied and described in the final report for sub-project 2, Pollution Source Inventory. Point sources are important contributors of contamination to the lake. Towns are the prime source for phosphorus, contributing with 50 % of the total load.

Table 11 gives an overview of the main industrial and domestic pollution sources relevant to the Lake. It shows the status in 2002, and the anticipated status in the near future. The latter includes the changes which took place since 2002 and the planned changed in the MCP. Among the changes since 2002, the operation of the partial treatment of Linhe domestic WWTP, Feiya industrial WWTP, and the closure of the Haojang papermill which was a main contributor with organic pollutants.

Table 10. Overview of industrial and domestic pollution in 2002 and now/planned.

	Treatment plant status		Volume, 1000 m³/a		discharge	Concentrations, mg/l (2002)			Concentrations, mg/l (now & planned)			Load, t/a (2002)			Load, t/a (now & planned)		
	In 2002	now	In 2002	Now*	Outlet	COD	T-P	T-N	COD	T-P	T-N	COD	T-P	T-N	COD	T-P	T-N
Hanghou total			2830	2828	Canal 3							2273	22.3	229.7	278	2,8	59,9
Urban sewage	no		1480	1480	EPS	547.3	7.43	58.8	100.0	1.0	25.0	810	11.0	87.0	148	1.5	37.0
Hetao Winery Group	Secondary	Same	233	233	EPS	77.3	1.72	4.3	77.3	1.00	4.3	18	0.4	1.0	18	0.2	1.0
Hetao Wood	Primary	same	307	307	EPS	146.6	12.38	5.5	100.0	1.0	5.5	45	3.8	1.7	31	0.3	1.7
Feiya	No	Improved	808	808	Canal 3	1732.7	8.8	173.3	100	1	25	1400	7.1	140.0	81	0.8	20.2
Linhe total			7070	5858	Canal 5							10447	43.7	287.2	586	5.9	128.2
Urban sewage	No	Partial	4930	4930	LPS	547.7	7.51	44.6	100.0	1.0	25.0	2700	37.0	220.0	493	4.9	123.3
5303 Factory	Secondary	Same	110	110	LPS	154.5	2.73	3.6	100.0	1.0	3.6	17	0.3	0.4	11	0.1	0.4
Jinchuan Beer	Secondary	Same	482	482	LPS	414.9	2.49	6.6	100.0	1.0	6.6	200	1.2	3.2	48	0.5	3.2
Haojiang Paper	No	Closed	1460	0	Canal 5	5068.5	3.42	43.2	0	0	0	7400	5.0	63.0	0	0.0	0.0
Weixin Cashmere	No	New	90	336	Canal 5	1444.4	2.2	6.7	100	1	4	130	0.2	0.6	34	0.3	1.3
Wuyuan total			6420	7060	Canal 7							3219	9.2	585.0	399	3.0	52.8
Urban sewage	no	New	810	810	WPS	370.4	7.8	43.2	100.0	1.0	25.0	300	6.3	35.0	81	0.8	20.3
Damingcai Paper	Primary	same	1790	1790	Canal 7	1452.5	1.2	13.4	100	1.0	13.4	2600	2.2	24.0	179	1.8	24.0
Hongchang Chem.	No	New	3800	4380	Canal 7	83.2	0.2	134.2	30	0.1	1.5	316	0.7	510.0	131	0.4	6.6
Renze Rare-earth	Primary	New	21	80	Canal 7	147.6		761.9	100	0	25	3	0.0	16.0	8	0.0	2.0
Sum			**16 320**	**15 746**								**15939**	**74.5**	**1101.9**	**1263**	**11.7**	**240.9**

** these figures will be increased due to the population growth, sewer connections and expansion of existing industries and new industries. The estimated total loads for Hanghou,Linhe and Wuyan in 2010 may be as high as 30 000, 60 000 and 40 000m3/d or11mill, 22 mill 15 mill m3/a, respectively.*

4.7.4 Operational environmental target for measure

According to Chinese regulations WWTPs in this area must comply with secondary standard of 'Pollutants drainage standard of town sewage treatment plants' (GB18918-2002):

- COD ≤ 100 mg/l
- T-P ≤ 3.0 mg/l
- T-N ≤ 25.0 mg/l

In addition to this national environmental target, a stricter phosphorus-target should be set for Lake Wuliangsuhai's catchment area. Eutrophication by phosphorous represents one of the major threats to the lake, and the following target is suggested:

- Long term target: T-P ≤ 0.3 mg/l
- Immediate target : T-P ≤ 1.0 mg/l
-

4.7.5 Technical content of measure

The three population centres need to have well functioning central WWTPs. While Hanghou and Wuyan needs to build new WWTPs, Linhe needs to upgrade its existing WWTP to meet the requirements.

Table 11. Main design parameters for the treatment plants in Hanghou, Linhe and Wuyuan

Design parameters	Hanghou	Linhe	Wuyuan
Design capacity (m^3/day)	30,000	60,000	40,000
Average flow rate (m^3/hour)	1,250	2,500	1,666
Maximum flow rate (m^3/hour)	1,750	3,500	2,165
Incoming T-P-concentration (mg/L)	≤ 10	≤ 10	≤ 7
Incoming T-N-concentration (mg/L)	≤ 40	≤ 40	≤ 40
Incoming COD-concentration (mg/L)	≤ 1,000	≤ 500	≤ 600

The Shaanxi Municipal Planning Institute has estimated that the proposed WWTPs shall have the capacities and the influent concentrations noted in Table 12 shall be the design criteria. The capacities in this table are calculated considering not only the population increase and improvement in sewer connections, but also considering the possible expansion of physical city limits in future. Table 13 presents the common conventional wastewater treatment methods and Table 14 analyses the suitable treatment methods to achieve the required treatment efficiencies.

Table 12. Standard treatment efficiencies

Process	COD	T-P	T-N
Mechanical treatment	30%	15%	15%
Biological- high load	70%	30%	25%
Biological- low load	90%	30%	30%
Simultaneous precipitation	90%	90%	35%
Pre-precipitation/Biological treatment	95%	95%	35%
Pre-denitrification/simultaneous precipitation	97%	90%	70%

Table 13. Required treatment efficiencies to achieve the effluent targets.

Process	COD	T-P	T-N
Influent quality, mg/l	500-1000	7-10	≤ 40
Effluent quality, mg/l	< 100	< 1 (<0.3)	< 25
Required treatment efficiency	80-90%	85-90% (97%)	>37,5%
Suitable methods	Low-loaded biological	chemical	nitrification

When comparing the tables 13 and 14, it is clear that to achieve the immediate environmental targets, it is necessary at least to have a simultaneous precipitation WWTP. In this process, one adds coagulants to the biological stage, where the oxidation of Ferrous (II) ions oxides to Ferric (III) ions, and subsequently react with phosphates to precipitate then. The phosphate removal needs specific treatments, and the most common method will be the chemical treatment. Alternatively, this can be achieved also with biological phosphorous removal, although that will be a more complicated method in view of many industrial waste inputs. To achieve the intermediate goal of 1 mg TP/l, a 90% removal is needed, while to achieve the long term goal of 0.3 mg TP /l, a 97% removal is required. If the influent quality can be maintained at the suggested levels for nitrates (<40 mg/l) it may be possible to reach the required effluent N-levels, even without specific N-removal techniques – as advanced and well functioning biological WWTP will remove over 35% of nitrogen.

In proposing the actions, the general configurations will reflect the fact that the most important parameter to control is phosphorus, in order to avoid an accelerating eutrophication of Lake Wuliangsuhai. Therefore, phosphorus removal has top priority, while removal of organic matter and nitrogen are also need to be considered.

As part of the improved municipal treatment, the sewer networks will also have to be expanded. According to urban planning in Hanghou, the coverage rate will be increased to 80 % by 2005. In Linhe, the goal is to reach 100 % and also Wuyuan will increase the sewer coverage, to 8.77 km^2 to enable concentrated treatment of whole town sewage.

- It is a prerequisite is that industrial wastewater entering the municipal treatment plants must conform to 'Water quality standard of sewage drainage to city sewer' (CJ3082-1999). The incoming industrial wastewater concentrations in the planned stage are considered according to this assumption. There are a number of industries which needs to establish their own pre-treatment facilities to meet these requirements, and these are addressed in the next chapter.

Alternative process configurations

At present, following process configurations and costs are proposed by the county/banner administrations:

- Hanghou WWTP will be using two-stage biochemical treatment, adopting A2/O ('secondary combined biological nitrogen and phosphorus removal oxidation ditch') technique.
- Linhe WWTP: Improvement of the treatment process with a combined nitrogen and phosphorus removal system referred to as A2/O technology (anaerobic/anoxic/aerobic)
- Wuyuan WWTP will be using two-stage biochemical treatment. It will have BMS biochemical pond and advective settling tank.

It is unlikely that the required phosphate removal levels (85-90%) can be achieved with the above proposed configurations.

IMESI has suggested an activated sludge process with biological phosphorus and nitrogen removal for municipal WWT. This process configuration is complex and can be difficult to operate. Furthermore, it can be hard to reach stable and low concentrations of phosphorus in the effluent without a polishing step of chemical precipitation. The suggested configuration will also be considerably more expensive due to both investment and operating costs. Having this in mind and access to skilful process operators this alternative is one option for treatment of municipal wastewater for the cities in the catchment area.

The other two options described in this section provide alternatives that can be interesting due to simpler and more robust technique. The first option with the chemical precipitation is an attractive alternative. Partly because is removes phosphorus very effective (better than biological phosphorus removal) and secondly because the treatment later on can be expanded while using the chemical precipitation step as a pre-treatment. With readily available and inexpensive ferric sulphate in Inner Mongolia, the use of this compound is recommended.

In the second alternative given above the chemical precipitation remains as a pre-treatment before the activated sludge process. The activated sludge process in combination with the chemical precipitation will give a high removal rate of phosphorus, organic carbon and nitrogen if wanted. Once should remember though that this configuration is much more expensive, especially if nitrogen removal is wanted due to excessive need of oxygen and high recirculation flow rates.

Comprehensive renovation project of urban sewage in Lake Wuliangsuhai valley is an enormous system project that relates to a lot of fields and many branches. Firstly, before implementing comprehensive renovation project of urban sewage, comprehensive renovation project of industrial wastewater in the jurisdiction area of urban wastewater treatment plant should be completed, which makes wastewater in jurisdiction area conform to *water quality standard of sewage drainage to city sewer* (CJ3082-1999). Then wastewater enters into urban wastewater treatment plant sewage for concentrated treatment.

Secondly, long-term, steady and effective operation of all kinds of wastewater pollution prevention can ensure steady standard drainage of industrial wastewater and urban sewage.

4.7.6 Owner responsible for implementing measure

Municipal wastewater treatment is the responsibility of the local governments.

4.7.7 Location and extent

The plan is to construct Hanghou's WWTP 3 km northwest from the town. It will collect the wastewater of east and west pumping stations as well as the wastewater of Feiya and discharge it into drainage canal 3. Thus, all sewage and wastewater from Hanghou will be treated at this plant.

Linhe WWTP is located 2 km east of the city's suburb and is built by utilising original Hongxinghaizi. The length of the plant's aerated lagoons is 2 920m, width is 600m and area is 141 hm^2. With the proposed improvement, it will have an increased capacity of 60,000 m3 and will collect all urban sewage from the city zone, industrial wastewater and rainwater. The plan is to re-route the wastewater from Weixin in order to treat it. The treated water is discharged into Drainage Canal 5.

Wuyuan WWTP is planned to be constructed in a suburb 2 km northwest from Longxingchang town, west of drainage canal 7. Living sewage in the city zone, industrial wastewater and wastewater of tertiary industry of whole town together go into WWTP, and then enters into #7 drainage canal.

4.7.8 Duration

The treatment plants in Hanghou and Wuyuan will start construction in 2005 and finish it in 2008. There is currently no set date for the expansion of Linhe's treatment plant. The expected lifetime for all plants is 25 years.

4.7.9 Environmental effect and feasibility of measure

Forecast of changed pollution situation
In order to give a better understanding of the future pollution situation in Hetao Irrigation Area and the effect of the planned treatment plants, discharge forecasts have been made for the cities at hand. Primarily, the changes will be due to increased population and expanded sewer networks. For example, Hanghou is said to reach 90 % coverage in 2008. Increase in population is estimated by BaMeng EPB based on statistical trends for the last years. The forecasted discharge volumes, on which the future effects are calculated, are presented below. The reason for Wuyuan's industrial output to increase so much is that the local government is promoting a drastic increase of production.

All proposed WWTP will receive not only urban sewage, but also wastewater from all major point sources. This will, together with the growth of the area result in a drastically changed pollution situation. Just as important, but more difficult to predict and thus not included below, are changes in the composition of major point sources. Factories may be closed down, or new ones may be opened.

4.7.10 Discharge loads from operational municipal treatment plants

The treatment efficiencies of WWTP will vary with the chosen process configuration, as described earlier.

Table 14. Total reduction of nutrient loads by municipal WWTPs, excluding pre-treatment effects, and assuming that the effluent discharges meet the requirements.

	Input to WWTP, t/a			Output from WWTP, t/a			Pollution reduction, t/a		
	COD	TP	TN	COD	TP	TN	COD	TP	TN
Hanghou WWTP	1115	22	110	278	3	60	838	19	50
Linhe WWTP	2935*	39	224	586	6	128	2349	33	96
Wuyan WWTP	1133	9	66	399	3	57	734	6	9
Sum	5183	70	400	1263	12	245	3921	58	155
Improvement							76 %	83 %	39 %

**COD load to Linhe WWTP was reduced by about 1800 in theyear 2004 compared with 2002. Thus the specific COD reduction is 550 t/a.*

4.7.11 Economic content of each measure

Itemised capital investment costs of measure
The WWTP plants described above are differing in size and choice of technology, which is reflected in the investment costs. The reasons for Wuyuan's plant being more expensive are higher capacity and more advanced treatment due to more major industries. The total investments and annual schedules are given in the following tables.

Table 15. Total investment costs per treatment plan, RMB x1000, for A2/O alternatives

	WWTP	Sewers	Sum	Year 1	Year 2	Year 3
Hanghou WWTP	57310	33620	90930	27280	45460	18190
Linhe WWTP*	37310		37310	11193	18655	7462
Wuyan WWTP	134000	47850	181850	35680	89590	56580
	228620	81470	310090	74153	153705	82232

**Only upgrading costs*

Table 16. Operational and Maintenance costs, RMBx1000/a, for A2/O alternatives.

	material	Energy	Salary	Maintenance	Other	Sum
Hanghou WWTP	20	1980	500	1430	700	4630
Linhe WWTP*	48	2216	400	992	1256	4912
Wuyan WWTP	60	2770	500	1240	1570	6140
	128	6966	1400	3662	3526	15682

* estimated to be 80% of Wuyan WWTP

Tables 16 and 17 presents the investment and O&M costs for the WWTPs based on A2/O concepts.
Note: The European cost estimates indicate that a WWTP of 7700m3/d (Hanghou) will cost about the same as the given estimates, although a plant with 30 000 m3/d will cost about 3 to 5 times more, with N and P removal, depending on the configuration. For this reason, the presented investment costs should be treated as only very preliminary, and should be verified when design concepts are chosesn.

4.7.12 Socio-economical impact

Municipal wastewater treatment is an important part of the urban infrastructure. The proposed investments will help attracting new investments to the region. The proposed actions are therefore socioeconomically beneficial for the town areas. Improved environmental and ecological status for Lake Wuliangsuhai's catchment will also facilitate the development of different agricultural enterprises.

Treatment of urban sewage (and indirectly of industrial wastewater) will enable better utilisation of the water resource. The water can be reused for irrigation or as cooling water in power plants. Assuming that all treated water is reused for irrigation, this volume can replace water that is bought from Yellow River, and this value can be estimated.

In order to finance the treatment plants a sewage treatment fee is recommended. For the cities in Lake Wuliangsuhai's catchment area the fee will be 1.20 RMB/m^3. In theory (yearly cost methods), a fee of 0.90 RMB/t would be sufficient. However, in order to make income generation cover all aspects of operation and maintenance it is suggested that the fee is set to 1.20 RMB/t.

The produced sludge will pass secondary treatment and eventually be used as landfill. There is no calculation on volumes and costs or incomes. The incomes and saved expenses for the water are given in the table below.

Table 17. Income from sewage treatment fees and saved expense for irrigation water. The sums are theoretical, assuming that the plants are operating at design capacity and that the same amount of water from Yellow River can be substituted

	Treated volume (m^3)	Income (RMB)	Saved expense (RMB)
Hanghou	10,950,000	13,140,000	390,000
Linhe	21,900,000	26,280,000	790,000
Wuyuan	29,200,000	35,040,000	1,050,000
Total	62,050,000	74,460,000	2,230,000

4.7.13 Implementation arrangements

Proposed plan of action with stakeholder involvement
It is the local governments' responsibility to assure that urban discharges comply with national standards, and if required, install treatment plants, which is the case for all three cities in the catchment. The governments are responsible for ordering or producing designs and plans for the plants.

Anticipated risks and mitigatory measures
The identified risks for constructing adequate treatment plants in Hanghou, Linhe and Wuyuan are:

- *Choice of configuration.* Since each proposed treatment plant constitutes a major investment, the need for a good choice is important. Linhe's current treatment plant is a good example of this. Even if a specific configuration is able to reach the standard, it can still be too polluted for Lake Wuliangsuhai. This must be taken into consideration, together with the possibilities for future improvements if the situation changes.
- *Difficulties in raising necessary funds.* According to the plan (presented below), there is need for external money from e.g. World Bank. These decisions remain outside of the local governments' control. Alternative financing possibilities may be considered.

4.7.14 Financing plans and considerations

Fund raising
In principal, the funds for these projects will be raised by the following ways:

1. Applying for national special funds and self-raised funds.
2. Loan from World Bank and/or Asian Bank.

Total investment includes the fixed assets investment, including investment load interests, and circulating funds. Total funds raised are the sum of existing funds (including circulating funds) and loans, including interests.

For these construction projects, revolving funds will be used. Generally 70 % will be bank loan and 30 % self-raised by the local government.

Conclusions of finance evaluation
For all three projects the internal rate of returns are higher than average level for this kind of investments (6.32 % for Hanghou, 6.62 % for Linhe and 6.42 % for Wuyuan). Combined with the fact that at least Hanghou and Linhe will be able to repay their bank loans in approximately 6 years, including 3 years' construction time, the projects are considered economically viable.

The estimated economical life span is 25 years for the plants.

4.8 Industrial wastewater treatment

4.8.1 Purpose

General objective of measure

The overarching purpose of this measure is to reduce the pollution load on Lake Wuliangsuhai. Pollution abatement measures will also have indirect consequences facilitating other aspects of this project.

4.8.2 Background

Technical, institutional, legal, socio-economical issues of relevance

Many industries in the Hetao area do not no treatment facilities of have inadequate treatment, mainly due to financial factors. Wastewater is often discharged directly into the drainage canal system and ends up in the lake, diluted with agricultural drainage water, which is also polluted. This combined load, in particular the phosphate, drives the eutrophication of Lake Wuliangsuhai. This process is considered one of the main reasons for the deteriorated water quality in the lake, expansive growth of lake vegetation and related problems.

It assumes that phosphorus (P) is both the main cause and the limiting factor for the eutrophication of the lake. Industries are considered minor contributors of phosphorus when compared to the domestic wastewater.

According to Chinese law, there are different wastewater quality standards for different industrial branches. It is the responsibility of each enterprise to make sure that their effluents meet this national standard. If not, they have to pay additional fees or, in severe cases, simply close down the operation. All investment costs as well as operational and maintainace costs are to be paid by the enterprise.

Local EPB (Environmental Protection Bureau) monitor the effluent quality with grab samples regularly (typically two to four times per year). It is also the EPB that commissions the new treatment plants.

According to the working hypothesis formulated above, eutrophication is Lake Wuliangsuhai's main pollution problem, as identified by the Lake Restoration Project. Other pollutants are consequently not discussed in this report. This does not imply that other forms and sources of contamination do not exist. For example, a cyanide concentration of 0.82 mg/L has been recorded for Hongchang. In order to concentrate fully on the main cause of pollution only phosphorous will be considered in the following.

Most of the data comes from a sampling campaign in September 2002. Remaining data comes from July 2004 and the local EPB's analyses during commissioning tests. The major pollution point sources are presented in Table 19.

Table 18. Industrial pollution sources and their descriptions

Name	Industry	Need for improvement	Wastewater 1000 m3/a	Load before WWTP, t/a			Load after WWTP, t/a		
				COD	Tot-N	Tot-P	COD	Tot-N	Tot-P
First Sub-factory of IM Armed Police 5303 Factory (#5303):	Leather processing industry	No, WWTP functions.	110	17	0,4	0,3	17	0,4	0,3
Wuyuan Damingcai Paper Limited Company, Damingcai	Pulp and paper production	No, WWTP functions	1 790	2 600	24	2,2	716	24	2,2
Hanghou Seasoning Factory of Chongqing Feiya Company, Feiya	Food processing industry	No, WWTP functions.	808	1 400	140	7,1	242	20	7,1
Haojiang Paper Limited Liability Company in Linhe city, Haojiang	Pulp and paper production	Closed at present	1 460	7 400	63	5,0	0	0	0
IM Hetao Winery Group, Hanghou	Food (alcohol) industry	No, WWTP functions.	233	18	1	0,4	18	1	0,4
IM Hetao Wood Limited, Hanghou	Pulp and paper production	Yes, WWTP not approved (closed)	307	45	1,7	3,8	45	1,7	3,8
IM Jinchuanbaojian Beers Factory, Jinchuan	Beer production	No, can dischare to sewers.	482	200	3,2	1,2	200	1,2	3,2
Wuyuan Hongchang Chemical Industry, Hongchang	Synthetic ammonia production	Yes, need a WWTP	3 800	316	510	0,7	131	6,6	0,4
Wuyuan Renze Rare-earth Limited Company, Renze	Chemical processing, high NH3-N	Yes, exiting WWTP inadequate	21	3,1	16	0	12	61	0
IM Weixin Cashmere, Weixin	Cashmere processing	Yes, need a WWTP	90	130	0,6	0,2	67	1,3	0,3
Total			9101	12129	760	21	1448	117	18

Only the three industries shown in white background requires construction or/and improvement of pre-treatment facilities.

4.8.3 Operational environmental target for measure

The target for each industry is to meet relevant sector standards as per the '*wastewater comprehensive drainage standard*'GB3898-1996.

The previous chapter presented the actions related to the municipal WWTPs. Most industries discharge their wastewater to the common sewers, thus are further treated by the municipal WWTPs. The Municipal WWTPs have specific influent requirements, and it is an absolute requirement that the industries pre-treat their wastewater before discharging.

The wastewater treatment is often a costly action. However, such actions should be carried out in such a way that costs for the industry is reasonable and with no negative effects on the number of employees (i.e. the solution of closing down industries should be avoided). Whenever possible these installations should consider 'cleaner production' approach, with better efficiency and utilisation of resources, rather than conventional 'end of pipe' solutions.

4.8.4 Technical content of measure

Hongchang

Hongchang produces chemicals and the wastewater mainly comes from the boiler, gas-making and desulphuring processes. The rest of the used water is recycled. The wastewater volume is 3.8 million m3/a. Main pollutants are cyanide (0.82 mg/l), volatile hydroxybenzene, sulphide and NH_3-N. The concentrations all exceed secondary standard of carbon and ammonia of "*discharge standard of pollutants in synthesising ammonia industrial water*" (GB13458-2001).

The suggested treatment process is an anaerobic- anoxic-aerated based biological treatment with activated sludge, for both N and P removal. It shall have a capacity of 12 000 m^3/d (4.38 mill m3/a).

The effluent shall have CODcr ≤ 30 mg/L, NH_3-N ≤ 1.0 mg/L, T-N ≤ 1.5 mg/L, T-P ≤ 0.1 mg/L and
PH: 6 – 9.

Weixin:

The wastewater of enterprise mainly originates from the wastewater of the textile raw material washing workshop, the wastewater from printing workshop, and the wastewater from shrinking workshop and ordinary sewage, discharging 90 000t/a. The effluent quality does not meet national standards.

The proposed treatment design is dimensioned for a yearly capacity of 336 000 t/a compared with the present volume of 90 000 t/a. This will allow for expansion of the enterprise, while it is assumed that the future wastewater quality will remain as today.

Treated water quality is required to reach class II discharge standard in the form 4 of '*comprehensive standard of sewage discharge*' (GB8978-1996):

- A biological WWTP with Activated Sludge process after chemical flotation is proposed as a suitable process configuration. The effluent shall have COD ≤ 200 mg/L, BOD ≤ 60 mg/L, SS ≤ 150 mg/L, Chrome ≤ 80 times and pH: 6 – 9.

Renze:
After enterprise wastewater is treated by multi-settling, NH_3-N still exceeds standard by far. The proposed treatment facility shall have a capacity of 80 000m3/a compared with today's 21 000 m3/a to cater the future expansions.

The proposed treatment concept is a NH3-crystallisation process based on Calcium oxide or/and a membrane process. The removal rate of NH3-N in this system can come to above 97 %, and the discharge will then conform to secondary standard of *integrated drainage standard of sewage* (GB8978-1996).

Owner responsible for implementing measure
The industries are responsible for the entire process of implementing adequate treatment capacity. Local EPB commissions the WWTP.

Environmental effect and feasibility of measure
Assuming that all treatment designs described above, except the secondary treatment for Renze, are implemented, the total reduction of pollutants will be:

Table 19. Pollution loads before and after abatement actions.

	Discharges in 2002, t/a				Discharges after pre-treatment, t/a			
	Volume	COD	T-P	T-N	Volume	COD	T-P	T-N
Weixin Cashmere	90 000	130	0,2	0,6	336 000	67	0,3	1,3
Hongchang Chem.	3 800 000	316	0,70	510,0	4 380 000	131	0,4	6,6
Renze Rare-earth	21 000	4	0,0	16,0	80 000	12	0,0	6,1
Haojiang Paper	1 460 000	7400	5,0	63,0	0	0	0,0	0,0
Sum	5 371 000	7850	5,9	590	4 796 000	210	0,77	14
Total reduction						97%	87%	98%

The pre-treatment facilities at 3 industries and the closure of the Haojiang paper industry results in the reduction of COD: 7640 t/a, T-P: 5.1 t/a and T-N: 576 t/a.

4.8.5 Economic content of each measure

Itemised capital investment costs of measure

The estimated investment costs are given in the below table. For comparison, the investment costs in the existing plants are also given.

Table 20. Investment costs for planned and new industrial treatment plants

Industry	Total investment	Investment per m3 ww
Hongchang	5 417 000	1.2
Renze	1 500 000	18.8
Weixin	3 225 000	9.6
Haojiang	closed	-

Table 21. Investment costs for existing industrial treatment plants

Industry	Total investment	Investment per m3 ww
Feiya	9 529 000	11.8
5303	3 000 000	27.3
Damingacai	12 040 000	6.7
Hetao winery group	3 200 000	13.7
Hetao Wood	3 200 000	10.4

Itemised operating / annual costs of measure
Wherever possible the running costs for the proposed treatment plants have been presented. Operating cost for existing treatment plants is only available for Damingcai. Unfortunately, the proposed technical solutions for Hongchang and Renze are not detailed enough to allow for an estimation of operational costs. The summary below is therefore incomplete.

Table 22. Annual Operations and Maintenance costs, RMB

	Volume, m3/t	O&M RMB/m3	O&M, RMB
Damingchi	1790	0.87	1555 000
Feiya	808	0.28	227 000
Wexin	90	3.20	288 000
*Hongchang**	*336*	*1.0*	*336 000*
*Renze**	*80*	*1.0*	*80 000*

** O&M costs are estimated based on 1 RMB/m3*

4.8.6 Socio-economical impact

Socioeconomical impacts from the proposed project are divided into two categories:

If the industries neglect to install adequate treatment technology, they face the risk of penal fees or forced closure. That would obviously have direct and severe social impact, in particular with respect to hundreds of employees. On the other hand, new treatment facilities will also create new employment opportunities, like in the case of Weixin there will be 7 new workers required to run the proposed new facility.

Hopefully, the new investments will also make the enterprises themselves more competitive and sustainable. Efficient treatment will force the industries to utilise their resources more efficiently and to recycle process water. The end products from the treatment processes, primarily sludge, can possibly be sold as fertiliser, landfill material and may generate extra income. As an example, it is anticipated that such secondary income will cover the annual operating cost of the treatment at Feya.

The industries which do not expected to reach the wastewater quality standard within the near future include Hetao Wood and Renze. Hetao Wood already has an operational treatment plant that has not got approval from local EPB. Renze lack the necessary funds. Moreover, there are presently no prospects of Hongchang starting construction activities. The operation in these plants is dependent on how long these plants will allowed to do so.

4.8.7 Implementation arrangements

The responsibility for industrial wastewater treatment is quite clear. Each enterprise has to follow the legislation and the local EPB checks if the effluents comply with the national standard. It is thus the responsibility of the enterprise to both design the treatment and to allocate the necessary funds.

Anticipated risks and mitigatory measures
Notwithstanding the fact that as long as the law is enforced, the risk of experiencing untreated effluents over a long period of time, is small. However, a few risks can still be identified:

- The enterprise could (maybe under certain circumstances) chose to pay higher discharge fees and penalties instead of treating the wastewater. Naturally, Lake Wuliangsuhai will not benefit from the fees, unless the discharged water will be treated at a different WWTP.
- There have been examples of enterprises closing down and then re-opening with new

management and/or production. This procedure can cause considerable periods of operation without any treatment.

- Since there are no stringent requirement and follow-up on the minimum treatment efficiencies, an industry can choose an inadequate solution (such as Hetao Wood). This will also result in delays when the first facility is constructed, followed by a test phase and new investigations. Hopefully, the treatment will have some effect even though it does not fully comply with standard.

4.8.8 Other comments

From Lake Wuliangsuhai's perspective there are two industries that need particular attention:
- Haojiang Paper
- Hongchang Chemical.

Haojiang, the paper factory in Linhe, closed down in summer 2004. By doing this, the single largest source of COD disappeared. Depending on what is decided in the future, Haojiang might re-open with or without a new production. If so, it could have consequences for the lake.

Hongchang Chemical in Wuyuan is by far the main source of nitrogen to the lake. Still there is no decision made on investing in local treatment. How this situation develops will also have direct effect on the lake's water quality, even though nitrogen is not considered the main reason for eutrophication.
There have been questions on the reliability of the monitoring results and it is recommended that supplementary samplings are taken, since Hongchang's effluents alone can change the nitrogen budget for Lake Wuliangsuhai.

In the list of industries all treatment solutions are based on'end of pipe' technology. However it is important to use a'cleaner' approach since the costs for such treatment will be lower (very often profit can be made) and at the same time the treatment will be more efficient and sustainable. Since the Inner Mongolia Lake Restoration Project did not include tasks for cleaner production, the benefits from employing such an alternative cannot be quantified. Instead a general description of the concept is given, together with a strong recommendation to evaluate the'cleaner' production-alternative before making any decisions on "end-of-pipe" solutions.

In general, there is not enough data available in order to recommend the optimal treatment technology. Therefore, additional measurements and sampling campaigns are needed. Since the parameters remain essentially unchanged, the proportional flow characterisation approach used for quantification of pollutant sources will also be the same. The goal of this process will be to ensure complete and continuous records in order to come up with mass balance characterisations.

Wit data sets covering the various streams a mass balance characterisation for the whole industry will be feasible, which will be the basis for finding the optimal approach for dealing with the treatment of different process waters. The optimal technology will not only consider the ability to removing the pollutants but will also consider the ability to recirculating both the water and the chemical compounds for reuse, rather than to discharge everything into the wastewater. Because the process effluents from various industries will differ, it will be recommended to make pilot scale experiments to evaluate the available and feasible technology options. Thus, the next task is to carry out pilot plant experiments.

Evaluation the technologies should not only consider the treatability of the wastewater but also consider the possibility in recovering both clean water and chemicals for reuse in production. Therefore, the cleaner production approach is much more attractive since pollutants effectively are removed at the same time as the production costs are lowered due to a more effective usage of the natural resources.

4.9 Increasing Lake Depth by Dredging

4.9.1 Purpose

The Purpose of this study is to provide further insight into the following aspects:

- Mitigate the process of the lake developing into a reed marsh land
- Improve water quality
- Ensure fish survival during the winter
- Maintain the biodiversity
- Create new areas for fishing
- Increase the water storage capacity of the lake by increasing the average lake depth
- Assess cost implications for various dredging scenarios.

4.9.2 Background

China is presently losing some 2.3% of total water storage volume per year due to silting up of reservoirs. Being one of the largest reservoirs, the Lake Wuliangsuhai shares the same fate as the estimated 86.000 other reservoirs in China, large and small. The total estimated reservoir volume being subjected to such degree of silting in China is 560 km^3, indicating that an estimated 13 km^3 of reservoir is under threat and will be lost on an annual basis unless countermeasures be taken. These figures underline the scale of the problem on a national level.

4.9.3 Environmental objectives

Improve water quality and mitigate the process of lake eutrophication

The polluted original sludge in the lake is the potential pollution source. When the lake environment changes, the nutrients in the sludge are discharged into water body again. This change makes great influence on lake water quality.

The process, which pollutants in the sludge are discharged into the water body, is related to water environmental situation and characters of sludge in the lake. After the point source and non-point source pollution is validly controlled, this process will generally be accelerated. That is, the velocity of sludge discharging pollutants into water body will be quicker.

Sludge is one of key reasons that restrict the water quality improvement of lakes. Lake Wuliangsuhai accepts much tail water from farms. The process, which suspended substance in the tail water and aquatic plants in the lake emerge and die, accelerates the biology filling in the lake bottom. Every year the thickness filled is > 1 cm. A black decayed sludge layer 0.2-0.5 cm thick with odour and exquisite grain has formed in the lake bottom. The organics content in upper layer is about 3.02% to 5.28%.

Secure conditions for fish survival during winter and Meet the demands of fish living through the winter and biological diversity.

Because of long term flood filling up and anaerobic aquatic plants sinking down, filling function in the lake bottom occurred. This function greatly made water level decline and much difficulty to aquatic plants, especially fish living through the winter. This function also made great difficulty to develop aquatic industry and keep general ecological balance.

In the past, the fish sources are abundant in Lake Wuliangsuhai. During the maximum period of fish, there were 24 fish species. Lake Wuliangsuhai was one of fish bases in China. In 1960s and 1970s, the fish yield of Lake Wuliangsuhai was about 5 million kg/year. The yield of Yellow river carp was about one half of the total yield. With the yearly decline of Lake Wuliangsuhai water level, present water depth is 0.7 meter. The lake water freezes in winter, so the fish cannot survive the winter. Further more, the water quality was polluted and Fish almost disappeared. Bird species and numbers greatly reduced in lake area. Tourist industry shrank systematically. The lake water depth and water quality pollution problems have made great influence on the ecological balance of Lake Wuliangsuhai.

To secure the fish survival during the winter and keep ecological diversity, it is necessary to enhance the part water depth of Lake Wuliangsuhai through dredging up certain parts of the lake. Moreover, this action is one of necessary steps to keep ecological balance and improve ecology environment of Lake Wuliangsuhai.

Increase the lake depth to improve the lake capacity and efficiency of water resource usage.

Lake Wuliangsuhai is one of eight biggest fresh lakes in China. It is the biggest fresh lake in the yellow river basin. It is also the biggest fresh lake in the west of Inner Mongolia Autonomous Region.

The area of Lake Wuliangsuhai and neighbourhood belongs to arid area. There is serious water shortage in this area. The water resources shortage has seriously influenced the development of regional industry and economy. Through dredging up the part of Lake Wuliangsuhai, the part valid water depth and lake capacity will increase.

After Lake Wuliangsuhai is treated, it can make use of the water during the flood period and spring free compensate water of yellow river. After saving water, Lake Wuliangsuhai will be one of important water resources in local area.

4.9.4 Technical content of the measure

One engineering technique is to dredge up part of Lake Wuliangsuhai. This engineering can remove the polluted sludge of lake and improve the water quality while enhancing the capacity and water level of Wuliangsuhai lake. It also can meet the demand of fish survival through the winter and increase the biological diversity.

After the sludge is dredged up, it can be transported to bank by pipe or barge. The work is sequential and the efficiency is high by pipe method. When the mud content of sludge is low, the sludge can be transported long distance away by pipe way. When the distance is beyond the discharging distance of sludge boats, the middle pump stations should be used. The work is not sequential by barge way. The dredged up sludge is loaded into the barge. Then the sludge is sent to bank. The sludge is discharged from barge by pumps or buckets. When the mud content is high or the discharging distance is long, barge way is usually used.

Whatever which way is taken, the technique of lake sludge dredged up is professionally done following successful experiences in China or other countries.

The project carried out pilot tests and investigations. Two ways to dredge up sludge in summer and winter according to the local environmental characters and plan of Lake Wuliangsuhai function are suggested. After investigated and discussed with relevant specialists, the two ways both can be used in Lake Wuliangsuhai.

Lake Wuliangsuhai farm and other companies accumulated much experience in dredging up Lake Wuliangsuhai river way. Though the dredging works are done in small area and short distance, the proposal of dredging up lake is proved to be feasible in engineering.

Environmental concerns

According to above functional demands, the regulation is as the following

- To improve the water quality of Lake Wuliangsuhai, the area of sludge dredged up should be as large as possible. Thus, the dredging area should be decided according to the available funds. Only the area with less than 1m now shall be dredged.
- To meet the demand of fish survival through winter, the dredged area in fish breeding area should be dredged up about 1.5m.
- To meet the demand of water resources supply, the dredged area should be settled in the area of category III.
- The ecological diversity should be considered. The dredged area should be in the rich ecological diversity area.
- The sludge treatment should be carefully planned considering the disturbances related to the tourist scenery. The dredged area should be considered with the treatment of sludge.
- In the limited investment, the engineering benefit should be considered highest.

4.9.5 Suggested sites and areas

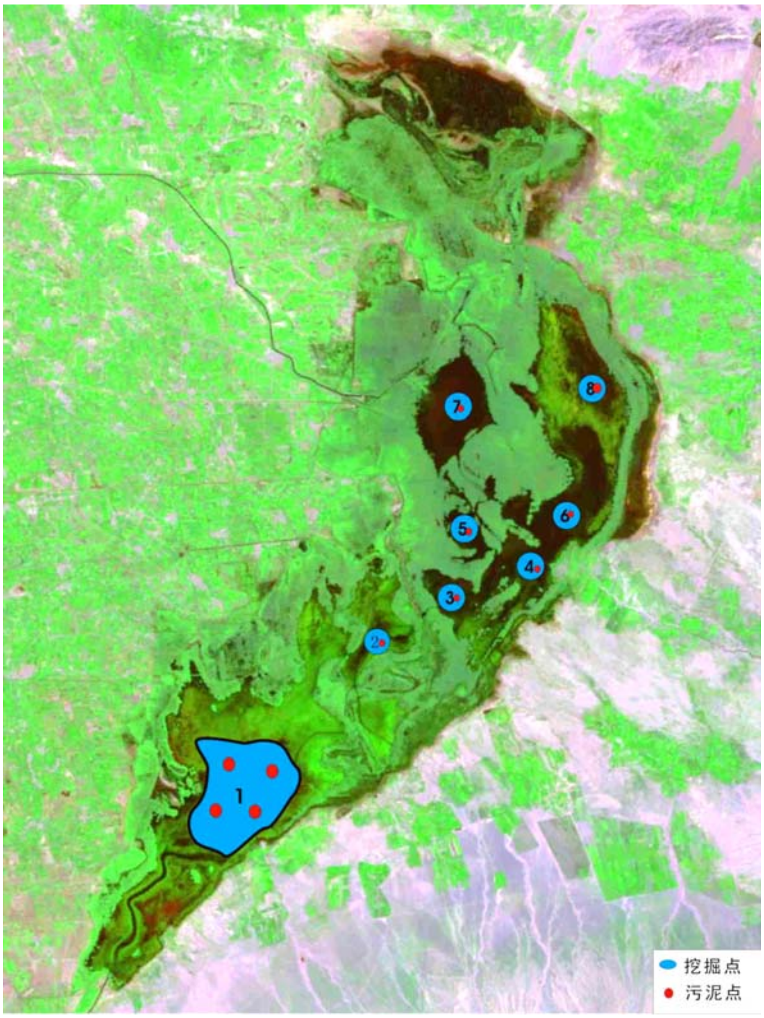


Figure 33. . Suggested areas for dredging: 1:improve water quality; 2-7: for fish breeding; 8: for improving biodiversity

It is suggested to dredge the areas given in the figure. The size of dredging area as following:

- Large areas to keep the water quality in category-III: 12 km^2 with a depth of 1 m
- Six areas for fish breeding: Each site with 1.5km^2 and 1.5 m depth.
- One site in the protected area of ecological diversity: area of 0.5km^2 with 1.5m depth.

The total dredging area will thus be 21.5 km^2, which is approximately 18% of the visible water area of the lake. The engineering volume is about 26.25 million m^3.

Engineering content

The components of Wuliangsuhai sludge mainly are two kinds: the anaerobic layer and the sediment layer. These two layers can be described as following, after the analysis.

Anaerobic sludge layer: The anaerobic sludge layer mainly is made up of black-grey plastic anaerobic silt. This layer is loose in composition and with a bad smell. The thickness of this layer is about from 0.2m to 0.6m. The average thickness is 0.4m.

The anaerobic sludge layer has low density and its structure is loose. So this layer is easy to dredge up.

Sediment sludge layer: Sediment sludge layer is mainly made up of grey-white silt and powdery clay. This layer is widely distributed under the anaerobic sludge layer in Lake Wuliangsuhai base. This layer has high density. Its structure is compact.

Considering the results from spot tests to remove sediment sludge layer, the grab method is the most appropriate method.

Engineering Proposal
Considering the results from pilot tests as well as discussions with other specialist, the following two concepts for summer and winter dredging are described.

- **Dredging proposal in summer (proposal 1):** dredging up sludge and sediment sludge layer, the engineering of constructing cofferdam, the engineering of treating tail water of sludge placement farm, the engineering of treating the anaerobic sludge layer, the engineering of treating the sediment sludge layer and the engineering of man-made sight to sludge placement farm.

- **Dredging proposal in winter (proposal 2):** The main engineering content are the engineering of dredging up lake sludge and the man-made sight engineering to sludge placement.

The two proposals are compared and analyzed in the report. The best proposal is recommended

Description of the Summer Proposal
The dredging engineering technique proposal mainly includes two parts: the engineering of dredging up the anaerobic sludge layer and the sediment sludge layer.
The dredging using a boat is not suitable for the Lake Wuliangsuhai. The grab method should be preffered.

Description of dredging the anaerobic sludge layer
Wringing and absorbing boat is used in the engineering of dredging up the anaerobic sludge layer. It can combine dredging, transporting and discharging to one process. In the construction it works sequentially. By the vacuum of sludge pumps on boats, It absorbs and exalts the

dredged up sludge through absorbing pipes. Then it sends the sludge to sludge placement farms (sludge treatment farms). It is an efficient process to use wringing and absorbing boats in dredging up the anaerobic sludge layer.

The anaerobic sludge layer treatment
There are two ways in treating the anaerobic sludge layer:
- Resume the sight of sludge placement farms (man-made sight)
- Synthesize the anaerobic sludge layer (the farm fertilizer)

Description of the dredging of sediment sludge layer
According to the structure of Lake Wuliangsuhai sludge and results of dredging tests, the way used in dredging up the sediment sludge layer is grabs and transporting boats

Cofferdam engineering
The aim of cofferdam engineering is to solve the problem of dredged up sludge and avoid its second pollution. To make the dredged up sludge grain fully settle down, traverse obstructs are used among big cofferdams. Thus sludge grain can settle in a long period. The quality of treated tail water can meet the discharge standard.
- Cofferdam method: knitting bags with soil
- Leakage prevention: two fabrics and one film

The treatment of sludge placement tail water
First the sludge should let to be settled and then disposed in to settling lagoons. The sludge laggons is divided into several districts. The discontinuous dredging method is preferred. The sludge retention time is then longer. Suspended solid content will be monitored, thus the discharged tail water can meet the standard.

Sludge treatment and the renewal of sludge lagoons
- Polluted sludge treatment: According to the analysis result of polluted sludge, the heavy metal content is much lower than the standard of used sludge in farm. The sludge will be mainly used in improving soil and making compound fertilizer and so on.

- The renewal of sludge lagoons: According to the detail in lake or out and the plan of Lake Wuliangsuhai tour, after researching, the dredged up sludge will be made up hill in lake to form man-made sight.

Based on the detail dredge spots, six man-made sights are planed at first.

Description of winter dredging Proposal

Explain of the anaerobic sludge layer
The method is practiced according to the weather condition and experience in dredging activities in other lakes and river ways. After the anaerobic sludge layer is dredged up in winter by grab, the sludge is sent to other places by trucks. The “Grabs + trucks”, has the lowest cost.

Treat the anaerobic sludge layer
There are two ways to treat the anaerobic sludge layer.
- Renewal of the sludge lagoons
- Synthetic the sludge layer

Explain of dredging up the sediment sludge layer
“Grab + Trucks Transporting” method is preferred.

Treat sludge and resume the sight of sludge placement farm

- Polluted sludge treatment: According to the polluted sludge analysis result, the heavy metal content in it is much lower than the standard of sludge used in farms.The treated sludge will be mainly used in improving soil and making compound fertilizer.

- Renewal of the sludge lagoon: According to the detail in lake or out and the plan of Lake Wuliangsuhai tour, after researching, the dredged up sludge will be made up hill in lake to form man-made sight.

Based on the detail dredging spots, eleven man-made sights are planed at first.

Comparison of two proposal

Table 23. Comparison of the proposal in summer to in winter

Sequence	Content	Proposal in summer	Proposal in winter
1	Cost	Very high	Low
2	Environmental impact	Big	Small
3	Sludge placement and treatment	Difficult	Easy
4	Construction condition	Difficult	Easy

Because Lake Wuliangsuhai has large water area and low water depth, the mud will make it difficult to utilise the technique, compared with the winder conditions.

Recommended concept
The winter dredging is preferred. It is suggested to reduce the water level from 0.7m to about 0.5m in the lake before dredging. Since most parts of the lake will be frozen in winter, a large grab can be used.

Table 24. Schedule of dredging activities

Sequence	No of dredging area	Schedule
1	1	In 2006 and 2007
2	2, 3, 4, 5	In 2008
3	6,7,8	In 2009

There will be 4 sludge lagoons constructed from the No 1 dredging area. Each lagoon will occupy 350m×350m×(25-30cm).

The additional lagoons constructed for sites No 2-7 and will occupy 350mx350m×(25-30cm). The lagoons will be placed in the center of the dredging area to minize the costs.

There is one lagoon for the No 8 site, with the size of 175m×175m×(25-30cm).

Analysis of Possible Pollution By Engineering Steps
The recommendation is the proposal in winter. During the execution period, the possible environmental impact is mainly as the following:

- Oil pollution in maintenance or leakage of grabs or trucks
- Sewage produced by executive persons
- Voice produced by executive machines
- Engineering trash or domestic garbage

Environmental Impact Analysis Of Engineering Pollution
Analysis of pollution by maintenance or leakage oil: In the engineering execution, the grabs and trucks will produce pollution of maintenance and leakage oil. The pollution of lake water must

be prevented. So in the engineering execution, the engineering executive companies will be asked to gather the maintenance and leakage oil and carry them out of the lake. The oil should be saved at the place suggsted by environmental department..

Sewage
The sewage is gathered in the fixed place to be carried to farm south to the lake as the farm fertilizer.

Noise by engineering machines
Because the engineering place is far away residential area and there is no environment sensitive area near the place, there is no noise impact.

Engineering trash and domestic garbage
There are some engineering trash and domestic garbage in the process of engineering execution. These trashes are gathered to fixed place and then should be carried out of the lake to other places asked by local environmental department. Trash saved in the lake is not permitted.

Environmental Impact And Feasibility Analysis of Engineering Steps
The main environmental impact is during the period of engineering execution. Strict management and countermeasures to engineering execution can avoid the environmental impact to the lake.

This engineering is feasible in environment.

4.9.6 Economical content

Table 25. Investment cost

No	Name	Quantity	Unit	Cost, RMB	Remark
1	Dredge and transport sludge	26.25	Million m^3	262 500 000	10 RMB/m^3
2	Cofferdam engineering	67500	m^2	33 750 000	500 RMB /m2(stones□5m high ,500RMB /m^2
3	Man-made sight and green engineering of sludge placement farm	1.368	Million m^2	13 680 000	10RMB/m^3
4	Total			309 930 000	

The total investment estimate is 310 million RMB

There are no operational costs anticipated, as the dredging should have a lifetime of about 15-20 years.

4.9.7 Utilising mud for agricultural purposes

The prospects of utilising mud dredged from Lake Wuliangsuhai for farmland fertilizers have been looked into. A project with the purpose of exploiting 50.000 tons of this material on an annual basis year has been analysed.

Some samples of lake bottom mud contained 165.8 ppm-P, 110.4 ppm NH_3-N and 6.86 ppm NO_3-N (ref. Prof Shang Shiouy). An another study reports 2.5 ppm-N and 0.547 ppm-P (ref. Jiang Xiangcan).

In an analysis conducted by prof Shang, Inner Mongolia Agricultural University, the fertilisers contained in the lake mud found feasible to be ‘extracted’ and compared quantitatively and economically with current typical market prices for the same constituents as used by farmers. In such a case, fertilizer can be sold at 500 RMB/t, and with an extraction of 50 000t/a, and income of 25 million RMB can be aniticipated.

However, due to the low concentration of relevant chemical constituents in the lake mud (P, N etc) and other technical difficulties may challenge this concept. Further investigations are recommended before making final estimates.

The real value of the lake mud would probably be found elsewhere: As a soil improvement agent, to recover the soil profile integrity and structure of farmlands, which has been seriously degraded over the past decades. The potential of soil improvement by lake mud application may be considerable and the message should be conveyed to stakeholders and decision makers.

A main concern will be that soil improvement is a long term affair, where economic benefits must be seen in a much broader and longer perspective than can be dealt with at this project level.

4.10 Harvesting of Submerged Vegetation in Lake Wuliangsuhai

4.10.1 Recommendations

A total of 10-20% of the total submerged vegetation in Lake Wuliangsuhai should be harvested annually, according to general agreement between project participants. The outcome of this action would be the balanced benefits of: socio-economic advantage for local people, the production of useful feedstuff and hence increase livestock production, removal of surplus plant nutrients from the lake, and the construction of a more diverse wetland habitat. The total harvested area (16-32 km^2) should be restricted to patches within 60 km^2 of pre-defined 'open water' areas with the smallest possible conflicts with other lake user interests: bird protection, fishing, tourisms etc. Additionally, the harvesting should not take place in the most important 'self-purification areas' close to the outlets of the main polluted canals (Main Drainage Canal and Drainage Canals nos. 8 and 9).

4.10.2 Purpose

The open water areas of Lake Wuliangsuhai is to a large degree covered by the submerged plant Fennelleaf Pondweed, also called Sago Pondweed (*Potamogeton pectinatus*). This successful cosmopolitan plant tolerates high salinity as well as high pH and eutrophication. The total area of submerged vegetation reached, according to interpretation of satellite images, ca. 115 km^2 in 2001.

Most of the submerged plants collapse and decompose every year and cause oxygen depletion under the ice and contribute to accumulation of organic particles in the sediments. The high rates of sedimentation in the lake, about 7-13 mm every year will convert Lake Wuliangsuhai to a continuous reed wetland without open water within 30-50 years, unless actions are taken to increase the water depth and/or reduce the sedimentation rate.

The lake's water quality is seriously deteriorated, and is in the Chinese water quality class IV and V. The lake is highly eutrophic of the macrophyte type, due to the high loading of plant nutrients (P and N) from Hetao Irrigation Area.

It is well accepted in integrated lake management that lake eutrophication should primarily be counteracted by reducing the phosphorus and nitrogen loading. This should be carried out by reducing the pollution at its sources (agriculture, industry, cities), but additional reductions can be obtained by pre-treatment of polluted water before it reaches the lake. These types of measures are considered in other MCPs.

Harvesting of submerged plants from Lake Wuliangsuhai may serve different purposes that are considered beneficial for the lake, as they all satisfy central goals for the management of the lake. It will result in a socio-economical benefit for the local people by establishing a new livelihood by the harvesting and feedstuff production activities. In addition, it will remove nutrients taken up by the plants and over time contribute to a balance between input and output of nutrients in the lake. In this way it is suggested that up to 40 000 tons of dry weight (D.W.) of high proteineous aquatic plants could be harvested each year, which could be utilized further for various economical purposes.

4.10.3 Background

Lake pollution
The main water source to the lake is the farmland backwater of Hetao Irrigation Area with an annual input of 400-600 million m^3 of water, and the second is the domestic and industrial wastewater counting as much as 180-220 million m^3. During the past years fertilizer usage in Hetao Irrigation Area has escalated from 7 000 tons in 1978 to 438 000 tons in 1997 and further to 520 000 in 2002. With a utilization rate of only 30-35% of the applied fertilizers, the runoff to the drainage canals is huge and inevitably keeps the lake in a highly eutrophic state, with typical dominance of submerged plants and reed.

Submerged plants
Fennelleaf Pondweed (*P. pectinatus*) is the dominant submerged plant species and its distribution in 'open water' areas has increased from 40% in 1990 to 95% in 2003.

From satellite image analysis 167 km^2 of the lake's surface is identified as 'open water'. In this context the 'open water' is defined as lake areas without reed. 'Open water' area includes some 25 km^2 of mud flats, whereas 115 km^2 (ca. 70%) is covered by submerged plants. This leaves some 25 km^2 of plant-less bottoms, mainly in deeper areas and areas in the far north of the lake. Reed (mainly *Phragmites* and *Typha*) covers a total of 178 km^2 (including 32 km^2 of reed on reclaimed farmland).

At an average wet weight (W.W.) of submerged vegetation of 12.85 kg/m^2 (max 22.5 kg/m^2), the total annual production of a biomass is about 1 474 000 tons W.W./yr, equivalent to about 295 000 tons D.W./yr.

Different parts of *P. pectinatus* is excellent food for many bird species (swans, geese, ducks, coots etc.) and the abundance of this plant is a major reason why many bird species are attracted to the lake. The plant is also a substrate and food for both fish and invertebrates, which in turn serve as food for birds and larger fish.

Dense surface mats of *P. pectinatus* are favourable substrate for stern nests in Lake Wuliangsuhai and it also creates a substrate on which different birds, e.g. herons, can forage.

On the negative side, this plant is substrate for dense growth of attached (epiphytic) filamentous algae. In the middle of summer, these together constitute a solid surface mat in some lake areas.

Two stable states hypothesis
The hypothesis of 'two stable states' is internationally well established for shallow lakes with moderate N and P contents. In many shallow, nutrient-rich lakes, it is observed that the ecosystem will often stabilize in either (a) a stage with clear water and dense submerged vegetation or (b) a stage with no submerged vegetation, but with massive phytoplankton blooms. Although the latter situation is favourable for boat transport etc., from an ecological

point of view the first state is highly preferred. For Lake Wuliangsuhai, the ideal situation is to retain sufficient submerged vegetation to avoid phytoplankton blooms, regardless of nutrient status. This applies to all the main project goals: to keep the lake as a lake, to achieve a good water quality and a high biodiversity, and at the same time provide income and feedstuff for the local people.

It is doubtful that a lake such as Lake Wuliangsuhai that received a long-time, heavy load of nutrients, will ever reach a phosphorus concentration low enough to avoid phytoplankton blooms in a situation with little or no submerged vegetation. Therefore, management measures like harvesting of submerged plants, in combination with nutrient reduction, dilution flooding etc. should be carried out to retard and counteract the inevitable development towards a continuous reed mars and, in the end dry land.

Proposal for harvesting submerged vegetation
As a compromise between the disadvantages of environmental impacts and the benefits of future utilisation of the lake's resources, a gradual increase of harvesting from 10% of the total submerged plant biomass to a maximum of 20 % of the plant biomass is suggested over a period of 4 years. It is strongly recommended to distribute the harvesting area to a mosaic of smaller areas, rather than to establish a few large ones. Monitoring possible changes in water quality in harvested and unharvested areas, especially turbidity, chlorophyll and growth of submerged vegetation, is suggested to uncover any unwanted changes.

In this action, it is suggested to harvest up to 40 000 tons D.W./yr (16-32 km^2) to keep the lake stability undisturbed. The harvesting areas of current interest are mainly located in Xiaowazi, Erdian, Xiaomingsha, and Koukounaobao. Today the main stores of plant nutrients in the lake are in the upper sediment layers, reed, submerged vegetation and water; listed according to decreasing importance. The by far highest amounts of nutrients are found in the active, upper parts of the sediments. The nutrient content in this store cannot be exhausted by plant harvesting, even after hundreds of years – even though a balance between nutrient inputs to the lake and output via the outlet might be reached. The sediment nutrient level is even then sufficient to support a high production of submerged plants and reed.

Submerged plants is one of the main primary producers and transferors of nutrients and energy in the lake. Beside submerged plants there are 3 other important plant types in shallow lakes: reed, epiphytic/attached algae (on the lake bottom or on floating plants) and phytoplankton. All plant types are stimulated by the enhanced loading of P and N. The balance between these plant groups is steered by a number of physical, chemical and biological complex interactions (the 'two stable states hypothesis' is one of the widely accepted models for the understanding of the most important mechanisms). One decisive factor is the surface area of each open water basin with no submerged vegetation.

During their growth period, submerged plants absorb nutrients (N and P) from water and lake sediment, thus functioning both as a nutrient pump (from sediment and water) and a temporary nutrient store (in their biomass). Because of the high density of submerged vegetation in the lake in summer, their biomass contains a high amount of nutrients, and hence only a small fraction of plant nutrients are available to phytoplankton in the lake. Subsequently, it is possible to remove N and P from the lake by mechanical harvesting. This loss process takes place in addition to the two other main loss processes: nutrient sedimentation in the lake and flow with water out of the lake.

Studies have shown that these submerged plants on average contain 1.65% of N and 0.17% of P (dry weight: D.W.). According to experiments reported by Song Fu and Chen Yanqing, total nitrogen and total phosphor removal rate of submerged plant from the water phase are 80.31%

and 89.82% respectively. Thus, 40 000 tons (D.W.)/yr will remove 530 tons N and 61 tons P from the water body, which will positively contribute to the nutrient balance. The estimated outputs of P and N from the lake in 2001 were 586 tons N/yr and 38 tons P/yr, respectively. Thus, harvesting of this magnitude will contribute significantly to the nutrient balance of the lake.

Use as feed
According to the calculations, the average total production per ha water area is 10,8 tons, which is 18.61 times the typical production of grassland and 49.06 times the production of desert grassland.

According to test results and breeding experiments, the aquatic plants of Lake Wuliangsuhai are rich in nutrient components, with a crude protein content of 15.1%~16.6% and a reasonable amount of essential amino acids. Thus, it is possible to produce high quality plant powder feedstuff or assorted feedstuff. The nutrient value of aquatic plant feedstuff is higher than green hay and dahurian wildrye, sunflower head powder, sugar beet leaves etc., and the nutrient index corresponds to the feeding standard of poultry and domestic animals. Thus it can be used as feed for cattle, sheep, pigs, ducks and geese with calcium, iodine, selenium, methionine, and cystine as important components of the feedstuff.

A feeding experiment with 40 sheep, monitoring the daily digestion rate, weight gain, slaughtering weight etc. has been carried out. The addition of 20 % aquatic plant feed in the sheep's normal daily diet seems to be the optimum feeding procedure.

The utilization of aquatic plant as feedstuff mainly depends on its taste properties. The attractive properties of the aquatic plant feed from the lake are unfortunately affected by too high content of sodium sulphate ($NaSO_4$) enriched from the dissolved minerals in the lake water. However, after crystallisation and drying, sodium sulphate is not poisonous, but still has a salt and astringent taste, which the cattle and sheep do not prefer. The sodium sulphate, which when dry looks like ash, should be removed by squeezing, compacting and sifting.

4.10.4 Technological requirement and Implementation process

Technological requirement
The main project technique approaches include the following steps:

- harvesting
- picking up
- transporting
- loading
- water transportation
- unloading
- airing and drying
- clearing and selecting
- bundling or smashing.

The moisture content of aquatic plants when harvested is about 82%. After manual, natural air drying, the moisture content is reduced to 13 - 17%. Manual natural air drying is vulnerable to the weather conditions, and the nutrient content can also be partially lost. Thus, it is suggested to use a continuous drier to carry out real-time drying.

Development and utilization of aquatic plant resources should be combined with a monitoring project of the eutrophication situation in the lake.

Aquatic plant feedstuff production management adopts contract management system; each dock shall set up a management station with 2 managers. An assorted grain feedstuff factory hires one factory director, 2 factory vice-directors to take charge of technique, equipment and production management.

The production flow of aquatic plant feedstuff from Lake Wuliangsuhai is shown in the figure below.

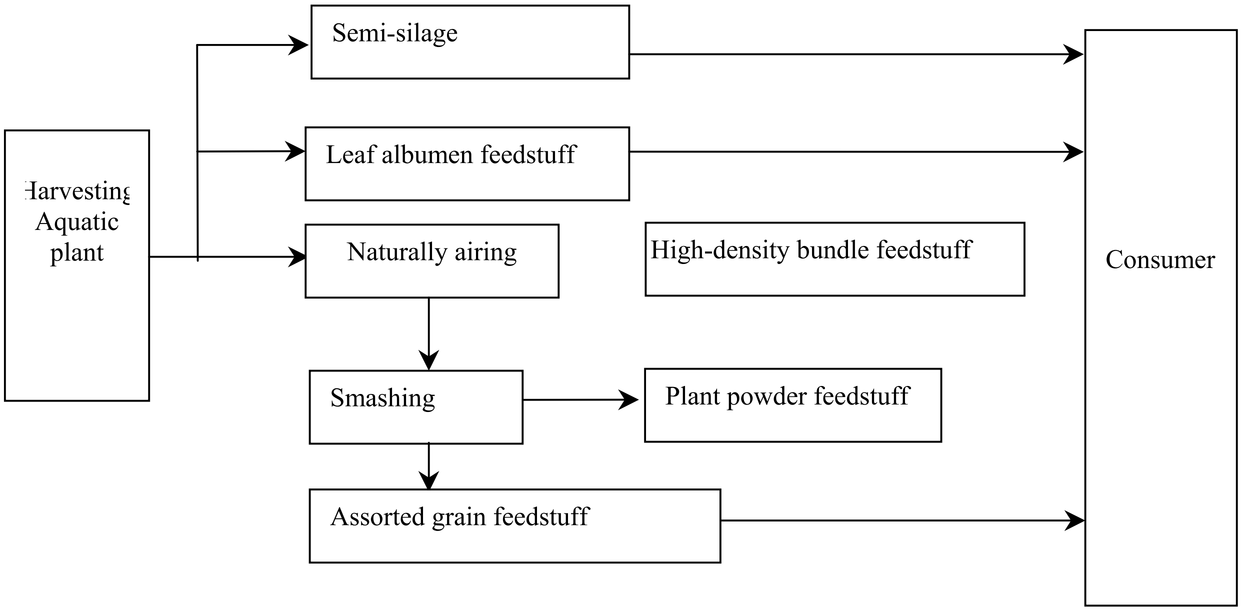


Figure 34. Production flow chart of aquatic plant feedstuff

4.10.5 Implementation process

It is suggested by experts at the Agricultural University of Hohehot that the proposed submerged plant harvesting will require 56 sets of 9GSCC—1.4H type hydrophytes harvester boats according to work area and distance (developed by the Inner Mongolia Agricultural University, and appraised by Inner Mongolia Farming Machine Appraisal Department in 1990). These machines should be supplemented with QY-15 type traction transportation boats. It is optimum to use one hydrophytes harvester together with one traction boat and five load transportation boats for continuous work. Each dock will have 5-7 sets of harvester boats. The following calculations are set up under the assumption that the harvesters will be in action continuously for 5 years between May 5 and October 25.

Management of the hydrophytes harvesting will require a contract management system, 2 managers will be hired. Each harvesting boat fleet has a crew of 4 men and a few men is needed to unload aquatic plants in the harbour.

Product sale direction

According to market demand, the product will mainly be supplied to Changhe feedstuff factory, Wulatezhongqi, Wulatehouqi, Wulateqianqi, Damaoqi etc. Some of the products will be exported to increase the income and to subsidise the emergency feedstuff.
The following different feed types will be produced:

1) High density hydrophytes bundling to secure disaster feed for the sheep and cattle
2) Common hydrophytes powder for pig, chicken, duck, and goose feedstuff
3) Grain feedstuff for breeding cattle and sheep
4) Assorted feedstuff for breeding cattle and sheep
5) Exported High density hydrophytes bundling for cattle feedstuff (to Japan).

At present, grassland degradation is serious in Wulatezhongqi and Wulatehouqi of Bameng. In addition, larger areas suffer from continuous drought. The proposed 40 000 tons hydrophytes powder feedstuff demand exceeds today's supply. In addition, many duckeries and cattle farms in the Beijing area have a high demand for feedstuff.

A local sale price of high-density hydrophytes bundling and common hydrophytes powder of 400RMB/t seems to be feasible compared with other products. The Green hay price of Humeng grassland to Beijing is 650RMB/t, Ningtiao plant powder price of Helin County to Ximeng is 750RMB/t, and the alfalfa price of Shanxi to Shanghai is 1300RMB/t. The high quality hydrophytes powder feedstuff nutrient value of Lake Wuliangsuhai is higher than grassland green hay and Ningtiao and corresponds to alfalfa, so the sale price is competitive and feasible.

4.10.6 Environmental objectives

It is suggested not to harvest aquatic plants when the depth is more than 0.7 m and very shallow areas shall also be left out. Access routes to harvest other parts of the lake surfaces must be established. The entire harvest shall be completed before the hydrophytes decay in late autumn. We shall also harvest only once per year in one and same area. It must, however, be questioned whether the activity of 56 harvesters covering more than half of the open water area of the lake, will seriously compromise the need for undisturbed conditions during spring migration and breeding in the first part of summer. Areas of special importance for birds should be identified and left with no harvesting activity during this period of the year.

Impact on environment

The project's impact on the environment is summarised as follows:

- The proposed harvesting of submerged plants of Lake Wuliangsuhai should take place in a mosaic of totally 16-32 km^2, distributed over 3-5 harvesting zones in the lake. The harvesting zones shall be limited to a total area of 60 km^2. The wetland environment will be improved by some more open water areas, which also satisfies fishing activities and tourism.
- Harvesting 40 000 tons aquatic plant can transfer 530 tons N and 61 tons P out of the lake, which will contribute to a better nutrient balance of the lake.
- The annual removal of plant biomass will to some extent reduce the problems of anoxic conditions in winter and therefore support a higher fish production.

4.10.7 Economic content of submerged plant harvesting project

Table 26. Investment costs

	Unit cost	units	Total cost	Year 1	Year 2	Year 3
Units:	RMB/unit		RMB	(RMB)	(RMB)	(RMB)
Item:						
subm vege boat-Hv	200 000	45	9 000 000	2 250 000	2 250 000	4 500 000
special docks of boats-Hv	1 650 000	6	9 900 000	2 475 000	2 475 000	4 950 000
transportation vehicles-Hv	150 000	4	600 000	600 000	0	0
yachts-Hv	20 000	2	40 000	40 000	0	0
office-Hv	600 000	6	3 600 000	3 600 000	0	0
maintenance station-Hv	300 000	6	1 800 000	1 800 000		
Other (Land, training etc.)	1 140 000	1	1 140 000	1 140 000		
Preparative expense	1 700 000	1	1 700 000	1 700 000		
sub veg airing field-Ut	1 400 000	6	8 400 000	8 400 000	0	0
feed factory-Ut	12 000 000	1	12 000 000	6 000 000	6 000 000	0
bundling equipment -Ut	25 000	12	300 000	300 000	0	0
Storehouse-Ut	180 000	6	1 080 000	1 080 000	0	0
weighbridge house-Ut	20 000	8	160 000	160 000	0	0
transportation vehicles-Ut	150 000	8	1 200 000	1 200 000	0	0
yachts-Ut	20 000	3	60 000	60 000		
flowing capital-Ut	4 000 000		4 000 000	4 000 000		
Total investment cost			54 980 000	34 805 000	10 725 000	9 450 000

Table 27. Annual Operational and Maintanance costs

	Unit	Unit cots RMB/unit	Number of units Units/year	Total cost RMB/year
Labour costs				
Manual labour- harvesting	man-months	1 200	7 men per boat group, 45 harvester boat groups	378 000
Administration-Harvesting	man-months	1 500	16 men, 4 months	96 000
Manual labour- utilisation	man-months	1 200	120 men, 5 months	720 000
Administration- utilisation	man-months	1 500	9 men, 5 months	67 500
Assistant man- utilisation	man-months	1 200	8 men, 5 months	48 000
Input costs				
Fuel- harvest	litres	4	389 000	1 478 200
other consumables- harvest	RMB/day per group	50	120 days, 45 boat groups	270 000
Depreciation costs- harvest	RMB/day	167	120 days, 45 boat groups	901 800
Fuel	litres	4	16 binders, 9 liters/hour	172 800
other consumables	RMB			19 440
Electricity charge	RMB			1 520 000
Maintenance and repair costs				
Labour- harvest	man-months	1 500	8 men, 4 months	48 000
Labour	man-months	1 500	9 men, 5 months	67 500
fitting				250 000
Total annual operating costs				6 037 240

It is anticipated that 40 000t of product can be sold at 400 RMB/t generating an income of 16 million RMB/y.

4.11 Reed bed control

4.11.1 Purpose

The purpose of the MCP on Reed Bed Control is to reduce the velocity by which the edge of reed expands into 'open water' areas in Lake Wuliangsuhai;

4.11.2 Background

In 1975 the reed area of Lake Wuliangsuhai was about 17 km^2 while reed production was 2.3×10^7 kg DW. In 2001 the reed area of Lake Wuliangsuhai was 116 km^2 and reed production was 11.5×10^7 kg DW. In other words, the lake has experienced a five-fold increase in reed production and a seven-fold increase in reed area in 26 years. Further reed spread and production increases may lead to the lake becoming reed marshland affecting the ecological functions of Lake Wuliangsuhai, as well as the drainage functions of Hetao Irrigation Area to the Yellow River. Because reed for paper making is an important economic activity, maintaining existing reed areas while preventing reed spreading through gardening measures is proposed. This should guarantee both ecological functions, as well as satisfy the sustainable development and utilization of reed resources. (The above chapter refers to Professor Shang Shiyou'spublications, Inner Mongolia Agircultural University)

4.11.3 Environmental effects

The environmental objective of the measures is to fulfil the main aim of the lake restoration project: to keep the lake as a lake. This includes keeping the lake ecosystem in a diverse wetland stage by reducing further expansion of reed into 'open water' areas. This goal could be achieved by different measured proposed in other chapters, alone or in combination, such as increasing the lake water level. Today, the reed covers about the same area as 'open water'.

4.11.4 Technological requirements

A proposed measure to reduce the expansion rate of reed was to cut the reed plants along the edges of the reed beds, preferably under the water surface, during summer. Harvesting the green summer reed was suggested as an efficient method to reduce the vitality of the reed and slow down its ability to expand horizontally into 'open water' areas. Cutting the stems under the water surface will probably give additional negative effect on the *Phragmites* and *Typha* productivity.

It was therefore, planned to carry out harvesting experiments along the edge of the reed beds in a 5 – 20 m wide zone to test whether this hypothesis holds true. However, no results from such experiments are presented until now.

This measure, if realised as a large-scale method, depends on the development of suitable technology; e.g. a variant of the harvesters already in use on Lake Wuliangsuhai to harvest submerged vegetation. In contrast to the reed harvesters operated on the ice during winter, these summer harvesters depend on a paddlewheel propagation technology to navigate along the edge of the reed.

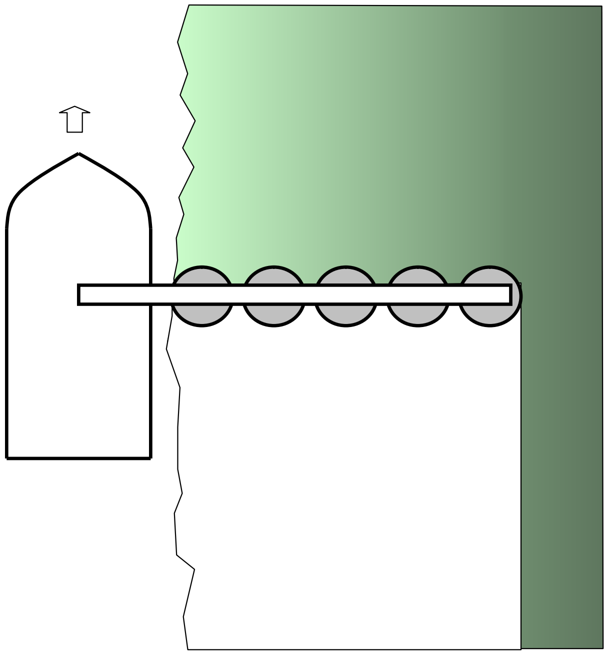


Figure 35. Rotary reed mower for edge-trimming of reeds. The length of the arm (boom) will depend on the size of the craft. The individual rotors are powered by hydraulic motors or via mechanical power-takeoff from the inboard engine. The concept is nearly identical to a modern agricultural grass cutting machine, from which this contraption can be modified.

Studies of satellite images have shown that the present expansion rate of reed in Lake Wuliangsuhai (since ca. 1990) has been rather slow. A similar situation is forecasted for the coming 5-10 years unless the water level is lowered below those observed in recent years (see sub-project no. 3. Monitoring Report). On a longer time scale the lake will gradually become more shallow caused by the sedimentation of particles, both by those brought in from the Hetao Irrigation Area and by the plant material produced in the lake. Hence, measures to retard the expansion of reed should be carefully considered.

Before demonstration tests have been carried out to study the effects of summer harvesting of reed along the edges, no conclusions can be drawn about the feasibility of this measure, as well as accurate investments and running costs.

The table below is an illustration of possible costs under the assumptions that a 10 m wide part of the reed edge is harvested over 200 km during 2 summer months (total reed area is 178 km^2, while approximated perimeter is 460 km. In this exercise, we assume harvesting 200 km of reed edge).

4.11.5 Economic content

Table 28. Specifications used for the estimate of costs.

Length of reed edges to be cropped	200 km
Width of cropping	10 m
Area to be cropped	2 000 000 m2
Speed of craft	2 km/h
Cropping capacity per 8 hour shift	160 000 m2
Cropping capacity per 2 months	6 400 000 m2

Table 29. Investment and Operational costs

Cost	Estimate
Investment costs	1 200 000 RMB
Operational and Maintanace costs	120 000 RMB/season

***No**te: an alternative concept suggests an investment of 7.4 mill RMB investment with 5.25 mill RMB/year operational and manintanatce costs, resulting of about 4 mill RMB/y income from the increased amount of reed harvesting (ref. Prof Shang Shioy)*

4.12 Introduce water from the Yellow River directly to Lake Wuliangsuhai and raise the water level

4.12.1 Purpose

The general objective of this measure is to provide more water to Lake Wuliangsuhai, and thereby increase the lake surface level. The measure includes widening of canals to support the transport of water directly from the Yellow River. The canals Changji, Tabu, Yihe and Tongji are identified as the means for water transport. The purpose for the project on reconstruction of canals is to enlarge and repair the original ditches, which are the ends of the main irrigating ditches.

The purpose of introducing water from the Yellow River is to meet the water demand in Lake Wuliangsuhai. Increased water volume and circulation is believed to alleviate the eutrophication, improve the water quality of the Lake, and restore the ecological functions including a high biodiversity. Larger effective volume (and area) will also be beneficial for the aquatic life, increase populations of fish and feed organisms, increase survival of aquatic organisms in the winter.

4.12.2 Background

Lake Wuliangsuhai is the biggest fresh water lake in Yellow River drainage area. A previous estimate of the whole area of the lake was 293 km^2. Within this project the area of open water was calculated as 165.1 km^2 and the area covered with naturally grown reed 148.7 km^2, in total 313.8 km^2. Another 32.2 km^2 is covered with reed grown on abandonned farmland. The volume of the lake was calculated to be 173.0 million m^3 and the average depth 1.05 m. It is thus an extremely rare large-scale, multi-functional lake with very high ecological qualities in this semi-desert region. It has a very important status in conservation of major wetland ecosystems and the nearby semi-desert communities. Lake Wuliangsuhai acts as a reservoir receiving drainage water and treated municipal wastewater from the Hetao Irrigation Area and the lake has important functions for social and economic development in the local communities.

In recent years, because the water resource of the Yellow River is decreasing and the Hetao irrigated agricultural area implements water-saving irrigation, the amount of water that enters Lake Wuliangsuhai is greatly reduced. Furthermore, mountain torrents have for many years deposited sand and gravel in the lake and thereby filling the lakebed and reducing the effective lake volume. At present, the average surface level at Lake Wuliangsuhai is 1018.5 m above sea level. Less lake water reduces the space for aquatic animals, especially fish and plants and furthermore decreases the survival for many aquatic organisms during the winter. Increasing the effective depth of the lake and increasing the water throughput at the same time would be considered beneficial for the ecological status of the Lake Wuliangsuhai.

In the 1950s, the salt concentration was below 0.8 g/L as compared to 1.8 g/L nowadays and pH of the water has increased from 7.9 in the 1950s to 9.0 at present. With the continuous increase of nitrogen and phosphorus nutrient concentrations, the water of the lake is eutrophicated. The

organic lake sediments keep growing thicker and the sedimentation rate reaches 6-9 mm per year. It is a surprising speed for the shallow-style lake such as Lake Wuliangsuhai. If the situation continues, all the functions of lake and the water conservancy will be lost; the direct economic loss may reach several billions, besides the unimaginable and irreparable environmental and ecological damages.
Before the 1960s irrigation water in the canals and flooded water were the sources of water in Lake Wuliangsuhai. The water quality was good. However from the 1980s to the 1990s, as the water quantity in the Yellow River became less available, the awareness of water saving in irrigation area was reinforced and water use in agriculture restricted. The source of water in the lake became farm run-off and excess irrigation water. At the same time, sewage from cities and towns and industrial waste water entered the lake through main drainge canals. Therefore, the lake water became heavily polluted.

Today the designed flow rate through the Changji fourth water gate to Lake Wuliangsuhai is 5 m^3/s, corresponding to 0.432 million m^3 daily and 23.8 million m^3 annually. The designed flow rate from the branches of the main ditches of the south ends of Changji to Lake Wuliangsuhai is 3.5 m^3/s, resulting in 0.302 million m^3 per day and 16.6 million m^3 per year. The designed flow rate through the grass water gate of the main ditches of Tabu to Lake Wuliangsuhai is 6.0 m^3/s. The daily flow of 0.518 million m^3 and annually 28.5 million m^3 will pass. The designed flow rate from branches of the main ditches of the north ends of Tabu is 3.5 m^3/s, corresponding to 0.302 million m^3 per day and 16.6 million m^3 per year.

The conservation status of Lake Wuliangsuhai today in not clear, apparently there is no specific protection today. Sign-boards informing about restricted access to some areas on the eastern shore have been put up at Twelve Farms.

4.12.3 Operational environmental target for measure

The desirable water volume in Wuliangsuhai should be 450 million m^3, taking into consideration of the development of aqua-culture, fishing, reed production, tourism, transportation and the conservation of wetland bird species as well as the depth and extent of the lake and the impact on surrounding environment.

The goal of the project is to increase the lake water level to 1019.0-1019.3 m above sea level, which in turn increases the average depth with 0.5-0.8 m. Annually 253 million m^3 should be introduced from the Yellow River through main canals in order to maintain the depth of the lake. This measure can ensure the current lake extent and, more importantly, dilute the water body of the lake, thus improving the water quality. Raising the water level and thereby increasing the average depth of the lake will have positive impacts on the biodiversity in the lake ecosystems, such as possibly stopping the recent decline and even increasing in diversity.

After the reconstruction of the canals, water can be provided to the lake before the irrigation period in the summer, or in several intervals between the irrigation periods. The provided water accounts for 80 % of the flow into the lake and the obvious effect will be seen in the same year. The volume of the lake water exchange should be completely every two years on average, making the lake water clear and transparent.

4.12.4 Technical content of measure

The increase of water level in Lake Wuliangsuhai is accomplished by passing water from the Yellow River into the lake. That can be achieved by widening the main ditch of Yihe, cleaning out the mud in ditch for 20 km, reconstructing 3 reserve water gates, 31 straight-mouth water gates, and reconstructing 1 bridge for work and 3 bridges as roads. Also widening the main ditch of Tongji, cleaning out the mud in the main ditch for 27.39 km, reconstructing 4 reserve water gates, 5 mouth-water gates for ditch branches, 12 tundish jaws, 16 jaws for farmland and crude jaws, and reconstructing 9 bridges for work can contribute to the increase in water level of the Lake.

In order to raise the water conveying abilities of four main ditches, the activities include enlarging the ditches at the end of the main ditches of Changji-Tabu for 31.55 km and covering the concrete and bricks on the inside of the ditches for 31.55 km. After enlarging and repairing, the following activities are to reconstruct 9 reserve water gates, 4 water end water gates, 4 sand-sinking pools, 17 bridges for work (including road bridges), 1 canal for ferry, and 59 mouth water gates at the straight-mouth ditches, and 12 rate measuring bridges.

The water-providing ability reaches 253 million m^3 every year after enlargement and transformation in the lower sections of the ditches of Yihe, Tongji, Changji and Tabu. By constructing, dredging, and enlarging the latter ditches of the fourth water gate of Yihe, the water-providing ability rises from 2-3 m^3/s to 9-10 m^3/s to Lake Wuliangsuhai, corresponding to 36.4 million m^3 per year. By transforming from the third water gates of the main ditches of Tongji to their ends (from the 40.460 km to the 67.850 km sections) the water-providing ability reaches 131 million m^3 per year.

After enlarging the water-providing ditches at the ends of Changji-Tabu main ditches, 18 effective flowing days can provide water to Lake Wuliangsuhai in the interval of irrigation, with the water volume of 1.56 million m^3 each day, 85.5 million m^3 each year.

The maximum lake level during the introduction phase will be 1019.2 m above the sea level, which will occur in March/April during a 14 days-period. Later in the annual cycl, (July/August) the level will be approximately 20 cm lower, not considering natural variations due to rain. In the winter, during the reed harvesting period, the level will be at 1019.0 m.

The time plan has not yet been scheduled. The project has not yet been included in the local government's planning. One year of planning is needed before the construction can start. The raise in water level can then be accomplished in one year.

The measures of the main-ditch project of Yihe – Tongji

Yihe scheme

The Yihe scheme consists of broadening the Yihe main-ditch from the 60.873 km to the 80.870 km sections (totally 20 km). Furthermore, taking the fourth water gate as a standard, activities include increasing the water-passing ability at every reserve water gate to reach 11.0 m^3/s, broadening and stabilizing the main ditches down the fourth water gate to the end water gate, and rebuilding the straight-mouth ditches and the bridges of production in this section. After this reconstruction, 9.35 m^3/s daily can be provided to Lake Wuliangsuhai on effective flowing days (Table 49). Supposing that the effective time period is 45 days, a total volume of 36.4 million m^3 water will be introduced into the lake. In the scheme, 504,000 m^3 of earth will be removed during broadening the main ditches. It is also necessary to rebuild 3 water gates, 1 bridge of production, 1 road bridge, 3 branch jaws, 3 tundish jaws, 125 jaws for farmland, and 10 crude jaws.

Table 30. The present rate of flow and the estimated rate of flow after enlargement of each water gate.

Water gate	Present flow-rate (m^3/s)	Flow-rate after measure (m^3/s)
Fourth water gate	5.17	11
Fifth water gate	3.72	10.7
Sixth water gate	3.50	10.3
End water gate	2.80	9.35

Table 31.Quantities of materials needed for the reconstruction of the Yihe canal.

Earth (m^3)	Concrete (m^3)	Bond-stone (m^3)	Padding layer (m^3)	Steel bar (tons)	Water gate and controller (set)	High-voltage line (km)
504000	2430	1600	671	124	37	9

Tongji scheme

Bb broadening the main ditch and rebuilding the reserve water gate (mouth water gate to bridge), the flow rate can reach 22 m^3/s through the third water gate after the reconstruction has been carried out, and the input flow rate to the lake is 18 m^3/s. From the third water gate to the end (from 40.460 km to 67.850 km sections, in total 27.49 km), the canal will be broadened and the buildingswill be reconstructed and stabilized. In order to reduce the muddy silt in Lake Wuliangsuhai, a sand-sinking pool should be built under the end (below 65 km), and 47 various construction buildings should be made.

Table 32.The statistics chart of newly built buildings at the Tongji canal

Reserve water gate	Water gate of branch of canal	Jaws	Bridge of production	Construction buildings
4	5	28	10	47

The quantities of materials for the Tongji canal project are given in the table below.

Table 33.Quantities of materials used in Tongji canal.

Earth (m^3)		Concrete (m^3)	Steel bar (tons)	Bondstone (m^3)	Padding layer (m^3)	Water gate and controller (set)	High-voltage line (km)
dig	fill						
471000	7220	4330	215	2770	1110	45	10

The project measures of Changji - Tabu canal

This water-providing project is separated into four parts: the front end of Changji canal, the south end of the canal branch, the frontend of Tabu canal, and the north end of the canal branch.

The front end of Changji canal

The canal can be transformed for 9.65 km from the fourth water gate (at the 44.000 km section) to the jaws at the lake (at the 53.650 km section) by covering the inside with concrete and bricks in order to reduce the water loss. Other activities include rebuilding 2 reserve water gates; building 1 water-end gate, 1 sand-sinking pool in order to avoid transport of silt into the lake; and rebuilding 3 production bridges, 13 water-entering straight water gates, and 3 bridges for measuring of the water flow rates.

The south end of Changji canal branch

The transformation of the canal for 7.25 km from the fourth water gate (at the 44.000 km section) to the jaws at the lake can be done by covering the inside with concrete and brick. Other activities are to rebuild 1 water-entering mouth gate and 1 reserve water gate; to build 1 water-end gate, 1 sand-sinking pool; and to rebuild 4 production bridges, 14 straight-mouth and ditch-mouth water gates, and 3 bridges for measuring of the water flow rates.

The front end of Tabu canal
Transforming the canal for 11.73 km from the point of at the 32.776 km section to the point at the 44.506 km section can be achieved by covering the inside with concrete and bricks. The measures taken consist of rebuilding 3 reserve water gates; building 1 water-end gate and 1 sand-sinking pool; and rebuilding 8 production bridges,which include one 15 km-long road bridge for bus traffic, 24 straight-mouth and ditch-mouth water gates, and 4 bridges for measuring of the water flow rates.

The north end of Tabu canal branch
Transform the canal for 1.92 km from the point at the 13.192 km section to the jaws at the lake at the 16.112 km section is carried out by covering the inside with concrete and bricks. The activities are to rebuild 2 reserve water gates; to build 1 water-end gate, 1 sand-sinking poo And to, rebuild 2 production bridges, 8 straight-mouth and canal-mouth water gates, and 2 bridges for measuring of the water flow rates.

Maintenance work
After completing the above measures, canals and building constructions need maintenance work and repairments.

Reconstructing and strengthening the outlet dam
In the past two years an overall reconstruction of the lake dam has been carried out with the aim to increase its height. The majority of work has presently been completed. The designed height of the dam is 1020.2 m. The level of the dam is 1.7 m higher than the water level at the lake stone, 1018.5 m. When the water level is increased to 1019.3 m, the dam is still 0.9 m higher. Therefore the lake dam can fulfill the requirements for an increase in the water level of the lake.

Construction of a ditch along the western shore of the lake
After the water level is increased, water will seep onto the farmlands on the western bank of the lake. Presently the farmland surface at the western bank is about 1018.0 m height, and the average depth of the groundwater is 1.9 m or at about 1016.0 m. The designed water level at the lake surface is 1019.3 m, which is 1.3 m above the farmland level and 3.2 m above the groundwater level. In order to reduce seepage, a cut-off ditch with the depth of 1.5 m is dug along the outside of the dam at the western bank of Lake Wuliangsuhai. The length of this ditch is 40 000 m, the dug-out earth volume is about 360 000 m^3, and the total investment is 1.8 million RMB.

4.12.5 Environmental effect and feasibility of measure

The transformation of Lake Wuliangsuhai is beneficial not only to the sustainable tourist development of Lake Wuliangsuhai, but also to the normal running of water conservancy project in Hetao Irrigated Area. It is very meaningful for ecological and environmental protection in Inner Mongolia.

Better conditions for fish to back-swim, spawn, propagate, and survive the winter can be created. Assuming that the quality of the Yellow River water is better than that of the lake regarding nutrients, suspended solids, and pollutants, the water quality can reach the fish-feeding standard by diluting the lake water. This may be achieved during the spring, but not at all seasons of the year.
A higher and especially controlled water level in the lake will have a positive impact on breeding birds that build their nests onto or close to the surface level of the lake. Variation in the water level will on the other hand hamper breeding. Increasing the water level in the nesting period will drown many nests. Decreasing the water level may provide access to nests for predators. Therefore a constant water level, especially during the breeding period (April, May, June, and the first half of July), is essential.

4.12.6 Economic content of each measure

Itemised capital investment costs of measure

The construction work at the Yihe canal will last three years starting from 2005. The investments will be 1.0, 2.5, and 1.74 million RMB for the years 2005, 2006, and 2007, respectively, and in total 5.24 million RMB. The project at the Tongji canal will take one year from the beginning to the end of 2005. The investment amounts to 6.55 million RMB. The construction project at Changji and Tabu canals will last two years, starting from 2005. In this year 74 constructions will be rebuilt and the investment amounts to 7.08 million RMB. Other constructions will be finished in 2006 and these will cost 17.1 million RMB.

The total cost of the canal construction along the western shore of the lake to prevent seepage of farmland has been calculated to 1.8 million RMB, and the running costs to 180,000 RMB/year. The cost for digging the ditch is 5.0 RMB/m^3 (1.8 million RMB for 360000 m^3, refers to labor costs only). This measure is performed within the first year. The reconstruction of the dam at the outlet is completed and will not require more investments.

Table 34. Basis for investment estimates

Canal	Designing volume (m^3/s)	Annual water supply (million m^3)	2005~2006 (million RMB)	2006~2007 (million RMB)	2007~2008(million RMB)
Sum	47	253	15.1	15.0	5.87
Yihe	11.0	36.4	1.00	2.50	1.74
Tongji	18.0	131	6.55		
Changji Sizha	5.0	23.8	2.00	4.47	
Changji, south end	3.5	16.6	2.00	3.05	
Tabu Caozha	6.0	28.5	3.00	3.00	4.12
Tabu, north end	3.5	16.6	0.56	2.00	

Table 35.Basis for operational and maintatamnce costs

Category	Price	units per year
Labor	20.83 RMB/working day	
Material		
Machinery		
Electricity	0.973 RMB/kWh	
Wind	0.200 RMB/m^3	
Water	0.582 RMB/m^3	

The price of restored water in the ditch is 1.5 Fen/m^3 and the price of provided water from the main ditches for farmland is 4.1 Fen/m^3. It may be accurate, but should be verified further also considering whether beneficiary can accept the price and how to distribute the water cost. Applying the two water costs to the volume of water, 253 million m^3 would give the costs of 3.80 and 10 million RMB, respectively. The annual maintenance of the ditch on the western shore is estimated at 180 000 RMB.

Table 36. Investment costs

	Unit cots	Units	Total cost	Year 1	Year 2	Year 3
Units:	RMB/unit	No	RMB	RMB	RMB	RMB
Yihe	5 241 300	1	5 241 300	1 000 000	2 500 000	1 741 300
Tongji	6 548 700	1	6 548 700	6 548 700	0	0
Changji Sizha	6 466 900	1	6 466 900	2 000 000	4 466 900	0
Changji South End	5 050 700	1	5 050 700	2 000 000	3 050 700	0
Tabu Caozha	10 124 400	1	10 124 400	3 000 000	3 000 000	4 124 400
Tabu North End	2 564 100	1	2 564 100	564 100	2 000 000	0
Western shore strengthening	1 800 000	|	5 000 000	2 200 000	2 800 000	
Total investment cost			40 996 100	17 312 800	17 817 600	5 865 700

Table 37.Operational and Maintenance (O&M) costs, mill RMB

Description	O&M costs/year
Water costs for storage, 0.015 RMB/m3 for 253 mill m3	3.8
Water costs for agriculture, 0.040 RMB/m3 for 253 mill m3	10.0
Maintenance costs of the ditches	0.18
Total	13.18

** The cost of the water is based on preliminary estimates, and are conservative estimates.*

4.12.7 Socioeconomic impact

After the project has been finished, 253 million m^3 of water will be supplied to Lake Wuliangsuhai annually from the Yellow River, which can dilute the polluted water and improve the water quality in the lake. It also alleviates the eutrophication and reduces the nutrients input. Tourism and fishery will be benefited. After restoring the ecological environment, the lake will become a valuable tourist resort in this area. The local economy will be stimulated by the development of tourism. By actively developing tourism, increasing investments, driving relevant business, communicating with the outside, flourishing nearby regions, the value of the "Bright pearl of the north of the great wall" must come true.

The income in fishing will be higher after the restoration. The production of natural economic-style fish can increase from 700 tons nowadays to 2000 tons. An increase in water volume may also provide possibilities for other aqua-culture projects. It is predicted that the increased production value may be 20 million RMB per year. The income in reed harvest may also increase due to more area available for reed growth, but the increased production could be hampered by the higher water surface level.

Raising the water level will cause flooded in new areas, which may interfere with other land uses. However, on the western shore, embankments will prevent flooding of new areas. There will be a limited expansion eastwards because the land is regularly flooded and therefore these areas are not exploited today. Therefore no risk of conflict of interests is expected. The new areas will be essential as bird habitats (mud flats).

A conflict of interest may be identified when raising the water level. On the one hand, conditions for fish survival are improved by the increased water level in the winter, the larger volume may minimize oxygen deficiency. On the other hand when harvesting reed, the water level should be low during the winter period. Creating conditions for survival of the fish populations seems more essential in the sustainable use of the lake resources than maximizing the reed harvest yield.

4.12.8 Implementation arrangements

Proposed plan of action with stakeholder involvement

The construction of the water-providing project at Yihe canal will last three years starting from 2005, whereas the project at the Tongji canal will be completed in one year from the beginning to the end of 2005. The project at Changji and Tabu canals will last two years, starting from 2005 and finished in 2006.

The Inner Mongolia government should apply to the Yellow River Committee for adding ecologically needed water to Hetao Irrigated Area in order to supply to Lake Wuliangsuhai. Meanwhile, the irrigation management should be encouraged to save water, and the saved water can be used to supply the lake.

A professional leading organization should be established, which is responsible for the project. The action should be instructed by the Section Office of Irrigation, which belongs to the Irrigated Area Bureau, and operated by Management Office.

Anticipated risks and mitigatory measures

A possible negative effect of the introduction of more water from the Yellow River is that this water may infiltrate along the shorelines at the ends of the canals and may cause the ground water level to rise. The shores lie, however, between wasteland and bulrush fields, so the effect on agriculture and the nearby environment may not be high.

The loss of water in the canals has been estimated as 15 %. However, in MCP 3 the loss has been stated as 20 - > 58 %. Therefore, there is a risk that the calculated water volumes are overestimated. The mitigation for this is to tighten the canals or to increase the flow periods.

In general larger wetland area and greater lake volume will improve conditions for birds breeding in the lake or migrating through the lake area. However, if the increase in water level is accompanied by constructing embankments to enclose the lake within its original area, this may have a negative impact. Areas that previously were used for feeding wading birds may become too deep to be suitable. In that case a negative impact on biodiversity is created. This drawback is circumvented by letting the lake area increase, especially on the eastern shore of the lake to allow new shallow shore-waters to be formed.

The beneficial impacts on the water quality by introduction water from the river could be counteracted if the water contains suspended particles. This risk may be highest at the times of the year, when there is high water flow. Negative impacts may be expected both regarding the water transparency and the sedimentation of particles that may reduce the water depth. Control and monitoring of the suspended solids in water would be a component of mitigation.

Because of permeation an enhanced water level also has impacts on surrounding groundwater and influences soil salinity, which may affect agricultural development. After water level is increased, water will seep onto the farmlands on the western shore of the lake. Presently the farmland surface at the Western bank is about 1018.0 m, and the average depth of the groundwater is 1.9 m or at around 1016.0 m. The designed water level at the lake surface is 1019.3 m, which is 1.3 m above the farmland level and 3.2 m above the groundwater level. In order to reduce seepage, a cut-off ditch is constructed on the western bank of Lake Wuliangsuhai (see above). The problem about occupying land in the process of engineering operation needs to be solved.

4.12.9 Measures to ensure sustainability of the action

Dredging of canals may be needed at intervals to maintain the desired flows.

Financing plans/ Considerations
The financial plan for the proposed project is as follows:

1) A loan from World Bank
2) Resources and Environment protection fees of developing western regions
3) Expenses spent for continuing construction of water saving project in the irrigation area
4) Investment from national ecological projects

Other comments
The population around the lake is 160,000 and the resource (is very rich. In contrast with the large transportation need, the local traffic is too inconvenient. So, a project on transportation in the lake area should be carried out to solve the problems. Furthermore, the project must help to develop rapidly tourism and service business.

According to comprehensive arguments and analyses, the project is technically feasible; the economic, social and environmental benefits are very obvious. It is suggested that the project should be established and conducted as early as possible.

4.13 Moving the lake's inlet and constructing a pre-treatment area

4.13.1 Purpose

The main objective with this measure is to reduce the eutrophication of the lake through treatment of the water from the Main Drainage Canal using a pre-treatment wetland. The focus is to reduce phosphorus since this is the limiting source of the nutrients. In order to fulfil the objective, actions need to be addressed:

1) Make a rough design of the required pre-treatment area (artificially controlled wetland) in the northern part of Lake Wuliangsuhai.
2) Change the inlet of Lake Wuliangsuhai, from its current position at the Main Pumping Station, further north to enable the usage of the northern part of the lake as a treatment area.

4.13.2 Background

Drainage canal system and inlet to Lake Wuliangsuhai
Most municipal and industrial wastewater from Heao Area flows through the drainage canal system and reaches Lake Wuliangsuhai without satisfying treatment. The industrial wastewater contains high concentrations of organic and inorganic matter, and the pollution of the water is serious. Sewage from main cities like Shanba town, Linhe city and Wuyuan county, etc. contains high concentrations of phosphorus and nitrogen due to poor treatment.

Hetao Area has a large and important agricultural sector. More then 90% of the drained water entering Lake Wuliangsuhai comes from agriculture. This water is polluted due to excessive us of chemical fertilisers, containing large amount of nitrogen and phosphorus, that causes eutrophication in the lake.

Water in Main Drainage Canal enters the middle of west end of lake. This causes part of the water in the northern part of lake not taking part in circulation and the water quality has become bad. The purpose of this project is to discuss a shift in the entrance of Main Drainage Canal to the northern end of Lake Wuliangsuhai in order to improve water quality by increasing the circulation. This is an alternative measure to introduce cleaner water from Yellow River to the northern parts via irrigation canals (discussed in chapter 3.12).

The Main Drainage Canal was built in 1965 and was extended in 1987 and 1997, and is managed by the Main Drainage Canal Management Bureau of Inner Mongolia Hetao Irrigation Area Management Bureau. It is made up of three parts including the main section, the Lake Wuliangsuhai section and the entrance section. It controls a drainage area of 75.84×10^4 ha and a catchment of mountain flood of 1.33×10^4 km^2. The channel with total length of 257.83 km spans six counties.

When the Main Drainage Canal was designed, there was no pollution problem thanks to the low productivity in the local area. Hence, when designing the entrance of Main Drainage Canal and the outlet of Lake Wuliangsuhai, the circulation for self-purification of the water body was not considered.

Pollution load on Lake Wuliangsuhai
If this project is completed, all discharge is centralised at north end of Lake Wuliangsuhai with the annual input capacity is about 300 – 400 million m^3.

The total area available for construction of a pre-treatment wetland is 46 km^2. Since the wetland will have none or minor effects during the freezing season, for the input to the wetland we will use data from April to the end of November of the year 2000 data as the base.

Table 38..Data on flow and composition of N and P, from the year 2000.

Month	Flow (x 1,000 m^3)	T-P (tonnes)	T-N (tonnes)
01-jan-00	5,240	4.8	85
01-feb-00	2,590	4.8	85
01-mar-00	7,220	4.8	85
01-apr-00	7,730	5.4	103
01-maj-00	62,900	9.3	234
01-jun-00	78,000	10.0	270
01-jul-00	55,600	8.8	217
01-aug-00	35,800	7.4	170
01-sep-00	19,700	6.3	132
01-okt-00	69,100	9.8	249
01-nov-00	53,400	8.7	212
01-dec-00	33,500	4.9	85
Total	431,000	85	1,932

Summing up the above table, the following figures apply:

- The total amount of water from April to November is 400 000 000 m$^{3.}$
- Total amount of phosphorus is 66 tonnes
- Total amount of nitrogen is 1 600 tonnes
-

4.13.3 Operational environmental target for measure

Removal of phosphorus
It is difficult to give accurate numbers on the nutrient removal efficiency of wetlands. This is not only due to the complex processes including hydraulics, climate, soil types and wetland designs, but also to the simple fact that reliable data is lacking. A lot of knowledge is compiled

in "Våtmarksboken, skapande och nyttjande av värdefulla våtmarker" ("The wetlands' book, creating and utilising valuable wetlands"), by Tonderski et al, published as Report 3 by Vastra, the Swedish Water Management Research Programme (www.vastra.org). The following calculations and guidelines come from that report.

Available data shows that the efficiency will vary within the wetland and over time. There are examples when the wetland acts as a nutrient source under specific conditions (extreme flow might flush out nutrients).

Based on Nordic experiences it seems realistic to get an average P-conc of 0.07 mg/L in the outgoing water from the wetland. That means a removal rate of

$$66 \text{ tonnes} - 400{,}000\,000 \text{ m}^3 \times 0.07 \text{ mg/L} / 66 \text{ tonnes} = 38/66 \approx 60\ \%$$

This efficiency corresponds reasonably well with the studies based on efficiency instead of outgoing concentrations. As for the required area the numbers differ greatly. The most careful estimates give a reduction of 3 kg P/ha year, and the most efficient observed wetlands remove over 1 tonne P/ha year. Due to this large variation, a careful estimate of 100 kg P/ha year is used. The area needed for the wetland would then be:

$$38\,000 \text{ kg} / 100 \text{ kg/ha} = 380 \text{ ha.}$$

The area calculated above is the minimum required area in order to remove the maximum amount of phosphorus. Another designed parameter for wetland area is the retention time. Assuming a true retention time of a minimum of 2 days is needed and using a hydraulic efficiency of 70 % it is possible to calculate a required area. With a daily average inflow of 1 700 000 m^3 the total volume needed is:

$$1\,700\,000 \text{ m}^3/\text{day} \times 2 \text{ day} / 0.7 \approx 4{,}900{,}000 \text{ m}^3.$$

The hydraulic efficiency states how much of available volume actually contributes to the processes and how much of the area is so-called "dead zone"; e.g. areas with little or no water exchange. It is crucial to minimise these dead zones to limit the required area.

The depths indeed vary in a wetland but a typical, average depth is about 0.5 m. Thus the area needed due to hydraulic measures would be:

$$4\,900\,000 \text{ m}^3 / 0.5 \text{ m} \approx 10\,000\,000 \text{ m}^2 = 1{,}000 \text{ ha.}$$

The available area in the northern part of the lake is 4,600 ha, which is more than sufficient to give the expected reduction.

Removal of nitrogen

The uncertainties of quantifying nitrogen removal are as large as for phosphorus. The most important process is denitrification. Sedimentation is believed to be of minor importance, or less than 10 % of the total removal. Denitrification is primarily depending on the inroganic nitrogen concentration in the water, retention time and temperature. Available studies range from as high as 8 tonnes per acre to even negative values (nitrogen-gas is released from the wetland). Using 500 kg N per acre a year is a careful estimation, and is also a designed value recently given by the Danish parliament for artificial wetlands in Denmark. An estimate of the removal rate of nitrogen would be

500 kg/ha x 1 000 acre = 500 000 kg

500 tonnes correspond to a removal rate of just over 30 %. This number is probably realistic.

4.13.4 Technical content

Designing the wetland

There is a huge variation in shapes and designing concepts of wetlands for removal of nutrients. The design is partly restricted by local constraints such as type of soil etc. Therefore, these data should be considered as an example of capacity of a wetland.

It is known that the following is beneficial for efficient removal of nutrients and suspended solids in wetlands:

- High nutrient and suspended solids load
- Long retention time
- Moderate to high vegetation density and diversity
- Moderate or adapted harvesting of vegetation
- Small variations in flow

Typically the treatment capacity in wetlands removing nitrogen can be high. Since most of the inorganic nitrogen is ammonia, both oxic and anoxic zones are needed in the wetland for efficient removal of nitrogen. It is not recommended with retention time of less than two days.

Designing wetlands is still a fairly new science, which in addition to the complex and hard-to-control chemical processes involved makes it impossible to give any exact specifications. Each wetland needs to be designed according to the local conditions.

There are however general experiences, which can be used to make an initial or conceptual design. Creating wetlands includes physical, bio-hydrological and social aspects:

-
- Erosion needs to be controlled,
- Sufficient capacity is needed,
- The flow needs to be regulated,
- Retention time and hydraulic efficiency need to be controlled,
- Plants must be properly selected and harvested,
- Public access to the wetland (for fishing, recreation, bird-watching etc) needs to be regulated,
- Access for maintenance and working.

Even though a single pipe is the most common *inlet*, it is not the most efficient solution. The inflow should be distributed evenly over an as large section of the wetland as possible. This will ensure an increased hydraulic efficiency. Perforated pipes, perpendicular to the inlet canal can be used. A simple perpendicular embankment can also be used if the inflow is stable. If aeration is necessary the inlet can facilitate this, e.g. by pumps or a small waterfall. Both in- and outlet should be placed in the central section of the wetland opposite each other, in order to maintain the hydraulic efficiency.

The *outlet* must be constructed in such a way that the changes in flow are manageable. Suddenly increased flow after a rainstorm can otherwise flood the wetland and in practice render it temporarily useless. Also for the outlet a wider, multiple-outlet construction or an embankment is preferable to a single pipe. The storage capacity of the wetland is however smaller with a wide outlet than with a pipe, where the embankment can rise above the pipe.

Deeper sections perpendicular to the flow direction increase the hydraulic efficiency. They are most important close to the inlet and outlet but are useful over the entire area. Deeper sections also reduce the flow velocity and hence facilitate sedimentation and counteract resuspension. Deeper sections along the main flow direction must however be avoided, since they tend to short-circuit the system. Reed belts between the deeper zones will act as biological filters, sediment traps and further increases hydraulic efficiency. It is important that the reed beds in the wetland are controlled. Compact reed coverage will hamper the hydraulic efficiency, and possibly increase the hydraulic resistance too much.

The *length-width ratio* should be about 2:1 to 4:1. This takes both cost-efficiency (for construction) and hydraulic aspects into consideration. The wetland should be as rectangular as possible to maximise hydraulic efficiency, but natural topography, aesthetic value and biodiversity can motivate irregularities. Oblonged dams (with high length-width ratio) can be curved or L-shaped without affecting the efficiency.

Constructing a new canal from the current pump station

The average water flow at Main pumping station is 55.13 m^3/s, which gives the water an average speed of 0.63 m^3/s and a depth of 2.64 m.

Maximum water flow at Honggebo pumping station is 99.78 m^3/s, which gives the water a speed of 0.76 m^3/s and a depth of 3.63 m.

This area is very suitable, while there is enough room for all kinds of work, relevant building facility, good roads for transport of people and material. Designed width of the bottom of this section is 22 m. The canal should be formed as a trapezoidal cross section with slope coefficients M1=1/5 and M2=1/3. The existing section has the same size as the start section and will lead the water out into the northern part of Lake Wuliangsuhai. This is today considered a stagnant water district with poor water quality. The water quality in this area will improve rapidly due to this measure.

Table 39. Estimation of materials needed to be transported and used in the construction.

Name	Total
Earth volume excavation (m^3)	1,800,000
Sand and gravel cushion (m^3)	2,250
Plasto-concrete(m^3)	9,000

Changing the course of Main Drainage Canal and moving the pump station

The project of changing the course of Main Drainage Canal is divided into two parts, which are respectively new drainage canal section and new pumping station. According to reconnaissance on the spot, the start of a new drainage canal in the project of changing its course in Main Drainage Canal is 192 km downstream the Main Drainage Canal, locating in Zhaoqitai village of Sudulun countryside of Wulatezhongqi banner. New drainage canal section will be 11.5 km long and enter into Lake Wuliangsuhai through Guangyizhan village.

The principal cause of choosing this course is that the excavated line will be short, passing few farmer houses, and low compensation to save investment. Its factors of waterpower are similar to those at the end of Main Drainage Canal. The cross-section with 2.2 m bottom is a compound cross-section. Slope coefficients are respectively M_1 with 1:5 and M_2 with 1:3.

For a new pumping station, its main technique indexes are the same as those of Hongqibo pumping station. Its design and check runoff are respectively 60.0 m^3/s and 100.0 m^3/s. Its design and check velocity of flow are respectively 0.65 m^3/s and 0.75 m^3/s. Its design and check depth are respectively 2.70 m and 3.65 m.

Location and extent
A conveyance canal with 13 km must be built from the preset depository before lake at the outlet of Hongqibo pumping station, E 108°51′11″, N 40°59′44.5″, to North.

4.13.5 Environmental effect and feasibility

It is estimated that a wetland of 1,000 ha can remove 38 tonnes of phosphorus and 500 tonnes of nitrogen per year.

4.13.6 Economic content

Itemised capital investment costs of measure

Constructing a 1 000 ha wetland:
Due to the lack of data on the construction of wetlands in China, Swedish numbers have been used. Of course, both labour and equipment costs are different ij the two countries, thus the cost estimation is highly uncertain. However, the estimates below indicate the relations between the different costs. The example is taken from Magle wetland in Sweden, which was constructed in 1995. The area of the wetland was 30 ha, thus much smaller than the one sketched above.

- Construction cost: 6 400 000 RMB
- Operating cost: 350 000 RMB/year (5.5 % of construction cost)

Thus the price per acre for the wetland is about 210 000 RMB. Without knowing how the natural conditions differ between Magle and northern Lake Wuliangsuhai, an unqualified assumption is made that the cost per acre is reduced with 50 % when constructing a wetland so much bigger than Magle. Thus the cost, still using Swedish numbers, is 105 000 RMB per acre. Secondly, it is assumed that Chinese costs for constructing wetlands are 1/10 of the Swedish costs, being a labour intensive project. Thus the price for the wetland would be roughly 10 000 000 RMB.

These calculated costs should definitely be considered as an example of calculating the costs, where all constants could be changed due to more specific data.

Constructing a new canal from the current pump station
A preliminary budget for constructing the sedimentation tank has been estimated in the table below:

Table 40. Investment cost for constructing a new drainage canal from the current pump station

Project or expenses name	Unit	Quantity	Unit price (RMB)	Total (RMB)
Earth volume excavation (m^3)	m^3	1,800,000	8.00	14,400,000
Sand and gravel cushion (m^3)	m^3	2,250	90.46	204,000
Plasto-concrete(m^3)	m^3	9,000	425.00	3,830,000
Total				18,400,000

Changing the course of Main Drainage Canal and moving the pump station
In this project of changing its course in Main Drainage Canal with total length of 11.5 km, taking-up area is 212.8×10^4 m^2 and excavated earth volume is 178.3×10^4 m^3 in all.
For a new pumping station, its taking-up area is 6.7×10^4 m^2 and excavated earth volume is 3.5×10^4 m^3; 0.18 billion RMB RMB is invested in capital construction and equipment; 0.09 billion RMB is compensated in excavated drainage canal and occupying land. Total investment of this project is 0.27 billion RMB.

Table 41. Quantity sheet of the project of changing its course in Main Drainage Canal

Item	Occupying area (m^3)	Earthwork (m^3)	Remark
Drainage canal	2,128,000	1,783,000	
Pumping station	67,000	35,000	
Total	2,195,000	1,818,000	

Table 42. Construction costs for a new main pumping station

Engineering or expenses name	Unit	Quantity	Unit price (RMB)	Total (RMB)
Compensate for occupying land	m^3	2,195,000	30	65,850,000
Excavated earth volume	m^3	1,818,000	13.03	23,688,540
Capital construction and equipment				180,000,000
Total				269,538,540

Itemised operating / annual costs of measure
Operating cost for the wetland is estimated to 5.5 % of total construction cost, i.e. 550,000 RMB/year.
The annual cost of management and work for the new canal is 990,000 RMB/year.
The operating cost for a new pump station would be:
Annual running expense is 4.5 million RMB.
Annual management expenses and service expenses is 1.8 million RMB in all.

4.13.7 Other comments

Maintaining the pre-treatment wetland
Totally different processes govern the removal of phosphorus and nitrogen. Phosphorus is mainly removed through sedimentation of particles and to a lesser degree uptake by plants, while nitrogen is removed through denitrification. This means that they are facilitated by different parameters and also that efficient phosphorus removal is depending on regular dredging, while denitrification is a permanent process.

Today there is an extensive harvesting of reed and submerged vegetation in Lake Wuliangsuhai. The reed is, however, harvested in wintertime when the phosphorus content is minimal. In the wetland, harvesting must probably be conducted in summer, during growth season. This might require new utilisation of the reed resource. Both Phragmites and Typha are very productive species, well suited for use in wetlands. Well-managed treatment wetlands should be able to fulfil three purposes: biomass production (for utilisation), reuse of nutrients (extracted from harvest and dredged sediments) and improved nutrient removal (productive wetlands have higher nutrient uptake). Studies in Sweden show that with two harvests during the same season, considerably more nutrients can be removed, even though the total biomass will be the same as with one harvest. This is due to young plants having higher nutrient content than older ones.

It should be mentioned that both birds and especially fishes could cause significant resuspension of the sediments when looking for food at the bottom. This means that the wetland is not suited for aqua-culture and that dredging is required to remove nutrients temporarily trapped in the sediments.

Using the wetland as a test field for Lake Wuliangsuhai
In order to reach this state a lot of knowledge is required. In fact, the proposed wetland is the essence of what is suggested for the entire lake – reed bed control, improved (note, not necessarily increased) internal circulation, better utilisation of lake resources, periodical dredging etc. Thus, the wetland can also be used as an experimental area where field tests can be conducted before new practices are introduced in full scale in the proper lake.

Choosing an extended inlet canal or a new pump station?
Based on the above feasibility study, the alternative keeping the current pump station is preferred. The reasons are as follows.

After Main Drainage Canal is changed its course, Lake Wuliangsuhai can realise more effective circulation, and use drainage to renovate water body in Lake Wuliangsuhai. In operation, however, at present there are a series of problems including following points.

- It is difficult to meet large investment with 270 million RMB under present economic conditions.
- Economic benefit is not high. Actualising this project only solves circulating problems of a part of water body in Lake Wuliangsuhai, but cannot really solve polluting problems of whole lake. In fact the unpurified water from the Main Drainage Canal coming into the lake can pollute the water considerably, leading to decreasing of both economic and environmental benefits.
- There exist other ecological problems. When the Main Drainage Canal and Hongqibo pumping station are out of use, leftover is treated with a large sum of investment and forms new pollution problems. For circulating problems of water body in Lake Wuliangsuhai, other substitute schemes may be found.
- Changing its course in Main Drainage Canal will take up lots of land and the social compensation is large, resulting in big conflicts.
- New pumping station needs to be added to institutional expenses.
- Changing its course in Main Drainage Canal needs further argumentation and be examined and approved by national irrigation works department.

Based on the above observations, it is suggested to keep the existing pumping station, and the cost estimates will then be as following:

Table 43. Revised investment costs

	RMB
Wetland construction	10 000 000
Canal construction	47 900 000
Total	57 900 000

Table 44. Revised operational and Maintanance costs

	RMB/year
Wetland operational costs	550 000
Canal management	990 000
Total	1 539 000

4.14 Erosion control

4.14.1 Purpose

This project is mainly to transform and control XiaoMingSha in the east shore and Wula Mountain in the southeast of Lake Wuliangsuhai, which cause severe loss of water and soil and mud deposit.
The purpose of this study is to reduce erosion in the lake's catchment by planting trees, shrubs and grass, protect areas from over-grazing from livestock and constructing ditches, deposit dams and flood-leading construcions.

Due to size of the project, it is divided into two steps. The first step focuses on the acute renovation zone at east and south banks of lake (15 km^2 in all). The total areas including two sectors, Shajianzi with 10 km^2 at east bank of lake and Erdiar with 5 km^2 at south bank of lake, are done comprehensive renovation of water and soil protection as important renovation regions.

The background of the project
Presently, because of the severe water and soil loss in eastern shore of the lake, large quantities of mineral particles (sand, gravel) enters the lake through torrential rain. The average annual volume of flood water to Lake Wuliangsuhai is 52 million m^3. This adds to the silting up of the lake at a dramatic rate.

According to the analysis of satellite images in 1987 and 1996, the area of Lake Wuliangsuhai had decreased by 20 km^2 in almost 10 years, when bulrush field and marsh areas had increased by 24 km^2. The alluvial area was 1.1 km^2, where floods from Wula Mountain have entered the lake directly through the ditches and deposited large amounts of mud and sand. The deposit was severe, with the average of 40 cm thick, and the thickest of 90 cm.

The ecological environment is deteriorating, and bird populations continued to decrease. In order to protect the ecological environment of Lake Wuliangsuhai thoroughly, soil erosion multi-control must be carried out at the section of severe loss in east side of the lake.

4.14.2 Background

Wula Mountain is on the southeast side of Lake Wuliangsuhai, and at the north is BaiYanChaHan Mountain. The MingAn valley comes into being between the two mountains connected with the east shore of Lake Wuliangsuhai, and the loss of water and soil is very serious in this area. The main phenomenon is large quantities of sand piles scattered in bands and stepped area caused by mountain-flood from the north side of Wula Mountain. The project area is the main source of mud and sand loading to Lake Wuliangsuhai, with stretching flowing sand, poor-quality soil, thin plants and grass, fully scattered pitches caused by mountain-flood. The total project area is 1.351 thousand km^2.

In the project area, the weather is dry and the plants are thin and short, mainly including liquorice, etc. On rainy days, plenty of flood water flow into the lake. The annual volume of water from this valley is about 52 million m^3.

The project area belongs administratively to DengBuLaGe town of Wulateqianqi is purely a pasture area, with the main pasture business in breeding goats as the principal economic source of this sector.

The present situation of loss and preservation of water and soil
The loss of soil in the project area is mainly caused by erosion from water and wind. The area of severe loss is 1,270 km^2, which accounts for 94% of the whole project area.

In recent years, people have increasingly known more about the importance of Lake Wuliangsuhai as a wetland, and the protection work has been carried out gradually. The main content of erosion control is to:

- Plant trees,
- Make fence, and
- Forbid herding freely.

However, because controlling measures have not been carried out from source and the investment is little, the harm caused by the loss of erosion protection is getting gradually more severe.

General situation of nature
Landform
In this area there are plenty of scattered sand hillocks, step-shaped alluvial and landskapes with valley and platforms. Sand hillock crowds scatter in stripe-shaped style from east to west and their approaching to the lake area consist of stabilised or half-stabilised crowds basically accounting for 36 % of the area. The others are flowing crowds, accounting for 64 %. The height of sand hillock is 4 – 8m generally. There are many ditches scattered around at the north slope of Wula Mountain, caused by mountain-flood. Floods enter into the lake area through the ditches.

Soil
Because of the dry weather in Lake Wuliangsuhai area, the soil features light brown calcium soil zone, including salt soil, sand soil, lawn soil etc.

General social and economic situation
This project area is purely pasture area belonging to EerDengBuLaGe town with 701 families, 2,741 people, including 1,831 labourers. The pastureland of villages is sparsely scattered throughout the project area. Some land having been reclaimed to plant grass or grain for feeding are wind-eroded land, land with stabilised sand hillocks, and step-shaped alluvial, etc. The pasture business being mainly to breed goats has the total quantity of livestock of 40,016, including big livestock 1,458; small livestock 38,067; and pigs 491.

Present situation of the loss of water and soil
Overgrazing by goats and reclaiming of land, cause land deterioration and low plant coverage rate. Consequently, the biological environment becomes worse, and the loss of water and soil is very serious. The added effects of wind erosion make the combined situation very serious.

According to measurements, the average annual erosion caused by water is 4,00 t/km^2. Wind erosion occurs all over the project area, especially from XiaoMingSha on the eastern shore of Lake Wuliangsuhai towards east to JiaQuan bay. The sand hillocks scatter everywhere, and during strong wind, the flowing sand causes sand storms, which intensifies the occurrence and development of wind erosion. The average annual effects of wind erosion reach almost 6,000 t/km^2. The following table gives further information about the water and wind erosion in the area.

Table 45. Water and wind erosion in the area

erosion style	light water erosion-light wind erosion	moderate water erosion-moderate wind erosion	strong water erosion-strong wind erosion	extremely strong water erosion-moderate wind erosion	amount
Area (km^2)	81.06	309	450.94	510	1,351
Proportion (%)	6	22.9	33.4	37.7	100

The present situation of water and soil reserve

In recent years, following the national attention paid to wetland protection work and the increase of people's awareness to the importance of wetland resources, the protection and construction of Lake Wuliangsuhai wetland have also appeared on governments' agenda. In order to protect the biological environment of Lake Wuliangsuhai thoroughly, "The biological protection model project of Lake Wuliangsuhai wetland" was confirmed and carried out in 2002.

According to the plan, 107 hm^2 (= ha?) of forest was planted along east shore of the lake; fencing and cultivating work of totally 2,207 hm^2 was finished; and 35 km net and fence were set to protect from livestock grazing. The Forest Bureau of Wulateqianqi Banner carried out "Nature protection project" on the alluvial of Wula Mountains, and natural plants were recovered to 400 hm^2 totally, through fencing and forbidding ways. Additionally, Fish Farm of Lake Wuliangsuhai also proceeded in biological and environmental construction actively, by planting trees and grass and building dams. These works can prevent mud and sand from actively entering the lake.

A lot of the minor drainage areas have been controlled, such as deposit dams and grain workshops in the channels, level terraces and slope-protecting forest and grass in slope surface. With these interventions the floods are partly obstructed. In terms of alluvial, lots of water and soil preservation and multi-control work has been carried out over the last ten years, such as flood-leading construction, the construction of water and soil reserve project by national loan, etc. As a result, flood can be partly prevented and damage to local regions can be reduced, so it is less harmful to Lake Wuliangsuhai.

4.14.3 Operational environmental target for measure

The targets of construction

The first target is to control the loss of water and soil. By means of stabilising drifting sand, recovering plants, building dam systems, the loss of water and soil can be effectively controlled, and the environment can be significantly improved.

The second target is to obstruct floods and reduce the quantities of sand and mud. Through comprehensively controlling the ditches stretching to the lake, when the project exerts its functions completely, 30.7521 million tons of sand can be reduced, and 66.7855 million m^3 of water will be obstructed and saved.

The third target is to improve the terrestrial environment. By the means of fencing and forbidding livestock grazing, planting and building dam system, the ecological environment of project area can be recovered and rebuilt. The plant coverage rate will reach 78.6 %.

The fourth target is to protect the wetland itself from receiving large amounts of eroded material. Lake Wuliangsuhai will be made to gradually recover the ecologically self-adjusting abilities, and become a beautiful resort.

4.14.4 Technical content of measure

The layout of various measures

According to natural conditions – land-use situations and characteristic of water-and-soil loss – the methods of controlling by fencing and restricted grazing should be carried out to natural grassland with good conditions or stabilised sand pile groups. In areas with severe wind erosion – largely gathered drifting sand and pass by river channel – the system of windproof and sand-stabilising forest could be constructed with two methods in two sides of river channel. One is to set up a wood and sand barrier, the another is to plant trees and grass.

The highland region on the northern side of Wula Mountain can be multi-controlled through small drainage areas as unit. A system of dams should be set up. Some projects should be constructed based on characteristics of channel, such as main dams, middle and small deposit dams, prevention of channel head, etc. The method of planting and forbidding of grazing can be carried out on the slope surface of two sides of channel as well, according to the actual situation.

Scale of construction

The first step includes: Wind protection and sand binding forest of 6 km^2 (including high-forest of 1 km^2 and shrub forest of 5 km^2), closed renovation of 1.5 km^2 and manual grass of 2.5 km^2 are built in Shajianzi; a badly wind-eroded place of about 10 km^2 at the eastern bank of the lake. Twenty sludge-land dams (including one main dam, two medium sludge-land dams, and seventeen small sludge-land dams), protection forest of 1 km^2 and closed renovation of 2.5 km^2 are constructed in Erdiar of severe flood of 5 km^2 at south bank of lake.

The project consists of making:

- 546 km^2 windproof and sand-stabilising forest,
- 150 km^2 high forest,
- 396 km^2 shrubbery,
- 414.94 km^2 fencing and forbidding,
- 309 km^2 grass seeding from air,
- 71 building main dams,
- 119 middle deposit dams, and
- 262 small deposit dams.
-

The controlling rate of the loss will reach 100%, the coverage rate of forest and grass will reach 78.6%.

Considering that the project area lies in pasture areas, plenty of labour force is needed, and it is difficult to provide and adjust the labour resource, so the project will be carried out during the next 30 years. The whole task affects 1,269.94 km^2 and controls 42.33 km^2 each year. The task should be in accord to the principle “easy first, difficult later; making progress gradually”.

Building forests and cultivating should proceed in each spring. Sand barriers should be constructed before creating forests in spring. Airborne-planting and planting grass should proceed in the rainy season; fencing and cultivating should proceed at the same time as planting;

and construction of dam system should proceed in the autumn to the beginning of rainy season next year.

Content and layout of prevention measures, directive ideas
The basic task is to protect the wetland, to control the mud and sand entering into the lake. The task should be combined with developing local pasture economy and improving the ecological environment.

The concrete content and layout of prevention measures
Control of wind and sand in the region, which is the multi-control of sand hillock areas around MingAn village in the eastern part of the project, includes the following:

- First is to fence and forbid grazing: In the sections with stabilised or half-stabilised sand hillocks, better plant coverage, stronger ecologically self-adjusting abilities, fencing and forbidding methods should be carried out. High trees, shrubbery or grass can be planted in lower ground between the hillocks.
- Second is to build windproof and sand-stabilising forests: In the sections with flowing sand on two sides of the channel passed by floods, shrubbery such as SuoSuo, which can grow up from the sand can be planted. The windproof forest system should be built, combined with the project on artificial wood-grass-sand barrier.
- Third is to air plant: the grass seeds, which grow in the sand, can be air-sown in rainy seasons.
-

The whole area of wind and sand region is 480 km^2, including stabilised or half-stabilised sand hillocks area of 171 km^2, and flowing sand hillock area of 309 km^2.

Control of the ditches leading into Lake Wuliangsuhai, and thus managing floods and alluvial deposits from Wula Mountain includes the following:

- First is to build deposit dams: The main dams and middle deposit dams can be set properly in long, shallow and wide channels in which the quantities of flood water and sand are large, according to hydrological calculation. The small deposit dams can be set in short and narrow sub-channels. By this means, a comparatively perfect dam system can come into being.
- Second is to control slope surface: The artificial biological measures can be carried out in the locations with better water condition and soft gradient on two sides of the channel. Some good grazing grass and shrub can be planted together to form prevention zone. To the sections with good plants conditions, controlling by fencing and forbidding is necessary. In the sections of steep slope, or the latter sections of watershed, proper economic forest or shrubbery can be planted. The method of air-planting grazing grass seeds can also be adopted and the ecological self-recovery is the main way. Orchards of economic forests can be developed on the land with good soil qualities. People can also take advantage of fertilised wasteland to plant trees and grass, develop stockbreeding business in order to promote the sound development of regional ecological environment and economic construction.

The alluvial area of north Wula Mountain is 789.94 km^2 totally, including high land with soft gradient and the land of valley and platform 539.94 km^2. The details of all measures are in the general disposal chart of the measures of water-and-soil preservation and multi-control project in east shore of Lake Wuliangsuhai.

4.14.5 Environmental effect and feasibility of measure

GB/15774-1995

According to the national standard – *the calculation method of the benefit of water and soil reserve and comprehensive control GB/15774-1995* – the benefits of water and soil reserve and comprehensive control include basic benefit, economic benefit, social benefit and ecological benefit.

Basic benefit

The basic benefit is mainly that of saving water and reserving soil. This is done through the parts of plants above or under the ground, the project obstructing and saving the flows on the ground to increase the volume of the infiltrating water to reserve soil, reduce flood, and decrease the quantities of mud and sand into the lake.

The considered measures mainly include deposit dams, high forest, shrubbery, fencing and forbidding, air-planting etc. According to telemetric investigation of loss of water and soil, the combined erosion modulus is confirmed as 4053 t/km^2, combined with actual situations, the flow of the channel is 5 mm deep. The wind and sand area is about 480 km^2, there is no channel flow, and only the benefit of decreasing sand quantity is calculated. According to international standard and controlling experiences of the similar regions, the water-saving and sand-reducing coefficients of the main measures are confirmed through analysis and calculation, as the following chart:

Table 46. Reducing coefficient of the main water-reserving measures

project	high forest	shrubbery	planting	Cultivation
Coefficient (t/km^2)	20	26	36	32

The volume of obstructed and saved water, the quantity of obstructed mud and sand, are calculated with typical calculating method, that is, multiplying the sum of single dam with the number of dams. The conclusion is that the volume of obstructed and saved water is 66.7855 million m^3, the quantity of mud and sand is 30.7143 million tons. The benefit is obvious.

Ecological benefit

The benefits of water cycle: the water-reserving ability increases year by year and the situation of the flow on ground surface is effectively improved. The rainfall is saved by the project and infiltrates under the ground. As a result, soil is fertilised and the volume of flowing water is increased; then the better cycle can be obtained.

The benefit of soil cycle: the soil-reserving ability will increase year by year, the organism and natural nutrients will be preserved. As a result, soil can be fertilised more and more, and soil structure can be improved considerably.

The benefit of air cycle: following that the measures of plants are increased gradually, the wind power in project area will be dramatically weakened. Because the airflow with sand is restricted, air will be fresh, the moisture content will increase, the changing range of temperature will decrease, and as a result, the regional weather will be improved obviously.

The benefit of biological cycle: following that more plants and forest are continually planted and cultivated, the animals and plants will increase significantly.

4.14.6 Economic content of each measure

Itemised capital investment costs of measure

Total investment is 253.65 million RMB over thirty years. The first step of renovating Shajianzi and Erdian constitutes of 3.9745 million RMB in all: Shajianzi needs 0.7759 million and RMB and Erdian need 3.1986 million RMB. At three years' period of renovation and implementation, annual investment is 1.3248 million RMB, including total static investment and total investment.

- Total static investment includes project measure expense, woods-and-grass measure expense, fencing and cultivating measure expense, special expense and basic preparation expense. Total investment includes project measure expense, woods-and-grass measure expense, fencing and cultivating measure expense, special expense and basic preparation expense and preparation expense of price difference.

Table 47. Investment costs in 10 000 RMB

No	name of project or cost	construction expense	expense of project of forest and grass	special expense	amount
One	Project measures	13447.19			13447.19
1	Main dam	5948.55			5948.55
2	Middle deposit dam	2906.36			2906.36
3	Small deposit dam	2592.28			2592.28
4	Mechanical sand-stabilising project	2000			2000
Two	Measures on forest and grass		7160.82		7160.82
1	High plants for water and soil reserve		3670.5		3670.5
2	Shrubbery for water and soil reserve		2736.36		2736.36
3	Air planting		753.96		753.96
Three	Cultivation measures		1912.83		1912.83
1	Fencing facilities		45.6		45.6
2	Supplement to plant		1867.23		1867.23
Four	Special expense			2105.7	2105.7
1	Construction and management expense			540.5	540.5
2	Inspecting and managing expense of construction			630.58	630.58
3	Designing expense of research and measurement			743.19	743.19
4	Inspecting and measuring expense of water and soil loss			135.13	135.13
5	Inspecting expense of project quality			56.3	56.3
	Amounts from 1 to 4				24626.54
	Preparation fund				738.8
	Static investment				25365.34
	Preparation fund for price difference				
	Total investment				25365.34

- Total investment excluding financing costs = 246.3 million RMB

Table 48. Basis for cost calculations (Unit x 10,000 RMB)

No	Name of expense	Basis of drawing up and calculation formula	Sum (ten thousand Yuan)
1	Construction and management expense	2.4% of the construction work	540.5
2	Inspecting and managing expense of construction	2.8% of the construction work	630.58
3	Designing expense of research and measurement	3.3% of the construction work	743.19
4	Inspecting and measuring expense of water and soil loss	0.6% of the construction work	135.13
5	Inspecting expense of project quality	2.5% of the construction work	56.3
	Amount		2105.7

Table 49. Unit price used in calculations (Unit x 10,000 RMB)

Unit price No	Name of unit price	Unit	Area	Unit price	Amount
1	High plants	km^2	150	24.47	3670.5
2	Shrubbery	km^2	396	6.91	2736.36
3	Air planting	km^2	309	2.44	753.96
4	Net and fence	km	120	3800	45.6
5	Cultivation and supplement	km^2	414.94	4.50	1867.23
6	Mechanical sand barrier	km^2	100	20.0	2000
7	Main dam	one	71	83.7824	5948.5504
8	Middle deposit dam	one	119	24.4232	2906.3608
9	Small deposit dam	one	262	9.8942	2592.2804
Amount					22520.85

Construction costs
The construction unit price consists of direct expense, indirect expense, predicted profit and tax.

- Direct expense: including basic direct expense and other direct expense. Basic direct expense includes labour expense, material expense and machine using expense; other direct expense is calculated by the proportion of basic direct expense, in which the proportion of project measure expense is 4.0 %, of woods-and-grass measure expense is 1.5 %, of fencing and cultivating is 1.0 %.
-
- Indirect expense: project measure is calculated by 7 % of the direct expense, woods-and-grass measure by 5 %, fencing and cultivating by 4 %.
-
- The profit of enterprise: the profit of project measures is calculated by 4 % of the amount of direct expense and indirect expense, in terms of measures of cultivation and wood-and-grass, by 2 %.
- Tax: the tax is calculated by 3.22 % of the sum of direct expense, indirect expense and the profit of enterprise.

Special expense
Special expense consists of five parts:

- Construction and management expense: calculated by 2.4 % of the construction work.
- Designing expense of research and measurement: by 3 % of the construction work.

- Inspecting and managing expense of construction: by 2.8 % of the construction work.
- Inspecting and measuring expense of water and soil loss: by 0.6 % of the construction work.
- Inspecting expense of project quality: by 2.5 % of the construction work.

Preparation expense
Basic preparation expense: calculated by 3 % of the sum of project measure expense, woods-and-grass measure expense and cultivation measure expense and special expense.
Preparation expense of price difference: the annual rising index of price is zero.
Predicted labour price.

The location of the project is the region with grade 7 salary, the construction measure is calculated by 1.9 RMB/working hour, the planting and cultivating measures are calculated by 1.5 RMB/hour.

Predicted unit price of main materials
The shrub seedling and grass seeds should be calculated according to local market price adding transportation expense and the expense of buying and keeping The rate of buying and keeping expense is 2.0%, and the rate of planting and cultivating expense is 1.0%.

Itemised operating / annual costs of measure
According to the actual situation of the project where the expense mainly consists of the investment to permanent assert and running cost, flowing capital is very small or not needed.
The investment to permanent asserts includes the whole construction expense of the main project and correspondent matching works. The expense of total construction and permanent assert is 253.6 million RMB.

Annual running expense is confirmed according to the whole cost of the project and actual needs. Mainly including caring expense, managing expense and repairing expense etc. The annual running expense of measures should be confirmed according to actual situation of project area and actual situation in similar regions in Bayannaoer League. One person is set to manage one dam, with 100 RMB/month as salary, there are 452 dams, then the running expense per year is 542.4 thousand RMB. Calculation on direct economy of measures and analysis of running expense are presented below.

Table 50. Operational and Maintatance costs, in 10 000 RMB/year

	Project	High forest	Shrubbery	Grass	Cultivation	Dam for deposit	Amount
	Measure area (km²)	150	396	309	414.94		
	running expense ration (x 10,000 Yuan/km²)	2.5	2.0	1.5	1.5		
Running expense (x 10,000 Yuan)	2005						
	2006	375	792	463.5	622.41	54.24	2307.15
	2007	375	792	463.5	622.41	54.24	2307.15
	2008	375	792	463.5	622.41	54.24	2307.15
	2009	375	792	463.5	622.41	54.24	2307.15
	2010	375	792	463.5	622.41	54.24	2307.15
	2011	375	792	463.5	622.41	54.24	2307.15
	2012	375	792	463.5	622.41	54.24	2307.15
	2013	375	792	463.5	622.41	54.24	2307.15
	2014	375	792	463.5	622.41	54.24	2307.15
	2015	375	792	463.5	622.41	54.24	2307.15
	2016	375	792	463.5	622.41	54.24	2307.15
	2017	375	792	463.5	622.41	54.24	2307.15
	2018	375	792	463.5	622.41	54.24	2307.15
	2019	375	792	463.5	622.41	54.24	2307.15
	2020	375	792	463.5	622.41	54.24	2307.15
	2021	375	792	463.5	622.41	54.24	2307.15
	2022	375	792	463.5	622.41	54.24	2307.15
	2023	375	792	463.5	622.41	54.24	2307.15
	2024	375	792	463.5	622.41	54.24	2307.15
	2025	375	792	463.5	622.41	54.24	2307.15
	2026	375	792	463.5	622.41	54.24	2307.15
	2027	375	792	463.5	622.41	54.24	2307.15
	2028	375	792	463.5	622.41	54.24	2307.15
	2029	375	792	463.5	622.41	54.24	2307.15
	2030	375	792	463.5	622.41	54.24	2307.15
	2031	375	792	463.5	622.41	54.24	2307.15
	2032	375	792	463.5	622.41	54.24	2307.15
	2033	375	792	463.5	622.41	54.24	2307.15
	2034	375	792	463.5	622.41	54.24	2307.15
	Amount(x 10,000 Yuan)	10875	22968	13441.5	18049.89	1572.96	66907.3

Table 51. Direct economic benefit

	Project	High forest	Shrubbery	Air planting	Fence	Increased production of the land around dam	Reduced mud-cleaning expense	Amount
Direct economic benefit (x 10,000 Yuan)	2005							
	2006							
	2007							
	2008		158.4	556.2	195.02			909.62
	2009	199.2	316.8	1112.4	390.04			2018.44
	2010	398.4	475.2	1668.6	585.07	24.56	3685.72	6837.55
	2011	597.6	633.6	2224.8	780.09	49.11	3685.72	7970.92
	2012	796.8	792	2781	975.11	73.67	3685.72	9104.3
	2013	996	792	2781	975.11	98.22	3685.72	9328.05
	2014	996	792	2781	975.11	122.78	3685.72	9352.61
	2015	996	792	2781	975.11	122.78	3685.72	9352.61
	2016	996	792	2781	975.11	122.78	3685.72	9352.61
	2017	996	792	2781	975.11	122.78	3685.72	9352.61
	2018	996	792	2781	975.11	122.78	3685.72	9352.61
	2019	996	792	2781	975.11	122.78	3685.72	9352.61
	2020	996	792	2781	975.11	122.78	3685.72	9352.61
	2021	996	792	2781	975.11	122.78	3685.72	9352.61
	2022	996	792	2781	975.11	122.78	3685.72	9352.61
	2023	996	792	2781	975.11	122.78	3685.72	9352.61
	2024	996	792	2781	975.11	122.78	3685.72	9352.61
	2025	996	792	2781	975.11	122.78	3685.72	9352.61
	2026	996	792	2781	975.11	122.78	3685.72	9352.61
	2027	996	792	2781	975.11	122.78	3685.72	9352.61
	2028	996	792	2781	975.11	122.78	3685.72	9352.61
	2029	996	792	2781	975.11	122.78	3685.72	9352.61
	2030	996	792	2781	975.11	122.78	3685.72	9352.61
	2031	996	792	2781	975.11	122.78	3685.72	9352.61
	2032	996	792	2781	975.11	122.78	3685.72	9352.61
	2033	996	792	2781	975.11	122.78	3685.72	9352.61
	2034	996	792	2781	975.11	122.78	3685.72	9352.61
	Amount	23904	19800	69525	24377.75	2823.84	92142.9	232573.49

It is suggested to carry out only the first phase of this activity at present, covering renovating Shajianzi and Erdian areas. The cost estimates for these actiosn are as following:

Table 52. Investment and Operational and Maintenance (O&M) costs, RMB millions

Investment costs	3.974
Operational and Maintenance costs per year	0.359
Economical benefits per year	1.455

4.14.7 Socioeconomic impact

After the measures of the project being carried out, the controlled area will reach 1,319.94 km^2, controlling rate reaches 97.7 %, and the loss of water and soil gets controlled basically. As a result, local economy will develop rapidly, including pasturing business and tourism.
Through the project, the producing conditions of local pasture business will be improved effectively. Thus herdsmen can take advantage of the land at the dam head to construct little grassland to plant grass for feeding and pen-raising. Consequently, people's living level will be highly improved.

Implementation arrangements include:

- Proposed plan of action with stakeholder involvement
- Anticipated risks and mitigatory measures
- Measures to ensue sustainability of the action

4.14.8 Financing plans and considerations

The total evaluated investment is 253.6534 million RMB. The amount of 8.4551 million RMB will be invested each year. Since the project is a public and beneficial project, the construction should be invested mainly by national sources or through raising fund from national organisations.

Economic benefit

Through calculating the cost of the project and comparing it to the output value, by adopting the method of dynamic analysis it shows that the project is economically feasible.
This conclusion is based on the assumption that social exchange rate is 7 %, and with calculated proportion of 2.09 between economic benefit and cost and present economic value is 401.8699 million RMB. The methods and calculations are presented in the paragraphs below.
Basis of evaluation and index of economic analysis
The economic evaluation and analysis is based on a number the following standards and methods:

- National standard calculation method for profit of water-and-soil preservation and multicontrol GB/15774-1995
- Professional standard of water conservancy department for economic evaluation of regulation of water conservancy construction projects SL72-94.
- Economic net present value (ENPV)
- Economic internal income rate (EIIR)
- Economic benefit cost ratio (EBCR)

The assumptions used are the following:

- The calculation period of economy is confirmed to be 30 years, which is 2005 – 2034.
- 2005 is stated as the base year.
- All investments are put in wholly at the beginning of each year and all benefits are calculated at the end of the year.
- Inputs and outputs are all calculated with present price;
- The social exchange rate is adopted as 7%,

The method of economic evaluation

Generally, "the contrast method of with and without" is adopted to compare and analyse the net present value of income and cost before the project is carried out and after. The output indexes of measures are confirmed through investigating and analysing the actual situation.
High woods are calculated with increased and saved quantities of woods; shrub and woods are calculated with produced quantities of branches while grass is calculated with grass production. The output index of deposit dam should be calculated through analysing and calculating the increased production of grain or grass in deposit area and the quantities of mud reduction to Lake Wuliangsuhai.
The increased production and sum should be confirmed by evaluating the actual increase in production in the years after the project is carried out. According to the investigation, the mud-cleaning expense of Lake Wuliangsuhai is 30 RMB/m^3 each year, but, after deposit dams being completed, the cleaning expense will be reduced by 116.7 thousand RMB through obstructing and saving mud and sand 30.714253 million m^3 per year.

Table 53. The increased production ration of measures

Measure	unit	ration	area
High forest	ten thousand Yuan/km^2	6.64	150
Shrubbery	ten thousand Yuan/km^2	2.0	396
Air planting	ten thousand Yuan/km^2	9	309
Fencing and forbidding	ten thousand Yuan/km^2	2.35	414.94
Area around dam	ten thousand Yuan/km^2	7.5	16.37

Calculation of benefit
The benefit of water conservancy project should be calculated according to direct and indirect benefits, by comparing the situations of existence with non-existence of the project.
Direct economic benefit includes increased production and increased value through comparing the product from controlled land with the product from non-controlled land. Indirect economic benefit is additional benefit got through processing, based on direct economic benefit. It is not calculated here. The conclusion of calculation is presented below.

Three indexes: ENPV; EIIR; EBCR are adopted to evaluate. The following is the conclusion:

- Economic net present value (ENPV) = 40186.99 > 0
- Economic internal income rate (EIIR) = 13.79 >7%
- Economic benefit cost ratio(EBCR) = 2.09 >1

Conclusion: The project is regarded economically feasible.

Table 54. Chart of flowing capital (unit x 10,000 RMB)

year	investment			benefit		7%			
	construc-tion investment	running invest-ment	gross invest-ment	Direct benefit	net benefit	exchanging coeffic-ient	present invested value	present value of benefit	present value of net benefit
2005	845.51		845.51		-845.51	0.934	789.71	0.00	-789.71
2006	845.51	2307.15	3152.66		-3152.66	0.873	2752.27	0.00	-2752.27
2007	845.51	2307.15	3152.66		-3152.66	0.816	2572.57	0.00	-2572.57
2008	845.51	2307.15	3152.66	909.62	-2243.04	0.763	2405.48	694.04	-1711.44
2009	845.51	2307.15	3152.66	2018.44	-1134.22	0.713	2247.85	1439.15	-808.70
2010	845.51	2307.15	3152.66	6837.55	3684.89	0.666	2099.67	4553.81	2454.14
2011	845.51	2307.15	3152.66	7970.92	4818.26	0.623	1964.11	4965.88	3001.78
2012	845.51	2307.15	3152.66	9104.3	5951.64	0.582	1834.85	5298.7	3463.85
2013	845.51	2307.15	3152.66	9328.05	6175.39	0.544	1715.05	5074.46	3359.41
2014	845.51	2307.15	3152.66	9352.61	6199.95	0.508	1601.55	4751.13	3149.57
2015	845.51	2307.15	3152.66	9352.61	6199.95	0.475	1497.51	4442.49	2944.98
2016	845.51	2307.15	3152.66	9352.61	6199.95	0.444	1399.78	4152.56	2752.78
2017	845.51	2307.15	3152.66	9352.61	6199.95	0.415	1308.35	3881.33	2572.98
2018	845.51	2307.15	3152.66	9352.61	6199.95	0.388	1223.23	3628.81	2405.58
2019	845.51	2307.15	3152.66	9352.61	6199.95	0.362	1141.26	3385.64	2244.38
2020	845.51	2307.15	3152.66	9352.61	6199.95	0.339	1068.75	3170.53	2101.78
2021	845.51	2307.15	3152.66	9352.61	6199.95	0.317	999.39	2964.78	1965.38
2022	845.51	2307.15	3152.66	9352.61	6199.95	0.296	933.19	2768.37	1835.19
2023	845.51	2307.15	3152.66	9352.61	6199.95	0.277	873.29	2590.67	1717.39
2024	845.51	2307.15	3152.66	9352.61	6199.95	0.258	813.39	2412.97	1599.59
2025	845.51	2307.15	3152.66	9352.61	6199.95	0.242	762.94	2263.33	1500.39
2026	845.51	2307.15	3152.66	9352.61	6199.95	0.226	712.5	2113.69	1401.19
2027	629.73	2307.15	3152.66	9352.61	6199.95	0.211	665.21	1973.4	1308.19
2028	845.51	2307.15	3152.66	9352.61	6199.95	0.197	621.07	1842.46	1221.39
2029	845.51	2307.15	3152.66	9352.61	6199.95	0.184	580.09	1720.88	1140.79
2030	845.51	2307.15	3152.66	9352.61	6199.95	0.172	542.26	1608.65	1066.39
2031	845.51	2307.15	3152.66	9352.61	6199.95	0.161	507.58	1505.77	998.19
2032	845.51	2307.15	3152.66	9352.61	6199.95	0.150	472.9	1402.89	929.99
2033	845.51	2307.15	3152.66	9352.61	6199.95	0.141	444.53	1318.72	874.19
2034	845.51	2307.15	3152.66	9352.61	6199.95	0.131	412.98	1225.19	812.19
amount	25365.34	66907.35	92272.65	232573.49	140301.04		36963.33	77150.30	40186.99

4.14.9 Other comments

The conclusion of comprehensive evaluation and suggestion: The project of water and soil reserve in east shore of Lake Wuliangsuhai, can not only protect the wetland of Lake Wuliangsuhai strongly, but also promote the economy of stockbreeding around area to develop rapidly. It is economically rational and technically feasible. It is suggested that relevant departments should establish the project and invest as soon as possible, and organise to carry out.

4.15 Farmland Surface Pollution Control

4.15.1 Purpose

There are two overall purposes of this study: to reduce the pollution pressure and prevent eutrophication of Lake Wuliangsuhai by decreasing the run-off of surplus fertilisers, and to save water within agriculture.

The pollution prevention and control layout in agriculture should be based on the investigation of the drainage area and the experiments in the field, according to the features of the pollution on the land surface and water resources in Hetao Irrigated Area. Effective measures will be adopted to prevent and control the pollution, and to control and relieve the eutrophication in Lake Wuliangsuhai.

4.15.2 Background

Run-off from farmland has been identified as one of the main sources of nutrients (phosphorus and nitrogen) pollution to Lake Wuliangsuhai. In this study we have focused on improving the situation based on measures taken within the agriculture. This project has already been initiated, and tests have been ongoing since 2002. The project has however been delayed, due to lack of funding.

The present pollution situation in Hetao Irrigated Area

Chemical fertilisers

The use of chemical fertilisers in Hetao Irrigated Area started in the 1960's. The total quantitity of fertiliser used in 1966 was 2065 tons, mainly including ammonium sulphate, calcium perphosphate, etc. The quantity of used chemical fertilisers increased rapidly from the 1970's, and were 210.000 tons in 1986, i.e. 102 times as much as 20 years before, and reached 563.800 tons in 1996, 2.76 times as much as 10 years before. The quantities used in the whole irrigated area reached 590.000 tons in 2002 (including 470.000 tons nitrogenous fertilisers and 120.000 tons phosphorus fertilisers), which is 280 times as much as in 1966. The varieties of chemical fertilisers also developed from single-component, low-concentration to multi-components, high-concentration. The average of fertiliser quantities per acre reached 70 kg, some even surpassed 100 kg, highly beyond the average of 23.5 kg of the whole country.

Meanwhile, the crop production has also boosted tremendously; wheat production increased from approximately 100 kg per acre in the 60's to 400-500 kg at present. The production of corn has also increased, from 300 kg to over 800 kg. The production even reached more than 1000 kg per acre by growing a mix crop of wheat and corn. However, during the last 40 years, though fertiliser quantities have increased rapidly, the fertiliser efficiency (i.e. the amount of fertilisers that is actually used by the plants) grew more slowly. According to the materials provided by the agricultural bureau of BaMeng City, the effectively utilising rate of nitrogenous fertiliser is 35% in BaMeng City, whereas that of phosphorus fertiliser is only 22.4%.

Table 55. Statistics on fertilised quantities in Hetao Irrigated Area from 1980 to 2000 (unit:tons)

Project year	1980	1985	1990	1995	2000
amount of used chemical fertiliser	18000	58000	85800	137834	171050
quantities of used nitrogenous fertiliser	10277	38636	59689	97471	119456
quantities of used phosphorous fertiliser	3984	13460	16387	28448	41072
quantities of used potassic and synthetic fertiliser	3739	5904	9727	11915	10522

Note: fertilised quantity is quantity of net nutrition.

Pesticides

Following the development of agricultural production and progress of science and technology, the quantities of pesticide production and usage have significantly increased. According to the materials provided by agricultural bureau of BaMeng City, the quantities of pesticides used in 2002 were 757 tons in Hetao Irrigated Area, an increase by 66.9% compared with that in 1996. The quantities of pesticide used in the 60's have never reached more than 1.400 tons, but the pesticide varieties in that time were quite different from those at present. The pesticides used in the 60's and 70's consisted mainly of highly toxic and highly persistent substances, such as organic phosphor, organic chlorine, organic mercury, etc. which contributed largely to the biological accumulation. Fortunately, the pesticide presently used are highly efficient, low-toxicity and low-persistency. The pesticide varieties used in recent years are mainly of three kinds: The first is insecticidal ester genus, mainly including decamethrin, etc. The second is carbamate genus, mainly including carbofuran, etc. The third is organic phosphor genus, mainly including dimethoate alkron (1605), thimet (3911) and methamidophos, etc. Much chemical pesticides being used protect the harvest of agricultural production, but on the other hand, the pesticide-resistance of insects has increased, leading to a increased quantity needed to kill the insects. Consequently, the pesticide remainder in soil and crops increases, causing death of beneficial species, and as a result, the ecological balance is seriously broken.

The application mode of chemical fertilisers and pesticides

Although the application mode of chemical fertiliser and pesticide has improved continuously, until today, deeply fertilising and scattering are still the main styles. Deeply fertilising is mainly seeding with base fertiliser and fertiliser for seeds, while scattering is a style used mainly during growing period. The fertiliser quantity used through the two styles covers over 98% of the used amount. Another style is to spray fertilisers to the surface of leaves, aiming at the usage of kalium biphosphate and plant growth regulators. In the fertilising styles consisting of mainly spraying and planting with fertiliser mixedly, less fertiliser is used to sterilise soil and kill worms through pouring roots with it, etc.

Loss of chemical fertiliser and pesticide

According to relevant materials and research, the loss of chemical fertilisers mainly depends on two factors. One is the fertilising style, which is closely related to the irrigating style. Based on the investigation and analysis during irrigating period, it is known that chemical fertiliser is dissolved in water and seeps down to the groundwater. This causes the main loss in Hetao Irrigated Area. The fertiliser used in fields and soil is dissolved into irrigated water or rain and seeps gradually down into deep layer of the soil. As the water quantity in the soil goes beyond the maximum water holding capacity of the soil, the fertiliser dissolved in the seeping water is drained into surface water. This causes not only the main loss of fertilisers in Hetao Irrigated Area, but also the pollution of land surface and water resources.

The second way of nitrogen fertilizer loss is by volatility. It can be naturally volatilising for some easily volatile substances, for example, ammonium bicarbonate genus. Another is loss by denitrification in soil and groundwater. The loss by volatility could happen during transportation, storage and usage, but mainly in process of fertilising in the fields. The means for transporting the volatile substances is air, which could cause pollution at long distance, including acid rain.

Estimation of the lost quantities

Based on the test results of lost fertiliser quantities in this project, made at irrigation test station of YiChang bureau, in YongLian village, YongLi town, Wuyuan county in different estimating ways, it has been estimated that the nitrogenous and phosphorus fertiliser loss into surface water in the whole Hetao Irrigated Area are 938.920 tons nitrogenous fertilisers and 13.265 tons phosphorus fertilisers annually, calculated as ratio of irrigation and drainage. Calculated by irrigated acreage the amount of nitrogenous fertilisers are 644.47 tons, and the amount of phosphorus fertilisers are 10.07 tons.

Table 56.. Estimation by ratio of irrigation and drainage.

		amount of nitrogenous fertiliser	nitrogenous fertiliser of ammonia genus	nitrogenous fertiliser of nitrate genus	nitrogenous fertiliser of nitrite genus	amount of phosphorous fertiliser
Drainage in spring and summer	concentration of drained water(mg/L)	3.799	1.135	0.396	0.031	0.165
	drainage quantities in spring and summer in Hetao irrigated area calculated as 0.032 billion m^3					
	drainage quantities(t)	122	36	13	1	5
Drainage in autumn	concentration of drained water(mg/L)	3.478	0.179	0.438	0.032	0.034
	drainage quantities in spring and summer in Hetao irrigated area calculated as 0.235 billion m^3					
	drainage quantities(t)	817.352	42.065	103.031	7.430	8.001
amount of drainage quantities in whole year in Hetao irrigated area(t)		938.920	78.369	115.703	8.406	13.265

Table 57. Estimation by irrigated acreage

test field area amounting to 290.34 acres	amount of nitrogenous fertiliser	nitrogenous fertiliser of ammonia genus	nitrogenous fertiliser of nitrate genus	nitrogenous fertiliser of nitrite genus	amount of phosphorous fertiliser
amount of drainage quantities in whole year in test field area(kg)	21.885	2.065	2.676	0.195	0.342
irrigated area calculated as 8.55 million acres, drainage quantities calculated by drainage rate of test field area					
amount of drainage quantities in whole year in Hetao irrigated area(t)	644.47	60.81	78.80	5.742	10.07

Compared with each other, there is a difference of one third between the two ways. In fact, estimating the lost quantities of nitrogenous and phosphorus fertilisers by irrigated acreage is less rational than by actually controlled drainage acreage. The results are closer to another as the actually controlled drainage acreage is estimated as 11 million ha, the confidence level of the estimation is much higher than that by irrigated acreage.

Table 58. Estimation by actually controlled drainage acreage

test field area amounting to 290.34 acres	amount of nitrogenous fertiliser	nitrogenous fertiliser of ammonia genus	nitrogenous fertiliser of nitrate genus	nitrogenous fertiliser of nitrite genus	amount of phosphorous fertiliser
amount of drainage quantities in whole year (kg)	21.885	2.065	2.676	0.195	0.342
Controlled drainage area calculated as 11 million acres, drainage quantities calculated by drainage rate of test field area					
amount of drainage quantities in whole year in Hetao irrigated area(t)	829.15	78.23	101.39	7.39	12.96

Table 59. Comparison of lost quantities of nitrogenous and phosphorus fertiliser calculated three ways of estimating

	amount of nitrogenous fertiliser	nitrogenous fertiliser of ammonia genus	nitrogenous fertiliser of nitrate genus	nitrogenous fertiliser of nitrite genus	amount of phosphorous fertiliser
the lost quantities calculated by ratio of irrigation and drainage (t)	938.92	78.37	115.70	8.41	13.26
The lost quantities calculated by controlled drainage acreage (t)	829.15	78.23	101.39	7.39	12.96
The lost quantities calculated by irrigated acreage (t)	644.47	60.81	78.80	5.74	10.07

The mode of pollution on land surface and water resource in Hetao Irrigated Area
Through research and analysis, we have come to a conclusion that there are 3 modes of pollution on land surface and water resource in Hetao Irrigated Area:

1) The mode of dissolving into irrigated water and rain
2) Nitrogenous and phosphorus fertiliser used in field or soil dissolves into irrigated water or rain, and enters in soil at first, as soil reaches it's maximum water-holding capacity, then seeps into groundwater.
3) In the areas with poor drainage conditions, the lost dissolved chemical fertiliser or pesticide accumulates in the soil and groundwater. Since the irrigation and drainage system is quite good in the Hetao Irrigated Area, the excessive seeping water is drained into surface water through drainage ditches. This is the main mode of pollution on land surface and water resource in Hetao Irrigated Area.

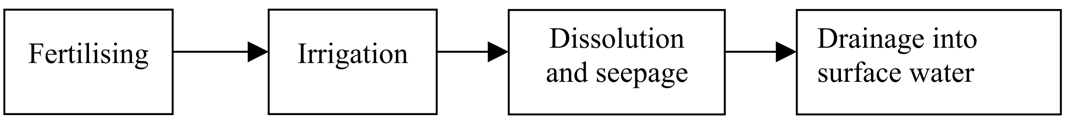


Figure 36.The mode of surface runoff

Various nutritional materials scattering on the surface of the soil are washed by surface runoff, for example rain. One part seeps into the soil following water and another dissolved by surface runoff enters in area surface water directly.

The mode of outflowing after being dissolved in groundwater:
Because rainfall or irrigation causes the groundwater level to rise, the nutrient salinities, such as nitrogenous or phosphorus fertilisers, lying in non-irrigation soil, dissolved in the groundwater, and enter surface water through drainage systems. In general, all three modes exist, but the first mode is the main factor.

4.15.3 Operational environmental target for measure

- To provide pollution prevention and control layout in agriculture
- To improve the agricultural production structure
- To recommend to use synthetic fertilizer with long-effect and slowly-released qualities and efficient low-toxic low-persistent pesticides
- To extend the technologies and skills of water-saving irrigation
- To adopt advanced scientific fertilizer-using techniques
- To reduce the quantities of chemical fertilizers, pesticides and irrigated water
- To control the pollution on both farmed fields and canal system
- To control and relieve the eutrophication in Lake Wuliangsuhai efficiently.

4.15.4 Technical content of measure

Containment of pollution of land surface and water resources from agriculture
On land, the pollution is a problem of interaction between fertilizers and water. The pollution cannot take place without water. To control the pollution, both fertilizer and water must be controlled at the same time. Water plays a key role here.

Construction of water-saving irrigation
Hetao Irrigated Area is a large naturally-irrigated area with Yellow River as its water source and an amount of 5.3 billion m^3 water is led in from Yellow River every year. Presently, the irrigated area is 8.7 million acres and an average of used water per acre is 610 m^3. According to the materials provided by Hetao general irrigation bureau of BaMeng city, the coefficient of irrigation is only 0.42 in Hetao Irrigated Area presently, i.e. 58% water is lost before entering the farmland and the volume of water actually entering the farmland is just 244 m^3 per acre. Water is lost through seeping and evaporating during conveyance. Looking at this situation, through experts' argument, it has been decided to carry out the watersaving irrigation project in Hetao Irrigated Area. At present, experiments are being made in every irrigation bureau. After the project being carried out, led-in water from Yellow River could be minimized by 1.2 billion m^3 per year; groundwater level could be lowered by 0.4 - 0.6 m; drained water from farmland will decrease from presently 0.4 - 0.5 billion m^3 to 0.1 - 0.2 billion m^3 per year. The main components of the project are outlined in the following.

Laying bricks and sticking concrete on sides and bottom of canal: The work of laying and sticking should be carried out for all canals in the irrigated area to reduce the water loss during conveyance.

Irrigating by groundwater wellss: Irrigating from groundwater wells should be carried out in areas with sufficient groundwater. Over 20 thousand power-operated wells have already been established in the whole area by now.

Irrigating by both well and canal: The combination of irrigation by well and by canal, can not only decrease led-in water quantity from Yellow River, but secure irrigation over time; furthermore, it can control the salinisation of the soil as well.

Developing water-saving agriculture actively:
The planned type of water-saving agriculture is a new agricultural producing style developed based on the global water resource crisis in recent years. It is different from the traditional ways of water-saving. Water-saving agriculture is to transform people's traditional water-using habits, to change from irrigating field into irrigating crops, to irrigate according to the best water-needing demands of the crops to get higher output benefits by less water. Water-saving agriculture is an effective way to save water for agriculture and to relieve the lack of water resource. It is a strategic measure transforming the traditional style to high-production, high-quality and efficient agriculture through changing agricultural increasing style It is also a revolutionary to traditional style of agricultural irrigation.

The main contents of the project include:

- To extend and use water-saving irrigating technique.
- To extend and use water-saving cultivating style.
- To extend and use chemical water-keeping technique.
- To extend and use the technique of adjusting water quantity according to fertilizers.
- To research and extend low water-exhausting and high-quality varieties of crops.
-

Absorbing and extending new-style agricultural producing techniques
This part of the project includes:

- To extend and use long-effect and slowly-released fertilizers, to reduce the loss of fertilizers, and to raise utilizing rate of fertilizers.
- To promote using natural fertilizers, organic fertilizers; to promote usage of parts of plants (the straw) as fertilizers to improve the soil structure, to elevate the fertilizer-keeping and water-keeping capacity of the soil, to decrease used quantities of chemical fertilizers.
- To promote and extend the producing techniques of food harmless to the public, such as natural food and organic food, no or less chemical fertilizer and pesticide.
- To research and extend biological pesticides, to reduce used quantities of chemical fertilizers, to keep agricultural ecological balance.
- Measures to control agricultural pollution on land surface and water resource

Measures on policy: Prevention and solution for agricultural pollution is a system engineering relevant to various factors of society. So government should coordinate relevant departments to research to draw up the policy and layout on prevention and solution for pollution. Preferential policy should be adopted to attract various social forces to participate the work of prevention and solution for pollution.

Measures on management: Government should authorize or appoint a special organization or department to be in charge of the work of prevention and solution for agricultural pollution, according to drawn up policy and layout on prevention and solution for pollution; and the special department must report carried-out situation of the policy and layout to government periodically. Government should promote and inspect the special department as well.

4.15.5 Environmental effect and feasibility of measure

Management of water resources and farming practices
Based on prediction and analysis, after water-saving irrigation engineering finishes, the deverted water volume from Yellow River will decrease by 1.2 billion m^3. This is vital for the downstream Yellow River drainage area, which since the 1970's have suffered from severe droughts. Water saving in the Hetao Irrigation Area is expected to cause positive influence on the environment as well as social and economical development.

As to Hetao Irrigated Area, salinity input will be decreased by 600 000 solids t/y (considering salinity in water of Yellow River as 0.5 g/L). The input of nitrogen will be decreased by 4 800 t/y (considering nitrogen in water of Yellow River as 4 mg/L).

The groundwater level in Hetao will descend yearly if water saving technologies are adopted. The decreasing supply to groundwater, causing descending groundwater level, is beneficial for soil desalination. Soil salinisation in Hetao Irrigated Area is thus expected to be controlled more effeciently, and the natural ecological environment will obviously be better in Hetao Irrigated Area. If several measures are well co-ordinated, saline wasteland in the Hetao Irrigated Area will be transformed into grassland and farmland with good quality. However, if these measures are not taken, more areas might instead turn into desert and sand hills.

Because of the descent of the groundwater level, the drainage quantities from farmland will decrease, and concentrations of nitrogen and phosphorus in water that enters the drainage canals and Lake Wuliangsuhai will decrease as well. Calculated by drainage water being decreased by 0.2 billion m^3 per year, the amount of nitrogen loaded into the lake will be decreased by over 800 tons per year, and the decreased amount of phosphorus is expected to be over ten tons. The pollution on land and water resources will obviously be relieved, and the ecological environment of Lake Wuliangsuhai will be improved.

Agricultural ecological system entering benign circle
Extension and promotion of water-saving agricultural technique will change unenlightened production style of broad irrigation and extensive management, which came into being many years ago in Hetao plain.

Effect on Lake Wuliangsuhai
After the above measures are carried out, as the quantities of diverted water from Yellow River will decrease, and the groundwater level will certainly descend. According to analysis and prediction, after all measures being carried out (mainly water-saving irrigation), groundwater level will drop by 0.4 m in Hetao, and the drainage quantities from the Main Drainage Canal to Lake Wuliangsuhai will decrease from 0.5 billion m^3 to about 0.3 billion m^3. Actually, in less than 3 years since the engineering was tested, the groundwater level has dropped by 0.2-0.5 m. The output of the Main Drainage Canal has been below 0.4 billion m^3 for 3 years, only 0.3079 billion m^3 in 2003, 10 years ahead of prediction. Presently, Lake Wuliangsuhai has already faced shortage of water, which will be increasingly serious during the coming years. Therefore, it is necessary to find new water sources for Lake Wuliangsuhai now, or its surface area will diminish rapidly, until the lake dries up.

Effects on agricultural ecological system in Hetao Irrigated Area

The decrease of led-in water quantities and the drop of groundwater level are beneficial to soil desalination and improvement of soil salinisation. The carryout of water-saving agricultural technique and new-style agricultural producing technique will improve the soil qualities of farmland, which could be beneficial to the exertion of production potential of farmland and to the sustainable development of agriculture.

Effects on ecological system of wetlands in the irrigated area:

After the project have been carried out, the groundwater level will descend, and stay at the depth of less than 1.5 m for long time (2 m is designed controlled depth). According to analysis and prediction, the present wetland in Hetao Irrigated Area will decrease by 50%. Consequently, almost half of the shallow lakes will dry up and transform into saline land or sand land. Lakes drying-up or disappearing will influence on wild creatures that rely on the lakes to live and breed. Bird will suffer in the most serious way. The communities and quantities of bird will decrease seriously; some species will disappear forever. Disappearance or decrease of wetland has a bigger influence on department and persons undertaking aquaculture, such as decreasing in their incomes and even abandoning their business to take up another employment, Additionally, because lakes and wetland have functions of improving local environment, the reduction or disappearance of wetland will cause certain negative impacts onthe environment of surrounding areas.

4.15.6 Economic content of each measure

An amount of 1.2 billion m^3 water of Yellow River can be saved yearly through water-saving irrigation in this project, therefore it is necessary to solve the contradiction between provision and need for water of Yellow River. Water used for lifes in towns, industries or other needs in both up- and down-river areas, the water saving is expected to cause benefits for social and economic development in these areas. Calculated by exhausted water quantities per ten-thousand-RMB production value, totally used for industry, it will achieve industrial production value of several hundred million RMB. Used for agricultural irrigation, it will newly increase irrigation area by 2.5 - 3 million acres. Calculated by present producing level in Hetao Irrigated Area, 1.5 billion RMB agricultural production value can be achieved.

Through water-saving irrigation engineering, the irrigation efficiency coefficient can be raised from 0.42 to 0.66: Based on research and test, by co-ordinating watersaving irrigation engineering with water-saving agricultural techniques, the irrigation coefficient can even be raised to 0.8. Its economic benefits are obvious. In addition, through water-saving agricultural technique, the quantities of fertilizer and pesticide uses can be reduced, the production quality of crops improved, the agricultural producing cost decreased, and the economic benefits raised. According to the introduction of experience, adopting water-saving agricultural techniques could decrease agricultural production cost by 10%, and boost production benefits by about 20%. Furthermore, the development and booming of local economy could be initiated and promoted during the execution of the project, for instance, by manufacture of building materials, supplies, transportation, etc.

4.15.7 Socioeconomical impact

As mentioned above, the socioeconomical impact is expected to be advantageous, especially concerning the possibilities to have more water available in other areas, since the out-take from Yellow River in the Hetao area will be decreased. On the other hand, as described above, people who depend on the wetlands might have to find new occupations since the wetlands are expected to diminish, or even disappear.

4.15.8 Investment estimatation and implementation plan

Budget and Engineering Schedule

The Hetao Irrigation Area water-saving irrigation engineering is divided into two parts, namely extending construction of irrigation system and water-saving system. The whole project is separated to two stages. The first-period engineering began in 2000 and will end in 2005. The main engineering content is to set up a drainage establishment, accessorial buildings and defence measure in Dongfeng sub-canal, YangJiaHe canal, YongJi canal, FengJi canal, YiHe canal, ChangJi canal and SanHuHe canal. It also includes the restoration of main drainage channel and set up accessorial buildings, the construction a demonstration area of 200,000 mu[1] with highly efficient saving-water capacity combining wells with channels.

The second-period engineering is from 2006 to 2015 with the main engineering contents consisting of setting up a drainage establishment, accessorial buildings and defence measures in canal No.1, DaTan sub-canal, WuLaHe River, Nanyizhi sub-canal, QingHui sub-canal, HuangYang sub-canal, HuangJi canal, HeJi sub-canal, Guangze sub-canal, ZaoHuo canal, ShaHe canal, FuXing canal.

Budget and financial sources

The whole project needs to invest 6.121 billion RMB, of which 3.754 billion RMB for main structure of the whole system, and another 2.367 RMB for construction within farmland (including agriculture comprehensive development); and 3.058 billion RMB used in first stage, 1.908 billion RMB for main structure, 1.15 billion RMB for farmland. The fund is supposed to get from the state, local organization and public self-fundraising. As to the investment of the main structure, the proportion will be 1:0.5 of the state and the local, the state 2,502,738,300 RMB and the local 251,369,100 RMB. Three levels of local organization such as the regional, the municipal and the county governments will share the investment respectively, 1/3 each. The investment for the engineering within farmland mainly depends on public self-fundraising amounting to 1,515,250,000 RMB, and the rest 851,680,000 RMB comes from the state. The details are seen in the following tables 79 and 80.

Implementation plan and investment estimation: According to the construction scheme of water-saving agriculture demonstration base offered by Agriculture Bureau of Bayannaoer City, the base will be set up within 2-3 years with 200,000 mu, of which:

- 50,000 mu of the flat ground limitation, of which, border method of irrigation 1000 mu
- The machine is deep loose, turn over deeply 30,000 mu
- A film overlay 50,000 mu
- Stereoscopic plant efficiently 10,000 mu;
- The equilibrium kit applies fertilizer 50,000 mus;
- The big medium shed and sunlight glasshouse facility cultivate 100 mu;
- The watermelon, muskmelon, the seed melon opens the ditch to rise the high film of rectangular vegetable bed to cultivate 500 mu
- Paper sleeve raise seeding transplant 500 mu
- Channel lining brickwork2000 mu
- Well and channel combined irrigation 2000 mu
- The technique of the high new tech stanza water irrigation 500 mu, of which, spray to infuse 200, the drop infuses and sprinkles to infuse 100, film descend irrigate 200 mu;
- Crop stalks overlays and crop stalk return the farmland, herbage to plant 4,400 mu;
- The sets up one divide fertilizer station and three monitoring points of soil fertilizer and soil moisture;

[1] 1 mu = $666m^2$

Budget and financial sources

The investment of the basement needs 6,000,000 RMB totally, among them:

- The farmland construction 1,300,000 RMB.
- 50,000 mu of the flat ground limitation and 2,000 mu of the construction shelter forest, 700,000 RMB;
- Deep loose, turn over 30,000 mu soil deeply, 600,000 dollars.
- The infrastructure construction 1,000,000 RMB.
- Construct the bridge, sluice gate, the machine-well house 10 base, 300,000 RMB;
- Channel reformation, lining brickwork, hardening to control area 2,000 mu, 200,000 RMB;
- Purchase the ambulation type sprays to infuse machine 10 sets, 50,000 RMB;
- Purchase 2 sets of transformer, low-pressure line of high pressure, 250,000 RMB;
- The kit machine electricity well, 200,000 RMB;
- The new technique promoting production & efficiency of watersaving measures, 2 mill RMB
- The expansion stereoscopic plant efficiently technique 10,000 mu, 200,000 RMB
- The technique of opens the ditch to rise the high film of rectangular vegetable bed to cultivate 500 mu, 10,000 RMB
- The technique of A film overlay 50,000 mu, 150,000 RMB
- Paper sleeve raise seeding transplant 500 mu, 10,000 RMB;
- Construct the big shed and glasshouse 100 mu, 1,000,000 RMB
- The equilibrium kit apply fertilizer 50,000 mu, 480,000 RMB;
- Crop stalk overlays & crop stalk return to farmland , herbage to plant 4,400 mu, 150,000 RMB
- The set up of one divide fertilizer station, 1,000,000 RMB;
- Construct workshops, warehouses, offices 1800 square meters, 680,000 RMB;
- Two deploy vehicles, 260,000RMB
- Purchase chemical equipments (a set) and printer (a set), 60,000 RMB.
- Develop the water-saving irrigation and high new agriculture innovative technology on trial, demonstration and promotion, 200,000 RMB.
- Set up three monitoring points of soil fertilizer and soil moisture, 500,000RMB;
- The fund is supported mainly by the state, and self-fundraising.

Table 60.First-period engineering and budget list of the water-saving irrigation engineering framework outlet and channel relate to the building to set up the kit to reform (2005)

Ordinal number	Project	Channel									Building (base)					Total investment (Million Yuan)
		Quantity (item)	Total length (km)	Flow (m^3/s)	Channel water utilization coefficient	Set revise length and area: Set revise length (km)	Lining brickwork length (km)	Lining length (Million m^2)	Prevent from leak structure type	Investment (Million Yuan)	Water parting building	Crossover building	Traffic building	Other building	Investment (Million Yuan)	
1	Main drainage canal	1	180.85	565	0.93	180.85	8	0.2743	Board and membrane	89.6538	3		14	27	69.2659	158.9197
2	Drainage canal	6	378.6	73-5.1	0.868	378.6	378.6	2.3075	Concrete board and plastic film	389.3394	32	2	54		27.5328	416.8722
3	Sub- drainage canal	17	414.92	24.5-2.7	0.892	414.92	414.92	2.658	Concrete board and plastic film	304.1918	85	2	69		38.0354	342.2272
4	Mini-drainage canal	173	1093.44	8.0-1.0	0.887	1093.44	1093.44	8.8875	Concrete board	560.2614	212	19	396		57.9951	618.2565
5	Total	197	2067.8			2067.8	1894.9	14.1273		1343.4464	332	23	533	27	192.8292	1536.2756

Table 61..Second- period engineering and budget of the water-saving irrigation engineering framework outlet and channel relate to the building to set up the kit to reform (2015).

Ordinal number	Project	Channel									Building (base)					Total investment (Million Yuan)
		Quantity (item)	Total length (km)	Flow (m^3/s)	Channel water utilization coefficient	Set revise length and area: Set revise length (km)	Lining brickwork length (Km)	Lining length (Million m^2)	Prevent from leak structure type	Investment (Million Yuan)	Water parting building	Crossover building	Traffic building	Other building	Investment (Million Yuan)	
1	Main drainage canal	1	180.85	565	0.93	180.85	8	0.2743	Board and membrane	97.3864	3		14		76.1757	173.5621
2	Drainage canal	13	780	73-5.1	0.95	780	780	4.4425	Concrete board and plastic film	858.6248	70	3	115		42.1531	900.7779
3	Sub-drainage canal	48	1069	24.5-2.7	0.95	1069	1069	6.7010	Concrete board and plastic film	847.1302	153	5	155		75.2280	922.3582
4	Mini-drainage canal	339	2189	5.0-1.0	0.95	2189	2189	15.7575	Concrete board	1160.1575	390	45	707		104.0233	1264.1808
5	Total	401	4218.8			4046	1046	27.1753		2963.2989	616	53	991		297.5701	3260.8690

4.16 Improvement of internal circulation

4.16.1 Purpose

A project involving improved circulation of water within Lake Wuliangsuhai is proposed. At present, water is introduced to the lake in the form of irrigation drainage water during the spring, in addition to replenishments from the Yellow River. Also, natural runoff from the Wula Mountains contributes to the replenishment of the lake. The purposes of the proposed project include:

- Strengthen the water circulation within the northern part of the lake,
- Improve the circulation in present stagnant areas
- Improve the general water quality of the Lake Wuliangsuhai
- Provide a more uniform distribution of flow in the lake

4.16.2 Environmental targets

The environmental targets of the proposed project is summarised below. Increased circulation of the whole lake will contribute towards:

1. Improvement of water quality, increased visibility, and towards National Surface Water Environment Quality Standard, Class 3 (GB3838-88.)
2. Improvement of the ecological environment for fish, possibly the restoration of new fish stocks.
3. Improvement of sustainable fish production
4. Increased reed production
5. Improvement of the natural landscape within Lake Wuliangsuhai
6. Increased biodiversity of Lake Wuliangsuhai by providing added food and improved habitat conditions for birds
7. Supporting eco-tourism.

4.16.3 Operational targets

The above targets can be met by combining computer model simulation services with necessary resources for field implementation of recommended scenarios. In other words, the operational target of the proposed project is a combination of theoretical model simulations and practical implementation, in an effort to provide cost effective resource management package.

The proposed approach is cost-effective, may accommodate any desired number of stakeholders, and enhances the general understanding of physical lake dynamics, both within the professional as well as the public sectors.

4.16.4 Background

Lake Wuliangsuhai is dependent upon artificial replenishment of water in order to remain as a lake. At present, most of this water enters the lake at 3 locations, (see map above) with the following influx figures:

- Main Pumping Station (MPS): average inflow 1992-2002 = 12.384 m^3/s
- Canal 8: average inflow 1992-2002 = 1.30 m^3/s
- Canal 9: average inflow 1992-2002 = 0.784 m^3/s

The above figures are averaged spring/summer values for the period 1992-2002. Note that inflow from Main Pumping Station and Canal #8 is considered a confluence, cfr. the map (above). Both water quality and quantity varies significantly over the seasons, controlled by water input from Yellow River, agricultural drainage, natural runoff, etc. During the cold season, when the lake freezes over, very little water passes through the lake system, except industrial and urban wastewater.

When Main Drainage Canal feedwater is being introduced at a high rate, water level of the north part of the lake is slightly higher than the southern part of the lake, and a gradient is formed. (There is no gradient during the winter season.) During the flow regime as outlined above a total gradient of 0.40m is assumed between the inlet points and the outlet to the South. The gradient is a function of cross sectional area, water flux and resistance due to vegetation and lake bed roughness. Moreover, the present lake is criss-crossed by a number of canals as outlined in the satellite photo below. For sake of simplicity the geometry of these canals is assumed to be of 2.0m depth and 10m width. These canals have impacts on the flow vectors of the lake, as will be demonstrated in the following.

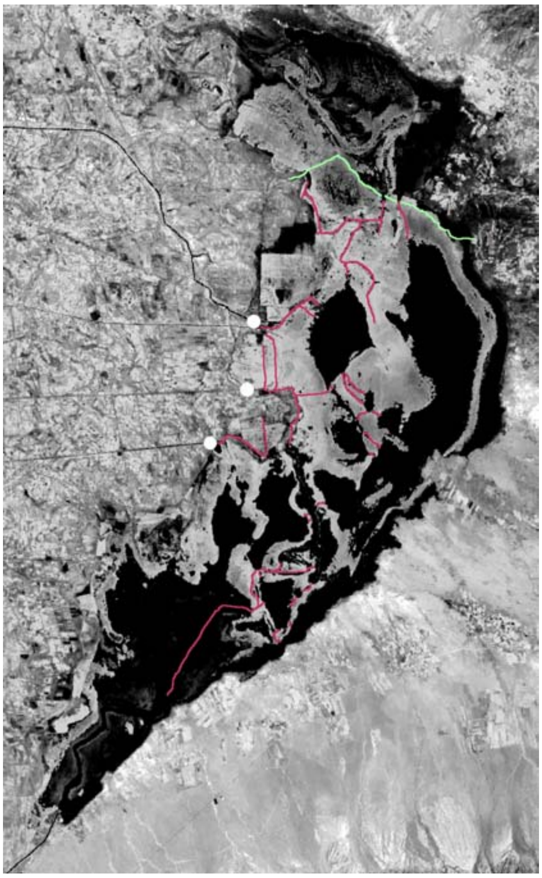


Figure 37. This satellite image shows internal lake canals (red). Water inlet points are shown as white dots. A road embankment crosses the northern part of the lake (green); effectively sealing off the northern basin from the rest of the lake. Please note that the accurate position of the road is not drawn.

4.16.5 Simulating flow vectors of Lake Wuliangsuhai

In order to assess the distribution of flow vectors within the Lake Wuliangsuhai a Finite Element Model (FEM) was established, see Chapter 3. The initial model was based upon bathymetric information, the above influx figures and the map of vegetation / open areas. The scenario was then expanded to include the existing lake canals as shown on the satellite image (below). This is termed 'Base Case Scenario'.

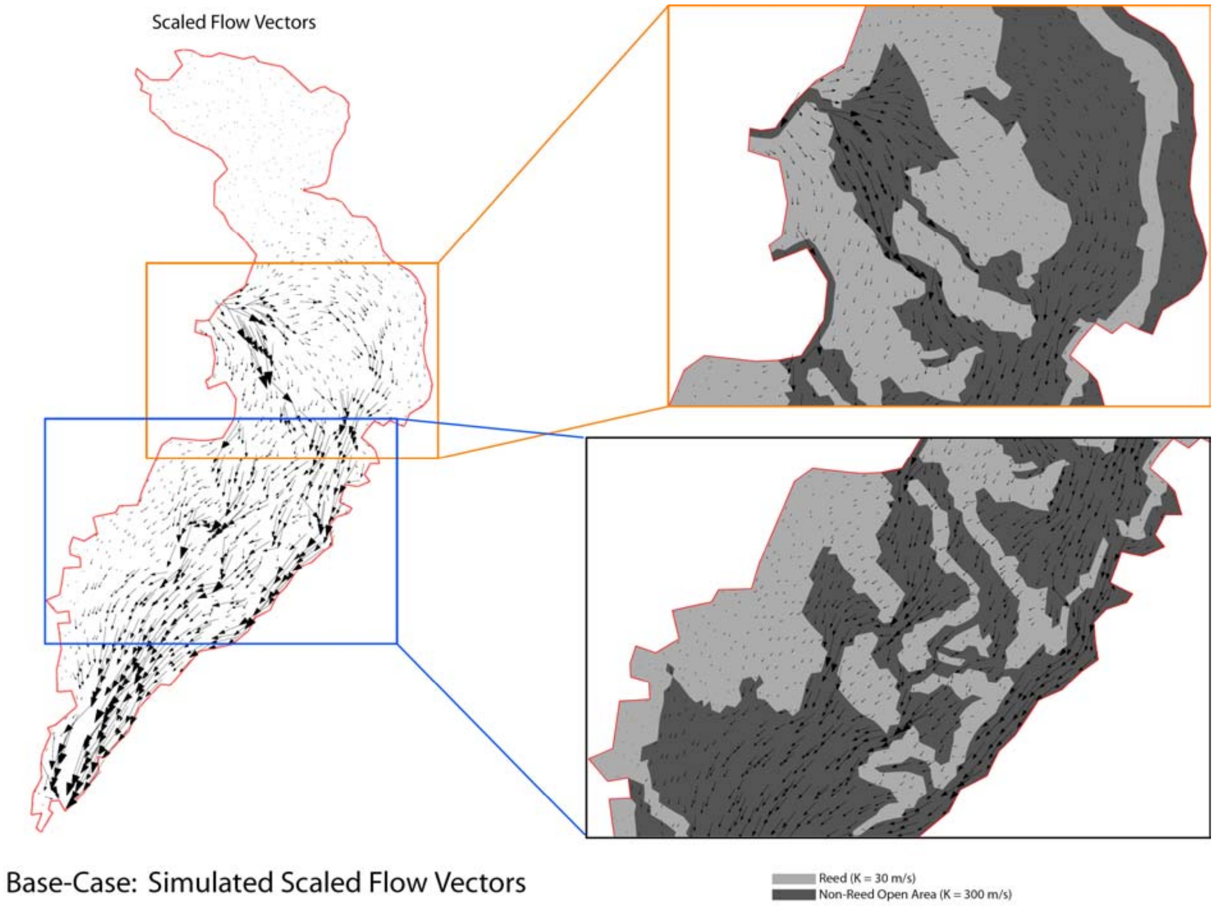


Figure 38. Results from Base Case Scenario simulations. For details and assumptions, see Chapter 3. Influx figures are as described above.

The overall effects from existing canals in the lake are illustrated on the maps above. The resolution of the FEM model is around 100m. In spite of this low resolution, the results from Base Case Scenario simulations clearly indicate the pronounced channelling effects of existing lake canals. The FEM model results are summarised as follows:

- Significant channeling of flow along canals
- Majority of water flows quickly through preferential pathways (=canals)
- Distribution of flow to northern 1/3 of lake is very limited.
- Stagnation zones apparent in N and SW

It has been common knowledge that the present water recycling situation in the northern as well as the northeastern part of Lake Wuliangsuhai is not satisfactory. The eastern area between Shajianzi and Nanchang is characterised by stagnant water, with reduced biodiversity. The model simulations seem to confirm this picture.

4.16.6 Increased circulation: canals vs. barriers

It has been shown that canals are effective in draining water, i.e. removing water *from* an area. However, the concept of increased circulation often implies the apposite: forcing water *into* desired areas. To illustrate this, a situation was simulated by FEM, where a levee (barrier) was simulated constructed South of the Main Drainage Canal inlet point. The map below illustrates this scenario.

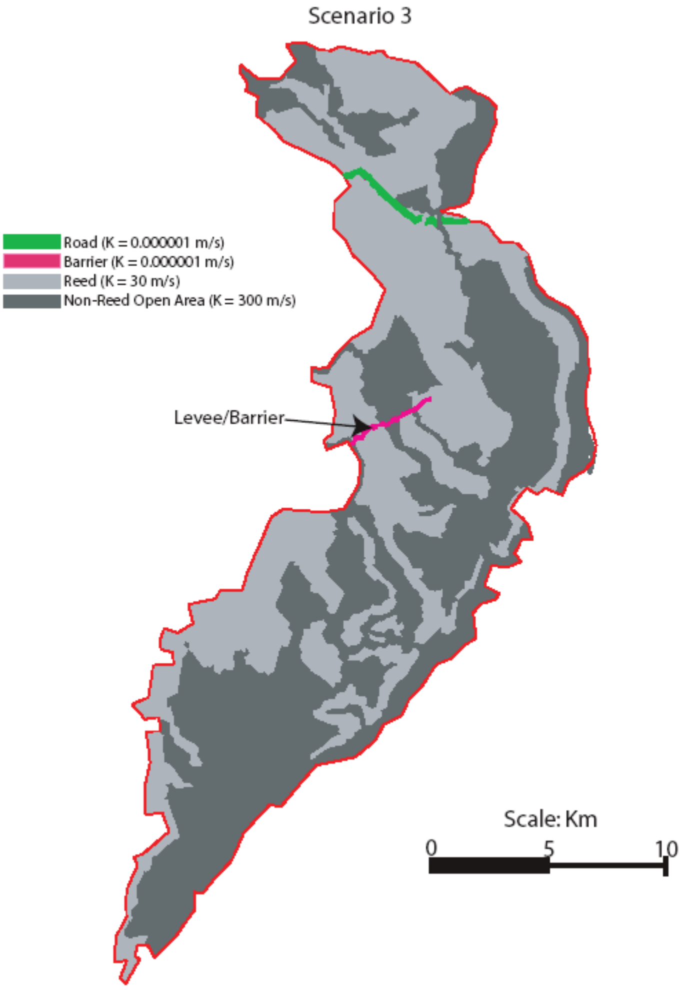


Figure 39. A levee (barrier) is simulated constructed South of the Main Punping Station inlet. A road in the northern part of the lake (green) also serves as a levee, having two culverts through which water may pass.

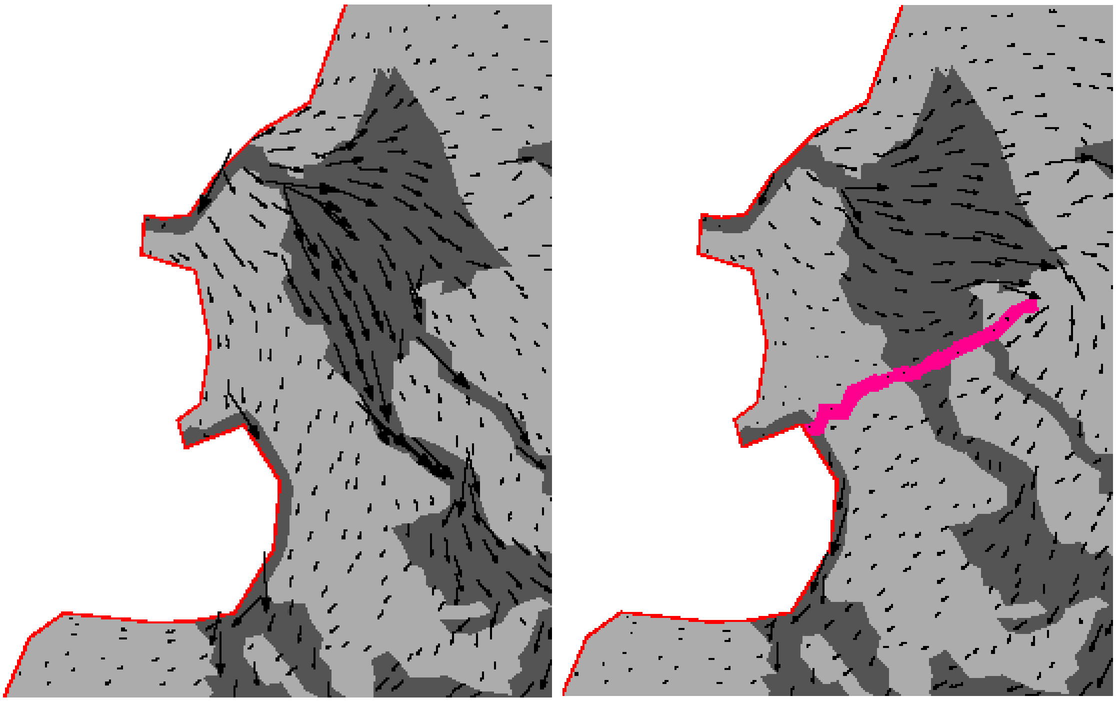


Figure 40. The effects of establishing levees (barriers) are more dramatic than those of canals. The left image illustrates a situation described above as the 'Base Case Scenario'. The right image illustrates the effects of a levee (barrier) (red) on water emanating from the Main Pumping Station. For more base information, see Chapter 3: Scenario 3.

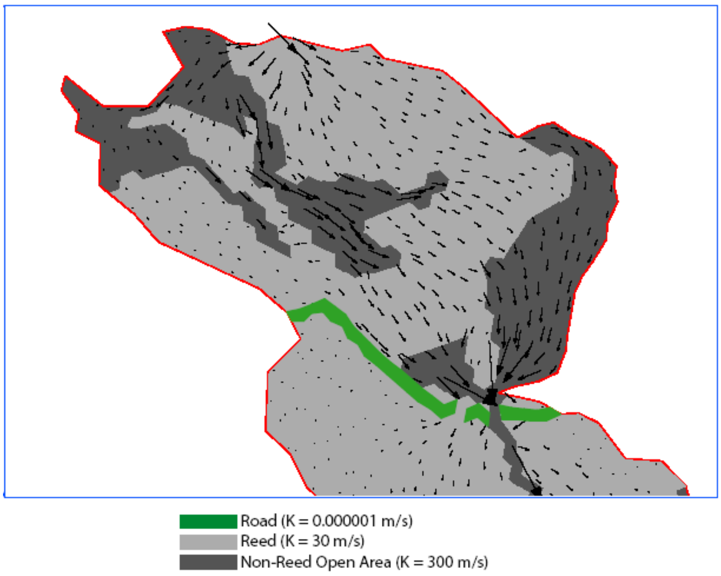


Figure 41. The effects of a levee is seen in this illustration, where water from the North (the model scenario assumes 8 m^3/sec to be introduced here) follows the road embankment and passess through the two culverts

Compared to canals, the use of levees (barriers) is obviously a more cost-efficient means of deflecting and redirecting water to desired areas, i.e. improve the internal circulation of the lake.

Moreover, the construction of levees is less costly and requires simpler technology, for several reasons:

- The transportation of excavated or dredged mud is a only few meters,
- The machines can operate from dry land (on top of the levee) as work progresses.

The resulting excavated strips on the lee (down) side of the levee may double as navigation canals, and will also ensure a minimum of water circulation on the downstream side.

An important aspect of canals vs. levees is the fact that the latter can make better use of smaller volumes of water. In the case that additional water from external sources such as the Yellow River becomes problematic, levees will assist in making good use of whatever water there is.

4.16.7 Technology requirement and implementation

Technology requirement

The targets outlined above will be achieved by the measures as described in the following.

Based on a calibrated computer simulation tool, such as presented above, a number of different scenarios can be tried and tested, in order to optimise effects and configurations. The model will be updated and calibrated in this process. Both the concepts of canals and levees can be modelled, and the cost-effectiveness of different scenarios can be compared and presented to stakeholders. The costs of model simulations are nominal, in particular compared to field implementations. For computer simulation, an ordinary PC will do. For more description of the software aspects, see Chapter 3.

Traditional excavation equipment or a modern rotary suction dredger will serve the purpose of constructing barriers. The need for culverts, if required will be decided by model simulations.

The use and results of a selected set of modelling scenarios have been demonstrated, cfr Chapter 3 above. These case studies can be infinitely refined and calibrated. The FEM model developed for this purpose (or any equivalent solution) should be hosted locally and be at the disposal of stakeholder groups within the lake area. The project would then act as a clearinghouse for users, being able to accommodate project proposals, new concepts or ideas that emerge.

4.16.8 Impacts on environment

- The environmental impacts by the creation of levees and canals in Lake Wuliangsuhai can be either dramatically positive or negative. A wrongly designed system of canals or levees can have severe environmental and economic impacts. Model simulations prior to field implementation may reduce the risk of project failures. Provided assumptions are valid and the procedure correct, no negative impacts are foreseen by establishing a system of circulation levees or channels within Lake Wuliangsuhai.

- The proposed circulation project may reduce the total area of reeds but the overall reed production may increase.

4.16.9 Economical content

With an estimated total length of 40km of levees or canals, with 0.5m depth increment and 15m width, and with a unit cost of 12RMB/m^3 the total implementation costs cost will amount to 3.6 Million RMB.

Table 62. Investment costs over 2 years

Computer software for modelling lake dynamics (RMB)	30 000
Training of operator, 1 month (RMB)	30 000
Estimated length of levees/canals (km)	40
Cross sectional area of excavation (m^2)	7.5
Volume of sediments to be moved (m^3)	300 000
Implementation period (years)	2
Estimated cost of sediment removal (RMB/m^3)	12
Total cost of implementation (RMB)	3 660 000

Operational aspects

The dredging project does not require operational costs once implementation has been completed.

4.16.10 Impacts on society and economy

Social impacts

Improvement of water circulation, combined with other measures of ecological management can improve the ecological conditions of Lake Wuliangsuhai. In particular, these measures are believed to counteract the process that may soon turn the reed areas into bogs; a process that will mark the end of the lake and also the social structures built around it.

Economic impacts

Water cycle improvement project may be beneficial to the fishery of the Lake Wuliangsuhai, and may renew the number of species and increase the quantity of fish. The annual output of fishery may reach 3000 tons.

Water cycle improvement project may minimise the water mineralization of the Lake Wuliangsuhai, enhance the production of reed, and reduce the problem caused by decaying plants.

5 Ranking of Management and Control (MC) Plans

After identification of potential actions and their benefits, it is necessary to rank them according to the priorities. In a given situation with limited financial resources, it is an important task.

The ranking of the proposed actions can be carried out using various approaches. A logical approach would be to:

1. actions to reduce the pollution loads to the lake
2. actions within the lake which reduces pollution
3. actions to secure sufficient quantities of water to control vegetation, provide favourable dilution and to improve biodiversity, etc
4. actions to sustainable utilisation of the lake's resources

Such an approach is widely utilised by internationally and in China, and are well in agreement among the Chinese, Swedish and Norwegian specialists. The ranking of activities following such an approach is presented in Table 63.

Table 63. Ranking of actions according to common approaches. (Recommended)

Rank	No	Description
1	2	Industrial wastewater treatment (all)
2a	1.3	Wuyuan wastewater treatment
2b	1.2	Linhe wastewater treatment
2c	1.1	Hanghou wastewater treatment
3	6	Yellow River water supply and lake level increase
4	7	Moving of inlet and wetland construction
5	4	Harvesting submerged vegetation and utilisation
6	5	Reed bed control
7	8	Erosion control
8	9	Agricultural pollution abatement
9	10	Improvement of internal circulation
10	3	Dredging (all)

The usage of a more comprehensive approach was demonstrated during the project.

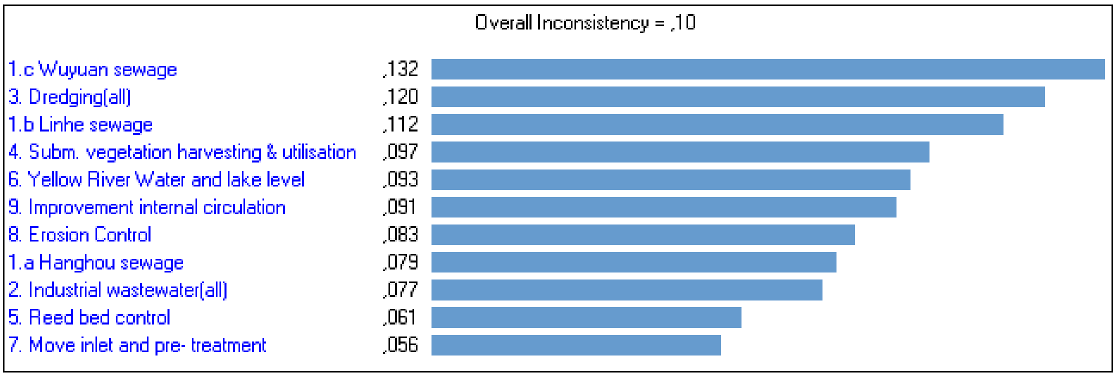
As part of the Management and Control Plan for Lake Wuliangsuhai a stakeholder workshop was held in Linhe 23-24 November, 2004, with the purpose of carrying out a multi-criteria analysis (MCA) and project ranking session with a group of stakeholder representatives. This chapter is based on a report that discusses the data and assumptions behind the MCA.

A series of scenario analyses for alternative future scenarios for lake water quality ("turbid" and "clear") were conducted, as well as the differences in preferences for different criteria expressed by the stakeholders. It was found that ranking of management and control measures (MCM) are not very sensitive to the choice of scenario or set of preferences.

In a clear water scenario, the ranking of MCM is presented in the table below, taking into account both the aggregate benefit calculated across 37 criteria, subcriteria and indicators, as well as cost of the measures. Based exclusively on environmental, social and institutional impacts ("benefits") the erosion control measure (MCM 8) ranks highest.

If cost of measures is also considered in the form of a cost/benefit ratio, the general conclusion is that the smallest, cheapest measures should be implemented first, starting with reed bed control (MCM 5). The ranking of measures with very different scales of implementation cost leads to this difference in implementation priorities. This is because environmental, social and institutional impacts ("benefits") are largely qualitative in the analysis and cannot capture the difference in the scale of the measures represented so clearly by 2 orders of magnitude difference in the costs of the cheapest and most expensive measures.

Figure 42. .Management and control measures ranked by weighted benefits



Limitations of the analysis include the fact that most of the environmental data used for ranking are based on qualitative expert opinion, rather than modelling. This was due to the fact that the decision to compare and rank measures using a multiple criteria approach was taken quite late in the project, after monitoring data and modelling tasks had been designed and carried out.

Table 64. Cumulative costs and benefits of management and control measures

Ranking based on benefits only	Alternative	Individual benefits (normalised)	Individual costs (million Yuan)	Cost/ normalised benefits (million Yuan)	Ranking based on ratio costs/normalised benefits
1	1.3 Wuyuan sewage	1	236 029 934	236 029 934	10
2	3. Dredging(all)	0,914	304 757 590	333 432 812	11
3	1.2 Linhe sewage	0,852	81 376 045	95 511 790	5
4	4. Subm. vegetation harvesting & utilisation	0,738	105 776 571	143 328 687	6
5	6. Yellow River Water and lake level	0,705	159 330 406	226 000 576	9
6	10. Improvement internal circulation	0,691	3 598 918	5 208 275	2
7	8. Erosion Control	0,629	7 213 328	11 467 930	3
8	1.1 Hanghou sewage	0,599	132 093 951	220 524 125	8
9	2. Industrial wastewater(all)	0,582	16 425 647	28 222 761	4
10	5. Reed bed control	0,462	1 249 238	2 703 978	1
11	7. Move inlet and pre- treatment	0,423	71 797 479	169 733 993	7

Further limitations include the limited experience in adequate budgeting of management and control measures and scaling of the impacts. Most cost and revenue of measures are only based on the MC reports by the Chinese authors. The use of this data is not an endorsement of the valuation methods used in the MC reports as the underlying data were not verified. For some measures revenue estimates play a large part in the high ranking of the measure, particularly: revenues from the sale of fertiliser from dredged mud (MCM 3) and from harvested submerged vegetation (MCM 4). In both cases, revenues are calculated based on existing fertiliser prices without consideration of how the market will evaluate these as substitutes for chemical fertiliser, nor are supply-side effects on local market prices considered. In the case of erosion control (MCM 8) large increases in revenue have been assumed in agriculture and pasturing. In a large number of projects around the world the predicted effectiveness of erosion control has been exaggerated. In a detailed feasibility analysis, these assumptions should be revised in detail.

Table 64 illustrates in the first column the ranking of measures if implementation is based only on environmental, social and institutional criteria (benefits). The last column illustrates the ranking if the cost/normalised benefits ratio is used. The latter illustrates the limitation of the MCA analysis when the cost of measures varies across a large scale, while the qualitative characterisation of impacts does not capture the same variation in scale. Consequently, the ranking based on cost/benefit ratio more or less implies implementing the cheapest measures first (because relatively little information is provided on the scale of benefits). Investments towards establishing sustainable conditions of the Lake Wuliangsuhai should follow this sequence if the budget for implementation is only gradually made available.

Despite the limitations in the underlying data, the ranking exercise itself conducted at the Linhe workshop was considered a success. Stakeholders found the description of the impacts of each MCM understandable and the process of recording their preferences manageable.

Assuming further quality control of the data and analysis in this report by our Chinese counterparts, and periodic updating of preference weights for the different criteria, we are cautiously optimistic that the method illustrated in this report has helped structure decision-making and will provide continued guidance in evaluating additional measures which may be proposed in a programme of measures for Lake Wuliangushai.

6 Concluding remarks: Achievement of results

The initially identified 15 potential actions were integrated in to 10 actions, which were studied in detail by various groups of specialists. The summary of these results were presented in the previous chapters.

When only limited amounts of resources are available, actions need to be priorities. This process is normally achieved by a combination of scientific and political priorities. It is important to have the participation of stakeholders to secure the ownership of such an action, which will inevitable improve the efficiency, results and the sustainability. The previous chapter has presented a methodology and an example how such a prioritisation can be made jointly with many stakeholder groups.

To achieve the overall goal of the project – to keep the lake as a lake – a series of objectives need to be achieved. Some of these objectives are qualitative, which is difficult to present quantitatively. Some of these objectives are achieved over a long period, thus it is difficult to measure any impact over a short period. However, there are a number of concrete objectives, which can be measured. The reduction of pollution loading is such an objective, which will be analyzed further.

6.1 Achievement of pollution reduction

The scientists, to a greater degree, agree about the current pollution loading and the required loading to reduce the eutrophication potential to a minimum and as well as to improve the current water quality status from Class-IV and V to III. Approaches to estimate these figures are presented in the chapter 2.10. The summery of values are presented in the below table.

Table 65. Current and required pollution loading to the lake

	Organic matter, COD	Total-Phosphorous	Total Nitrogen
Current loading, t/a	18750	106	1673
Recommended loading, t/a	10 000	30	800
Required reduction, %	47%	72%	52%

Table 66. Change of pollution loading after wastewater treatment

	COD	TP	TN
Current loading, t/a	18750	106	1673
Reduction by domestic WWTP, t/a	3 921	58	155
Reduction by industrial WWTP*, t/a	7 639	5	464
Sum loading after actions, t/a	11 560	63	619
Remaining loads after actions	7190	43	1054
Recommended loading, t/a	10 000	30	800
Loads should be reduced by Wetland	0	13	254

**Including the effect of closure of Hongjiang paper mill.*

The domestic and industrial wastewater treatment requires 310 and 10 million RMB, respectively. The wastewater discharges to the sewers from industries and municipal WWTP should comply with the Chinese national effluent standards of GB 18918-2002. The standard for municipal WWTP effluent according to the Class-I B is 1 mg/l of Tot-P, 20 mg/l of Tot-N and 60 mg/l of COD. The above table shows that the proposed domestic and industrial wastewater treatment plants can reduce the pollution loads to by far to the required levels. The phosphates need to be reduced further by 13 t/a or 12% and nitrogen by 254 t/a or 15%. Both these targets are easily achievable with a well functioning wetland, which is proposed. Both these targets are easily achievable with a well functioning wetland, which is proposed.

Alternatively, the phosphorus and nitrogen removal can be achieved by upgrading the domestic treatment plants to more efficient systems. One has to remember that with the proposed improvements in the sewer connections, more pollutants will be transported directly to the lake via a treatment plant, a loading that is probably not fully accounted for in the current figures. On the other hand, the environmental authorities are demanding higher treatment efficiencies than the design capacities of the proposed wastewater treatment plants, which will naturally reduce the loading. With the other actions improving the circulation and even retention within the lake, one can assume improved self-purification levels. However, it is safer to assume that a wetland will be a quite important activity to secure the safe loading levels.

6.2 Securing water quantities

Although the inputs of water into Lake Wuliangsuhai vary considerably between years, the loss by evapo-transpiration and percolation to the groundwater from the lake is relatively constant at ca. 400 million m^3/yr. This implies that the minimum annual water input from canals cannot go below this value without gradually reducing the water level on an annual basis. A lower water level than today might cause a rapid expansion of reed further into 'open water' areas of the lake. To achieve a replacement of the water volume, as well as to have a sustainable development and utilisation of the lake resources, at least another 200 mln m^3 should be supplied to the lake. The proposal is to obtain 253 million m^3/y from the Yellow River.

In addition, timing of the water inputs must be considered together with regulation regime of the outlet dam, not to reduce the water level below accepted levels. The annual mean water level of Lake Wuliangsuhai has varied in the range 1018.4-1018.9 m with an average of 1018.5 m above sea level in later years. It is proposed to increase the lake water level to 1019.0-1019.3 m above sea level, which in turn increases the average depth with 0.5-0.8 m.

6.3 Improving the internal circulation

The retention of incoming water within the lake and its circulation has valuable functions in the self-purification process. As is demonstrated in a number of simulation figures (as well as observed manually), the retention time of water masses vary quite significantly. Additionally, the vegetation and sedimentation reduces the volume available for this function. Thus, it will be very beneficial to the lake restoration activity to improve the internal circulation of the lake. It will secure a more even retention and transport of water through the whole lake area. The canals may easily create short-circuiting worsening the current situation. The actions should be preferably verified using hydrological models as done in this study to avoid costly errors.

6.4 Improving biodiversity

Biodiversity will be improved from the results of number of actions. There are actions like dredging and increasing the water level that will directly improve the biodiversity. Other actions, like improving the water quality of the lake, may increase the diversity and number of species found in the lake water and surroundings. The livelihood activities such as fishing and tourism must be carefully monitored that they will not create a negative impact on the biodiversity.

6.5 Socio-economical aspects

Although the project's main objective is to suggest actions "to keep the lake as a lake", the authors acknowledge the need for sustainable utilisation of lake associated natural resources for direct and indirect benefit of the more than one million of people that lives surrounding it. The suggested actions will definitively have a positive impact on the population on the quality of life by having access to a water body with better water quality and functionality. They will also have an impact on their livelihoods, which will increase their income. The increasingly practiced and observed stakeholder participation will secure the ownership and the sustainability of the actions, but attempts should be made to increase the current level of participation in the decision making process – by awareness raising.

6.6 Special restrictions

The role of the submerged vegetation in phosphorous control should not be underestimated. This type of vegetation consumes phosphates that are otherwise available for the alga, thereby limiting the potential for eutrophication. This is a special feature in shallow lakes with reference to the "two stable states", which is described in other project reports in this series. The removal of organic matter is critically important, as they will otherwise consume the oxygen in the water leading to further oxygen depletion in the lake. That will result in fish kills during winter also in coming years, causing a low survival of fish beyond one or two years' age.

It is extremely important to keep in mind that the Lake Wuliangsuhai is at present in a clear stage due to the phenomena described as the two stable states of lakes. Even a smaller action may convert larger parts of the lake to be turbid in a very short time, and making it a lengthy and difficult process to reverse. Therefore, it is emphasised that all actions within the lake should be verified on pilot scale and observed carefully for any possible indication of loosing the stable state. One potentially dangerous action is the harvesting of submerged vegetation. It is suggested to follow the limitations proposed in this study, which is maximum 16-32 km^2. This should be carried out in stripes so only half of the total area is harvested. The maximum harvesting area should be less than 25% of the total area of submerged vegetation.

Any new activity that may introduce pollutants to the watercourses must be strictly regulated. The environmental authorities must be entrusted with such decisions, and must be given the opportunity to build their knowledge basis.

6.7 Financial issues

The fact that the restoration of the lake is proposed as a specific issue in the next 5-year plan is a significant acknowledgement. However, most of these funds need to be secured externally through bi- or multi lateral loans. Considering the ownership of the action, it is recommended the following financing structure:

- Industries should bear 100% of the investment costs
- Municipal WWTP: 30% from the local government and the enterprises
- Other costs and measures: loan and investments from the Inner Mongolia Central Governments as well as donors

The proposed actions sum up to an investment of 800 million RMB, excluding the pollution reduction from agriculture. For the domestic wastewater treatment plants, the total is about 310 million RMB, indicating a need of over 200 million RMB as loans. The industries have a relatively lower investment burden of 10 million RMB, provided the Haojiang paper mill will remain closed. Otherwise, heavy investments will be required.

Table 67. Summary of investment, O&M costs and annualised costs, RMB. (NB! Based on preliminary estimates)

MCP		Investment(I)	O&M	Investment life, years	Present value (O&M)	Present residual value of investment year 30 (R)	Total present value(I+O&M+R)	Income/year	Present value of income
1a	Hanghou WWTP	90 930 000	4 630 000	25	41 770 962	607 011	132 093 951	5 830 000	52 597 129
1b	Linhe WWTP*	37 310 000	4 912 000	25	44 315 111	249 066	81 376 045	20 020 000	180 616 557
1c	Wuyan WWTP	181 850 000	6 140 000	25	55 393 889	1 213 955	236 029 934	28 702 000	258 943 877
1	Sum domestic WWTP	310 090 000	15 682 000	25			449 499 930		
2a	Hongchang	5 417 000	336 000	25					
2b	Renze	1 500 000	80 000	25					
2c	Weixin	3 225 000	288 000	25					
2d	Haojiang paper	closed							
2	Sum industrial WWTP	10 142 000	704 000	25	6 351 351	67 704	16 425 648	2 500 000	22 554 515
3	Dredging	309 930 000	0	20	0	5 172 410	304 757 590	25 000 000	225 545 151
4	Harvesting submerged vegetation	54 980 000	6 037 240	10	54 466 808	3 670 237	105 776 572	16 000 000	144 348 897
5	Reed bed control	200 000	120 000	5	1 082 617	33 378	1 249 239	0	0
6	Introduce yellow river water	40 970 000	13 180 000	50	118 907 404	546 997	159 330 406	0	0
7	Moving of inlet and wetalnd construction	57 912 920	1 539 000	30	13 884 560	0	71 797 480	0	0
8	Erosion control	3 974 500	359 000	30	3 238 828	0	7 213 328	1 454 760	13 124 563
9	Farmland pollution control	ommited - estimate >3 billion RMB							
10	Improvement of water circulation	3 660 000	0	20	0	61 082	3 598 918	0	0
	Sum	**791 859 420**	**37 621 240**		**339 411 530**	**11 621 839**	**1 569 149 041**		

Note: present values calculated using:
Discount rate 0.12
Analysis horizon (years) 30
Residual capital values in year 30 using linear depreciation

Among the additional actions not studied in detail during the course of the project, the following three could be mentioned:

1. Wulateqianqi wastewater treatment plant (RMB 33,5 mill)
2. Restoration of fish population and fishing (RMB 20 mill)
3. Automated water quality monitoring facility (RMB 10 mill)

6.8 Ranking of the actions

The ranking of the proposed actions can be carried out using various approaches. A logical approach would be to:

- actions to reduce the pollution loads to the lake
- actions within the lake which reduces pollution
- actions to secure sufficient quantities of water to control vegetation, provide favourable dilution and to improve biodiversity, etc
- actions to sustainable utilisation of the lake's resources

Such an approach is widely utilised by internationally and in China, and are well in agreement among the Chinese, Swedish and Norwegian specialists. The ranking of activities following such an approach is presented in Table 68.

Table 68. Ranking of actions according to common approaches. (Recommended)

Rank	No	Description
1	2	Industrial wastewater treatment (all)
2a	1.3	Wuyuan wastewater treatment
2b	1.2	Linhe wastewater treatment
2c	1.1	Hanghou wastewater treatment
3	6	Yellow River water supply and lake level increase
4	7	Moving of inlet and wetland construction
5	4	Harvesting submerged vegetation and utilisation
6	5	Reed bed control
7	8	Erosion control
8	9	Agricultural pollution abatement
9	10	Improvement of internal circulation
10	3	Dredging (all)

The usage of a more comprehensive approach was demonstrated during the project. The performance of each management and control measure (MCM) were studied according to the four main criteria ENVIRONMENT, ECONOMY, SOCIAL and INSTITUTIONAL, and using large number of subcritera. The major disadvantage in this approach is the need for more detailed information and the difficulty in securing reliable data.

This concept was presented in this report as a tool to be used in future activities.

This exercise has resulted in the in the following ranking of the priorities as presented in Table 69.

Table 69. An example of ranking of measures according to four main criteria: Environment, Economy, Social and Institutional. (subject to the verification of input data).

Rank	No	Description
1	1.3	Wuyuan wastewater treatment
2	3	Dredging (all)
3	1.2	Linhe wastewater treatment
4	4	Harvesting submerged vegetation and utilisation
5	6	Yellow river water supply and lake level increase
6	10	Improvement of internal circulation
7	8	Erosion control
8	1.1	Hanghou wastewater treatment
9	2	Industrial wastewater treatment (all)
10	5	Reed bed control
11	7	Moving of inlet and wetland construction

Although the costs of the measures need to be verified with detailed pre-feasibility studies, the following ranking is suggested based on the cost-benefit ratios. The need for a revised ranking with more secure cost and revenue measures is emphasised.

Table 70. Ranking of the measures according to cost-benefit ratios. (subject to the verification of input data).

Rank	No	Description
1	5	Reed bed control
2	10	Improvement of internal circulation
3	8	Erosion control
4	2	Industrial wastewater treatment (all)
5	1.2	Linhe wastewater treatment
6	4	Harvesting submerged vegetation and utilisation
7	7	Moving of inlet and wetland construction
8	1.1	Hanghou wastewater treatment
9	6	Yellow river water supply and lake level increase
10	1.3	Wuyuan wastewater treatment
11	3	Dredging (all)

Table 69 illustrates the ranking of measures if implementation is based only on environmental, social and institutional criteria (benefits). Table 70 illustrates the ranking if the cost/normalised benefits ratio is used. The latter illustrates the limitation of the MCA analysis when the cost of measures varies across a large scale, while the qualitative characterisation of impacts does not capture the same variation in scale. Consequently, the ranking based on cost/benefit ratio more or less implies implementing the cheapest measures first (because relatively little information is provided on the scale of benefits). Investments towards establishing sustainable conditions of the Lake Wuliangsuhai should follow this sequence if the budget for implementation is only gradually made available.

It is recommended to follow the ranking based on common approaches as presented in table 68. However, it is suggested to utilise the ranking tools and concepts presented in the previous chapter and in table 69 & 70 with more reliable data for a more precise and logical prioritisation.

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