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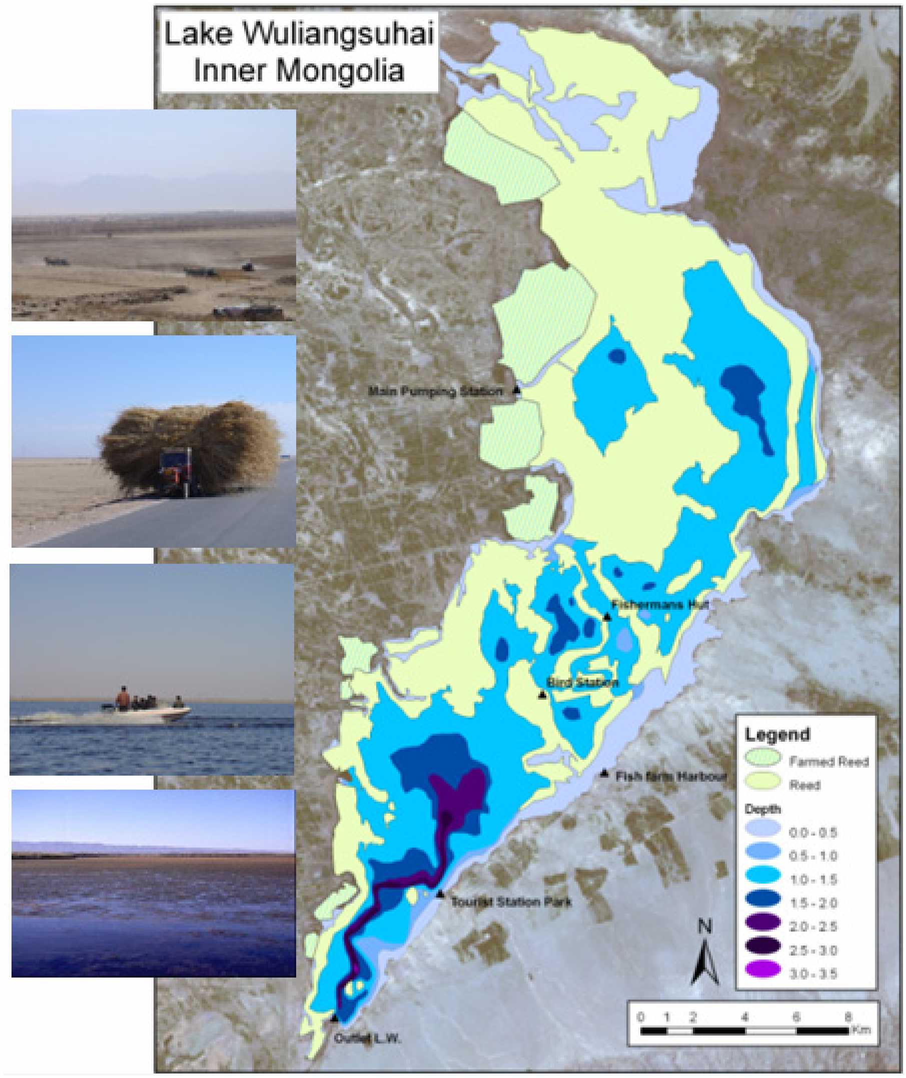
Economic analysis of the value of water in alternative uses in the Lake Wuliangsuhai catchment, Inner Mongolia, China



Norwegian Institute for Water Research
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REPORT

Main Office	Regional Office, Sørlandet	Regional Office, Østlandet	Regional Office, Vestlandet	Regional Office Midt-Norge
P.O. Box 173, Kjelsås N-0411 Oslo, Norway Phone (47) 22 18 51 00 Telefax (47) 22 18 52 00 Internet: www.niva.no	Televeien 3 N-4879 Grimstad, Norway Phone (47) 37 29 50 55 Telefax (47) 37 04 45 13	Sandvikaveien 41 N-2312 Ottestad, Norway Phone (47) 62 57 64 00 Telefax (47) 62 57 66 53	Nordnesboder 5 N-5008 Bergen, Norway Phone (47) 55 30 22 50 Telefax (47) 55 30 22 51	P.O. Box 1266 N-7462, Norway Phone (47) 73 54 63 85 / 86 Telefax (47) 73 54 63 87

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Abstract

While Lake Wuliangsuhai is one of China's largest freshwater lakes, its existence relies on the amount and quality of return flow from the Hetao irrigation area, in turn supplied from the Yellow River. The report estimates the economic value of lake uses including reed and typha harvesting, fishing, lake tourism business and recreation. Net returns to irrigated agriculture in Hetao irrigation area are estimated, including data on losses in irrigation transportation of water, and compared to published estimates of the returns to downstream uses of water in the Yellow River. Historical economic returns to multiple uses of Lake Wuliangsuhai are used to estimate average unit value of return flow from irrigation to the lake. Based on a simple model relating inflow – volume - lake level - area, several scenarios for impacts on total "reed area" and total "open water" area due to changes in inflow to LakeWuliangsuhai are constructed. Finally, the report estimates the marginal value of water supplied to Lake Wualiangsuhai to avoid a "worst case" scenario of permanent reduction in lake level.

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Table of contents

Tables

Figures

1 Revision information

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1	2005-08-20	David N.Barton	3	Final printed version

2 Executive Summary

The present study uses available data on historical income and operating and capital cost data to reed and typha harvesting, returns to fishing, lake tourism business and non-market valuation of recreational benefits to calculate net annual returns to these lake uses. A similar analysis of net returns to irrigated agriculture in Hetao Basin is undertaken, as well as obtaining published estimates of the returns to downstream uses of water in the Yellow River. Net returns to different crops are compared to total water use by crop in field, including data on losses in irrigation transportation of water. Based on this data we can construct a simplified demand curve for water in irrigated agriculture. Comparing historical returns to multiple uses of Lake Wuliangsuhai with historical data on water inflow/return flow from drainage canals in the irrigation area we also obtain average unit values for water delivered to the lake. Based on data in the Monitoring Report and simple models relating inflow – volume - lake level - area, we construct several scenarios for impacts on total "reed area" and total "open water" area due to changes in inflow to Lake Wuliangsuhai. Consistently using conservative assumptions to estimate lake water uses, we then estimate the marginal value of water supplied to Lake Wualiangsuhai to avoid a "worst case" scenario of permanent reduction in lake level.

Based on available data, primary data collected in the field[1], and the assumptions in the report we discuss issues of water allocation in Hetao. We conclude that the average economic values per unit area of reed and open water calculated in the report 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 Yuan/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 Yuan/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 we assume 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

[1] A large data collection effort was made by Chinese M.Sc. students affiliated to the project to document income to tourist business, as well as consumer surplus of visitors to the lake through a travel cost and contingent valuation survey. Much additional data on agricultural returns and water use were also collected with the help of M.Sc. students and their field assistants.

211 million m^3/year - is between 0.04-0.06 Yuan/m^3. This is higher than the 0,0274 Yuan/m^3 the lakeside Fish Farm company paid for about 78 million m^3 in 2004. We therefore conclude that the Fish Farm's purchase of Yellow River water at the 2004 terms had net benefits from a 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.

The reader should keep in mind that no effort is made in the report to assign economic values to potential future lake uses which are not present today. The most likely additional future uses are harvest of aquatic plants for production of animal feed, utilization of mud for fertiliser production and international ecotourism based on bird watching. 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 (Monitoring Report, this project). Future revisions of this report should include transferring estimated economic benefits of bird conservation for international tourism from similar RAMSAR wetlands to Lake Wuliangsuhai.

We have also used conservative assumptions for recreational values based on data collected in the visitor's survey. Currently the main reasons for visiting lake among the mainly Chinese one-day visitors are 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.

We have excluded from the analysis potential new businesses based on lake resources, such as production of fertiliser from mud dredging and production of animal feed from harvesting of Potamogeton. These were excluded because historical site-specific or reliable secondary data was not available. For all of these reasons lake values we have calculated are conservative.

Furthermore, no value is assigned to water stored in Lake Wuliangsuhai and released into 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 Yuan/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 lake shore. 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 we make some simple comparisons on the value of water allocation (Figure 1). If irrigation water losses are excluded from calculations (0% loss) we see that the values of water in irrigated water in Hetao are considerably higher than values with irrigation losses observed in 1989[2] . Increase in the water value of economically marginal crops such as wheat may be as much as 0,5 Yuan/m^3. This is more than our most conservative marginal value of water for lake uses. 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 using 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 Yuan/m^3 (1999) – 0.39 Yuan/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 Yuan/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 we add 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.

[2] SHI Yaohua, LIU Huizhong, Wu Tongshun, The Study of Water Saving in Hetao Irrigation Area, paper collection edited by China Water Academy Association, (1999). Data from experiments conducted in 1989.

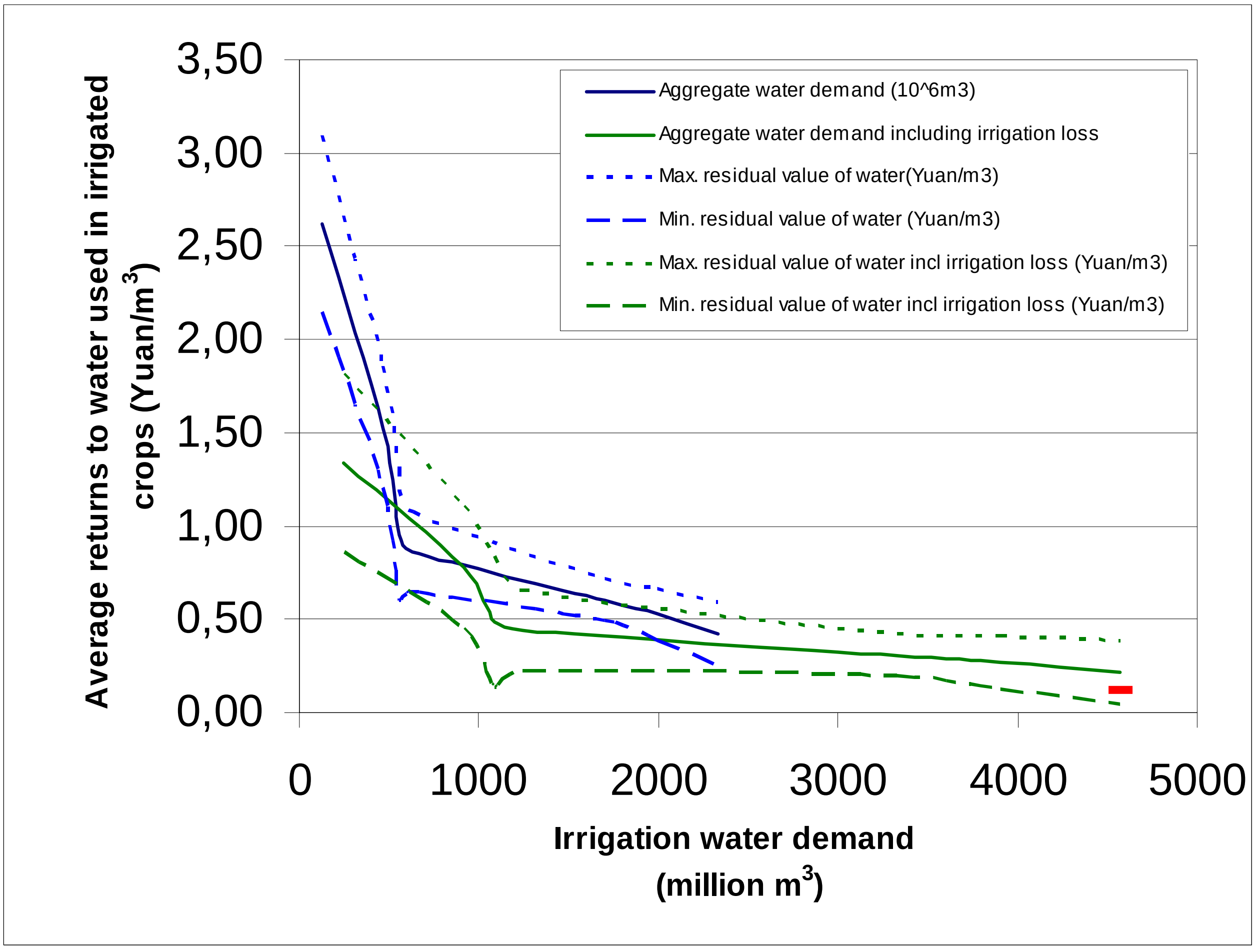


Figure 1 Returns to use of water in agriculture (1999-2003), average opportunity cost in Yellow River (grey line), estimated value of return flow for lake water uses (short red line lower right hand corner).

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 Yuan/m^3 (638 million m^3 = 1998 return flow); 0.10-0.11 Yuan/m^3 (440 million m^3 = 2001 return flow) and 0.04-0.06 Yuan//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.

3 Purpose and Scope

The purpose of the following report is to provide some answers to questions raised in other project reports regarding the economic value of current and historical lake uses, and the value of water supplied to the lake from the Hetao irrigation area. Furthermore, the report sets out to evaluate the value of upstream competing uses of water, principally for crop irrigation.

Given that irrigation water use is by far the largest competing use of water with lake uses we focus benefit-cost analysis on trade-offs between these two sets of water uses. Therefore, the report does not cover drinking water and industrial water use versus other uses in the Hetao Basin.

Chapter 4 gives a brief description of the main water uses in Lake Wuliangsuhai and the Hetao Basin. Chapter 5 discusses several scenarios for future inflow to Lake Wuliangsuhai as the result of water saving measures in agriculture, consequences for inflow to Lake Wuliangsuhai, and estimation of impacts on lake volume, level and reed and open water area, based on data from the Monitoring Report. Chapter 6 details scenarios for future water use which are the basis for evaluating the marginal value of water. Chapter 7 carries out a benefit-cost calculation for each of the main water users and calculates net annual financial returns to the activity and compares this to water use. Chapter 7 concludes with some benefit-cost comparisons of returns to water in different uses within the basin and related policy recommendations.

Two M.Sc. students from the University of Oslo are conducting their theses within the topic of valuation of alternative water uses and lake visitation (Tianyi Shen and Wenting Chen). A joint aim of the activities described in this report has been to provide tutoring in fieldwork and data analysis, contributing towards completion of their theses.

4 Background

4.1 Lake Wuliangsuhai's catchment

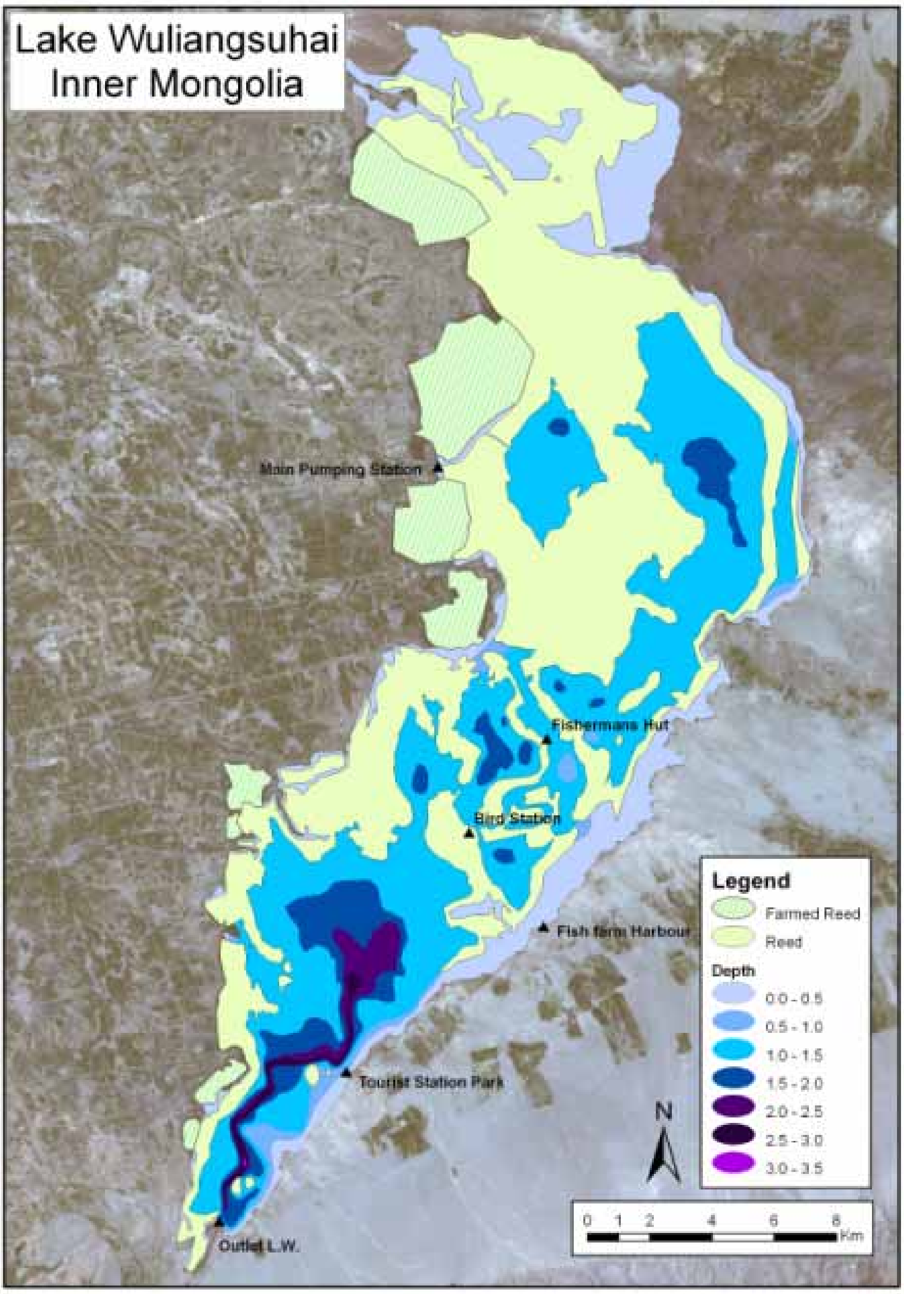
Hetao irrigation area has been irrigated for centuries. The downstream part of the current system consists of a number of drainage canals (numbered 1 to 7) entering the Main Drainage Canal and finally Lake Wuliangsuhai. Two canals (#8 and 9) enter the lake separately at its southern end. The layout of the area is given by Figure 2 (MCP Report). Total irrigated agricultural area is 603 800 hectares[3], dominated by wheat, maize and intercropping of wheat- maize, with smaller areas of sunflower, grazing, forest, orchards, oil plants and beet.

Figure 2 Map over Hetao and the irrigation system. Source: (BaMeng Hydrological Bureau, 1980) and MCP Report 1.
Note: 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

[3] Statistics of crop irrigation area by subcatchment from 1960 to 2000, the collection of irrigation and drainage information in Hetao Irrigation Area, p25-43, 1998-2002.

4.2 Lake Wuliangsuhai

Lake Wuliangsuhai is the biggest fresh water lake in Yellow River drainage area. Based on satellite images for 2001 the area of open water has been calculated as 167,64 km^2 and the area covered with naturally grown reed 146 km^2, in total 346 km^2. Another 32.2 km^2 is covered with reed grown on abandoned farm land. The volume of the "open water" areas of the lake was calculated to be 174.0 million m^3 and the average depth 1.034 m (Monitoring Report). Water balance calculations in the Monitoring Report were made for 2001. We use these figures in scenario evaluations in continuation. For purposes of comparison, in June 2001 average lake level was 1018,25 masl. Maximum and minimum level recorded for 2001 were 1018,82 and 1017,9 masl respectively (Monitoring Report).



The map in *Figure 3* shows the largest areas at depths of less than 1.5 meters. Natural reed cover seems to dominate at depth between 0.5 and 1.5 meters, although no depths is given in reed areas.

Figure 3 Lake Wuliangsuhai depth map

4.3 Current and potential direct uses of lake

The recent history of Lake Wuliangsuhai has seen an important fishery which today can only be characterised as potential if water quality improves and/or lake depth increases in spawning areas. Historical development of the lake is discussed further in the Historical Development Report. Excerpt from interview with 4 retired fishermen is included here providing a good context for the description of present versus past and historical uses of the lake (Historical Development Report).

'The fishermen interviewed came to Lake Wuliangsuhai in the 1950s they were fishing all year through, both summer and winter. At that time there were several more fish species than today, and the amount of larger fish was higher (up to several kilograms). The colour of the fish-skin has changed from then to now: before the fish was clear yellow, now the colour is black or pale. The water level was also higher in the 1950ies and 60ies, maybe 1-1,5 meter higher than today. The fishermen explained that the level of the sediment was about the same as today, but the water surface level was higher. They supported this by telling that the lake surface area was also larger in that period. At that time it also happened that during flood periods a back-flow of water from the Yellow river would come into the lake, through the normal outlet. Today the highest water level is 1018,5 meter. (..) Earlier the water in the lake was clean, and the farmers could use it for drinking and cooking. Due to water pollution that is not possible today. '

In the 1990s visitation to the lake by Chinese tourists, both locally and from afar, reached more than 100 000 visitors per year, before dropping sharply in 2000-2001 due to the effects of the SARS epidemic and road construction which made access more difficult. Table 1 gives an overview of lake uses considered in this report and their current status.

Lake use	State	Critical environment parameter
Reed harvesting	Current	lake seasonal water level
Typha harvesting	Current	lake seasonal water level
Recreation	Current (recent decline)	access/summer water level;
Aquaculture	Incipient	groundwater
Fishing	Historical / Potential	water quality / lake water depth
Animal feed production	Potential	eutrophication level: macrophyte dominance over phytoplankton
Fertiliser production	Potential	available sediment

Table 1 Present and potential lake uses

By far the largest single employer in and around the lake is what is known as the Fish Farm Company[4], henceforth called the Fish Farm, employing more than 6000 people (2004) mainly in reed harvesting and visitor services (hotel, restaurant, visitor centre, boating).

[4] . Li Tianbao, Tuesday, November 09, 2004.

4.4 Current water uses in the Hetao Basin

Agriculture

Data on water loss in irrigation are based on experiments and actual measurements carried out by water research institute of Hetao Irrigation Bureau, Shahao Qu Experiment Station, Yichang Yonglian Experiment Station, Yongji Experiment Station (1989), Inner Mongolia Hetao Irrigation Bureau. Data on crop water use are based on statistics of crop irrigation area by subcatchment from 1960 to 2000, the collection of irrigation and drainage information in Hetao Irrigation Area, p25-43, 1998-2002. Data is also taken from SHI Yaohua, LIU Huizhong, Wu Tongshun, The Study of Water Saving in Hetao Irrigation Area (1999).

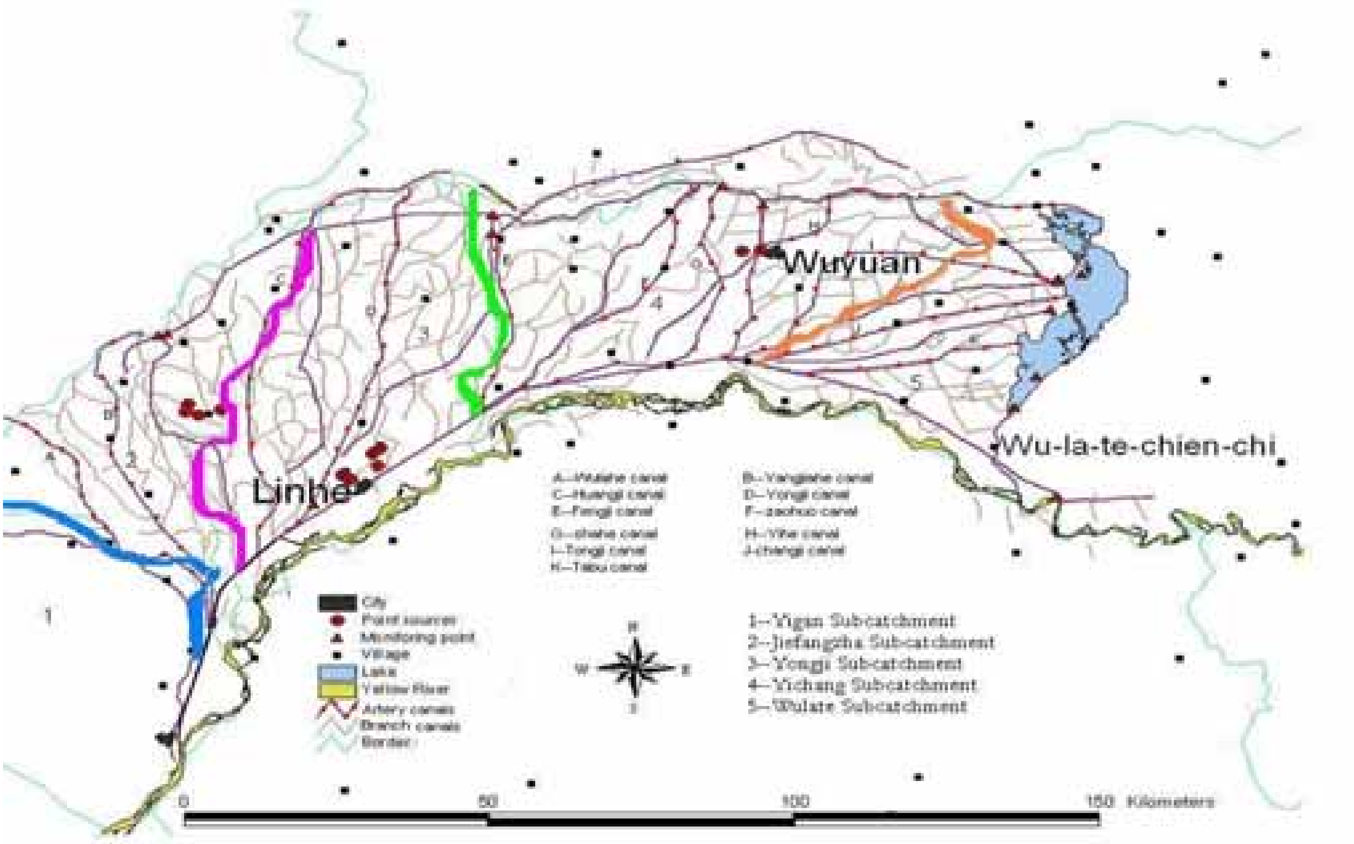


Figure 4 Definition of catchments for accounting of water use in agriculture.

Source: Project GIS database; map prepared by David N. Barton and Tianyi Shen

Data on water use from these sources has been compiled using the Irrigation Bureau's definition of 5 subcatchments which has some differences from the catchment definitions used in the pollution monitoring. The names of and divisions between the 5 subcatchments are illustrated in the map above.

By far the largest user of water in the Hetao Basin is irrigated agriculture of more than 603 000 hectares, consuming an estimated 4.915 billion m^3 of water per year. Of this 2.5 billion is water used "in the field" and the rest is loss in transport trough the irrigation system (evaporation, infiltration, leakages etc.).

Crop type	Gross total water use including irrigation losses (million m^3)	Total water use in field (million m^3)	Total crop area (hectares)
wheat	671	342	67 310
oil plants	180	92	31 934
summer mixture	79	40	21 594
maize	574	293	59 225
beet	151	77	17 128
sunflower	662	338	120 858
autumn mixture	220	112	44 489
interplanting (wheat-maize)	2088	1065	172 275
double cropping	42	21	23 879
forest,orchard and grazing land	250	127	45 110
Totals	**4 915**	**2 508**	**603 801**

Table 2 Crop areas and estimated water use in Hetao Basin

Source: based on data from Experiments and actual measurement carried out by water research institute of Hetao Irrigation Bureau, Shahao Qu Experiment Station, Yichang Yonglian Experiment Station, Yongji Experiment Station (1995); Statistics of crop irrigation area by subcatchment from 1960 to 2000, the collection of irrigation and drainage information in Hetao Irrigation Area, p25-43, 1998-2002.

The table shows that by far the largest water users in agriculture are wheat and maize (alone or in a system of interplanting). It should be noted that the statistics on water loss are from the 1980's. At this time almost as much water was lost in irrigation system as was used on crops. Thanks to a national project on water saving figures may be somewhat lower today (although see footnote 5). The residual value of water calculated with irrigation loss may therefore be somewhat underestimated. Further data on agriculture productivity are given in chapter 5.

Domestic and industrial water use

Water use by industry and the domestic sector are not considered in this report given that water use by these two sectors is low compared to agriculture and water saving recommendations here will have small effects relative to in irrigation.

Discharge forecasts have been made for the largest cities within Hetao Basin (MCP Report 1). 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. Forecast discharge volumes are good approximations of total water demand from the sectors. Rural population are not included[5] . Short term forecasts indicate total water demand of 30,5 million m^3 per year, or about 1,2% of total water use in field for crops and 0,6% of total water use for irrigation (including loss).

Banner and county	Discharge volume (x 10^3 m^3)			Gross industrial output (billion RMB)	City area population (persons)
	Total	Urban	Industrial		
Hanghou (Hangjinhouqi)	4,230	1,530	2,700	1.778	89,353
Linhe	9,380	5,080	4,300	4.134	225,871
Wuyuan	16,890	840	16,050	1.112	89,062
Total	30,500	7,450	23,050	7,024	404,286

Table 3. Prognosticated discharge volumes, economy and population of city areas in 2008

Source: MCP Report 1

[5] Population statistics for rural population within Hetao have to be estimated.

5 Wuliangsuhai catchment water budget

While monitoring data for lake water quality and lake level are relatively abundant, there are only few indications of how changes in lake level under alternative scenarios for inflow would impact on lake level, reed cover and water quality. This is a serious limitation for the economic analysis of alternative scenarios for water saving in upstream irrigated agriculture.

Figure 5 taken from the Monitoring Report shows the historical water balance of Lake Wuliangsuhai until 2000. Estimated water loss was at that time almost equal to water input. Using available data in the Monitoring Report, this section evaluates scenarios for 'projected' inflow to Lake Wuliangsuhai (from 2001) given scenarios for water saving in upstream agriculture.

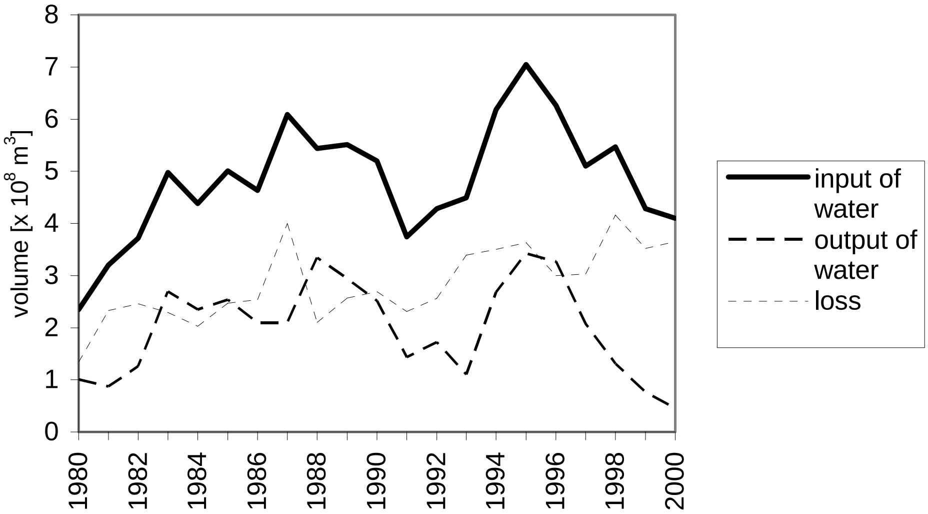


Figure 5 Simple water budget for Lake Wuliangsuhai

Source: Monitoring Report

Constructing a water budget for Hetao Basin was necessary in order to evaluate different scenarios for future water use in agriculture. The water budget for Hetao basin comes from a number of different sources (Table 5). A water budget for Lake Wuliangsuhai was prepared as part of the Monitoring Report with data until 2001. Unfortunately data from other sources is most often not for comparable years as the table shows. Experiments on water loss in irrigation were based on monitoring from 1989, while the irrigation norms used to estimate crop water needs where based on experimental data from 1995. Data on water purchases from the Yellow River by the Fish Farm are for 2003 and 2004 after this Project finished its data collection. In the following we have therefore had to assume that irrigation loss from the late '80's is applicable and use 2001 as a base year for projections[6].

Water loss in irrigation has a large impact on calculations of the residual value of water in agriculture. Some addition background on the data available is in order.

Sources of irrigation water loss are (Figure 6):

1. Evaporation from the water surface
2. Deep percolation to soil layers underneath the canals
3. Seepage through the bunds of the canals
4. Overtopping the bunds
5. Bund breaks
6. Runoff in the drain
7. Rat holes in the canal bunds

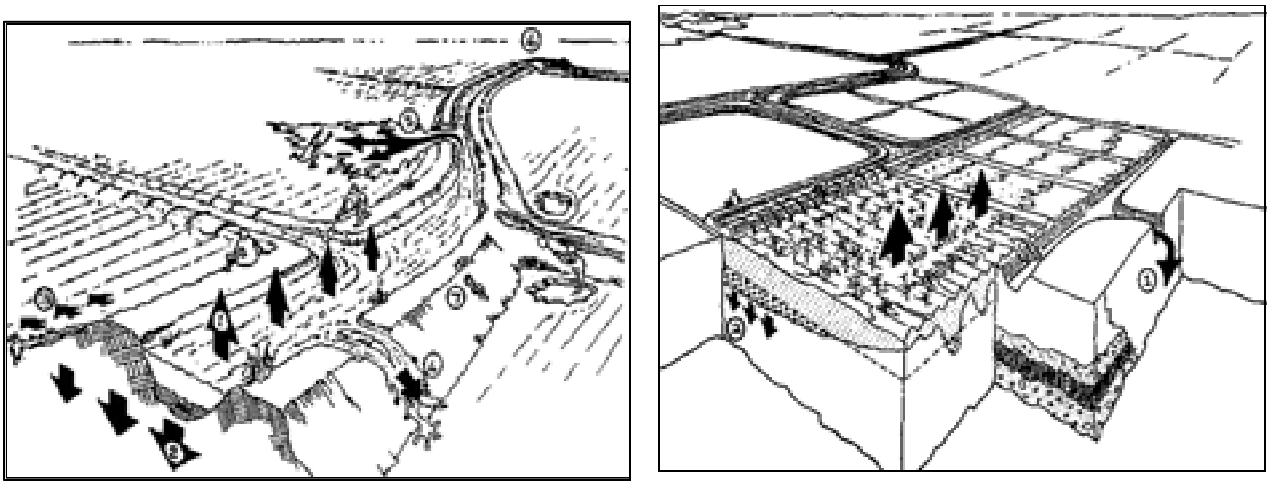


Figure 6 Sources of irrigation water loss in transport and in field

Source: http://www.fao.org/docrep/T7202E/t7202e08.htm

[6] Experiments on water loss have also been carried out in 2003. Water loss had not changed much compared to experiments in 1989 (personal communication Mr Liu in Hetao Irrigation Bureau).

In calculations of water loss in irrigation we have used estimated water loss from canals levels 1-7 using the definition by Shi et al. (1999) given in Table 4. Irrigation water loss is assigned to each crop based on the crops relative area in the Hetao Basin (we did not have access to GIS data on crop distribution). This underestimates irrigation losses for crops far from the Yellow River intake and overestimates water losses for crops with short water transportation distances. For water use "in field" we have used data on irrigation norms established by the Water Research Institute of Hetao Irrigation Bureau, Shahao Experiment Station and Yichang Yonglian Experiment Station.

	Water loss in Hetao Irrigation Area				
Canal level	general arterial canal (level1)	arterial canal (level2)	branch canal (level3)	canal at level 4 or under (level 4 to level 7)	In field
number of sections	1	13	43	109721	
total length(km)	229	833,92	1044,18	74478,2	
water loss (billion m3)	0,34	0,995	0,635	0,437	0,75
accumulated water loss (billion m3)	0,34	1,335	1,97	2,407	3,157
percentage of total water loss(%)	10,8	31,4	20,1	13,9	23,8
accumulated water loss (%)	10,8	42,2	62,3	76,2	100

Table 4 Water loss by type of irrigation canal and in field

Source: SHI Yaohua, LIU Huizhong, Wu Tongshun, The Study of Water Saving in Hetao Irrigation Area, paper collection edited by China Water Academy Association, Year 1999.

Table 5 Available data on water budget in Hetao Basin and Lake Wuliangsuhai

	1989	1995	Mean '95-'00	2001	2002	2003	2004	Source
Hetao Irrigation Area Input from Yellow River (BI)			**4607**	**4302**	**5323**			Monitoring report
1.Crop water irrigation norm (supply at field level, includes water to return flow)		2 508						Ministry of Water(2000) and Hetao Irrigation Bureau
2. Irrigation cannal water loss (cannal levels 1-7 all the way to the field)	2407							Shi, Lui et al. (1999)
Difference (BI-(1+2))								Calculated
Hetao Basin Output/Loss (BO=1+2+3+4)			**4607**	**4302**				Monitoring report
1. Evapotranspiration from irrigation area + infiltration - precipitation - mountain run-off			3941	3824				Monitoring report
2. Output to/input into Wuliangsuhai (MPS, Cannal 8 and 9)			631	441				Monitoring report
3. Return flow directly to Yellow River (irrigation area 15, not routed through Lake)			35	38				Monitoring report
4. Water routed directly back to Yellow River through main cannal			0	0				Monitoring report assumption
Lake Wuliansuhai Input (LI)								
1. Input into Wuliangsuhai through MPS, cannal 8 and 9			631	441				Monitoring report
2. Water introduced directly from Yellow River to flush Lake (2002)					1020,5			Calculated relative to 2001 based on Monitoring report
3. Water purchases by Fish Farm from Irrigation Bureau (2003-2004)						13	78	Irrigation Bureau interview
Lake Wuliansuhai Output/Loss (LO)			**631**	**441**				
1. Outlet to Yellow River			188	37				Monitoring report
2. Evapotranspiration + infiltration - precipitation - mountain run-off			443	404				Monitoring report

6 Scenarios of future water use

In the various Management and Control Plans (MCP) a number of different scenarios have been discussed. While the Monitoring Report and MCP Reports have largely focused on nutrient mitigation measures within the lake which will slow sedimentation and eutrophication, hydrological changes in the upper watershed have just as immediate impacts on lake extent than nutrient loading. The limited hydrological modelling, topographical mapping and ecological data and modelling in the project make it difficult to make more than the "guesstimates" provided here for the purposes of an economic analysis of lake development scenarios.

Because we have had to base calculations on 2001 data we are evaluating projections of hypothetical situations for the very near future. For the scenario analysis to be more relevant hydrological and GIS data for 2004 should have been used. The reader should therefore see the discussion of hydrological scenarios in this report as the basis for 'environmental economic reasoning' that Fish Farm managers and environmental authorities can practice in future, rather than as a *bona fide* prediction of conditions that will actually take place in the lake.

In an economic benefit-cost analysis marginal values for water are ideally used. The definition of alternative scenarios is necessary in order to analyse the economic value of changes in water suplied to the lake. Further work on benefit-cost analysis of the alternative scenarios is being conducted within the M.Sc. thesis of Tianyi Shen (2005), University of Oslo.

Data collected as part of this Economic Indicators study show Fish Farm purchases of Yellow River water in 2003 (13 million m^3) and 2004 (78 million m^3). The proposals are both to avoid the reduction in lake area predicted above, as well as increase flushing, decrease eutrophication, and ensure return-flow to the Yellow River during dry season. In line with this recent strategy we propose the following scenarios (Table 6).

Scenario 0 is a "water deficit" projection whereby we assume that inflow to the lake may eventually reach historical lows of (equivalent to inflow observed in 1980, 230 million m^3 / year). Scenario 1 is a " water balance" projection whereby inflow is reduced to 319 million m^3 / year equivalent to proposals made by the Water Savings Project, but where the resulting deficit is covered by water purchases made by the Fish Farm. This scenario has no return flow to the Yellow River. Scenario 2 supposes inflow of 319 million m^3, but evaluates water purchases of 253 million m^3 proposed in the MCP on importing Yellow River water. This scenario results in substantial return flow to the Yellow River.

Scenario 2 is a simplification of the proposed management and control measure of importing water because it does not contemplate raising the water level as in the MCP report. This simplification was necessary because we have insufficient topographical data to evaluate the effects of a raising of water levels on lake area and by extension on evapotranspiration. Water purchase in Scenario 2 may be justified by expected improvements in water quality due to increased flushing and benefits for tourism, fishing and biodiversity. The trade-off between achieving increased flushing and increasing lake level is not analysed in this report due to lack of hydrological and water quality models. However, it is central to lake management and should be the subject of future studies.

Table 6 Hypothetical scenarios for water balance in Lake Wuliangsuhai

	Scenario 0 "Water deficit"	**Scenario 1 "Water balance"**	**Scenario 2 "Water surplus"**
Description of assumptions	"Do nothing" ; worst case scenario with loss of lake area	Water purchases from Yellow River equivalent to lake water deficit	Water purchases of 253 million m^3/year (proposed in MCP import Yellow River Water *)
Return flow from Hetao (in)	Gradual reduction to historical low (230 million m^3 in 1980). See Figure 7 and Figure 8	Reduction to 319 million m3 projected by irrigation water saving project. See Figure 7 and Figure 8	Reduction to 319 million m^3 projected by irrigation water saving project. See Figure 7 and Figure 8
Lake water loss	Initial condition based on observed water loss for 2001; proportional to previous year lake volume (average depth 1m)	as scenario 0	as scenario 0
Outflow to Yellow River	none	Regulated to achieve lake volume and area equivalent to a projection for 2004. Surplus flow returned to Yellow River	as scenario 1, but with return flow to Yellow River
Lake volume, area, level (July 2001)**	Reduction to 172 million m^3 ("whole wetland"). See Figure 13.	1018,17 masl (2001) "Open water":174 million m^3 and 164 km^2; "Wetland": 299 million m^3 and 313,8 km^2	as scenario 1 due to lacking data on lakeside topography.
Reed area and harvesting	See Figure 13 and discussion, regarding colonisation speed of reed.	constant at 2001 levels	as scenario 1 due to lacking data/model for lake expansion
Lake visitation	Assumption: proportional to open water surface area (relative to 2001).	Constant at 2001 levels (assuming constant water quality).	as scenario 1 due to lacking data/model for lake expansion

Note: *Objective in MCP on introducing Yellow River water:1019,2 (April), 1019,00 masl (July and January); new area and volume unknown due to lacking topography. **Taking into account fish farm purchases of water in 2003 and 2004 and projections of return flow from the irrigation area, a simple projections of lake volume in 2005 is 292 million m^3. This is so close to 2001 values for which we have hydrological and GIS data that 2001 was taken as a baseline/reference year for the economic analysis.

Figure 7 illustrates how projections of inflow were made based on historical data from the Monitoring Report. The Monitoring Report makes a distinction between "observed volume in" and "calculated total volume in (Main pumping station, canals 8 and 9). "Calculated water in" is used in the Monitoring Report to estimate evapotranspiration from the lake as the difference between calculated inflow and outflow. In our scenarios we wanted to evaluate "worst case" scenarios, so we projected inflow based on the falling trend since 1995 and then extended that trend until 230 million m^3 / year (scenario 0) and 319 million m^3/year (scenario 1).

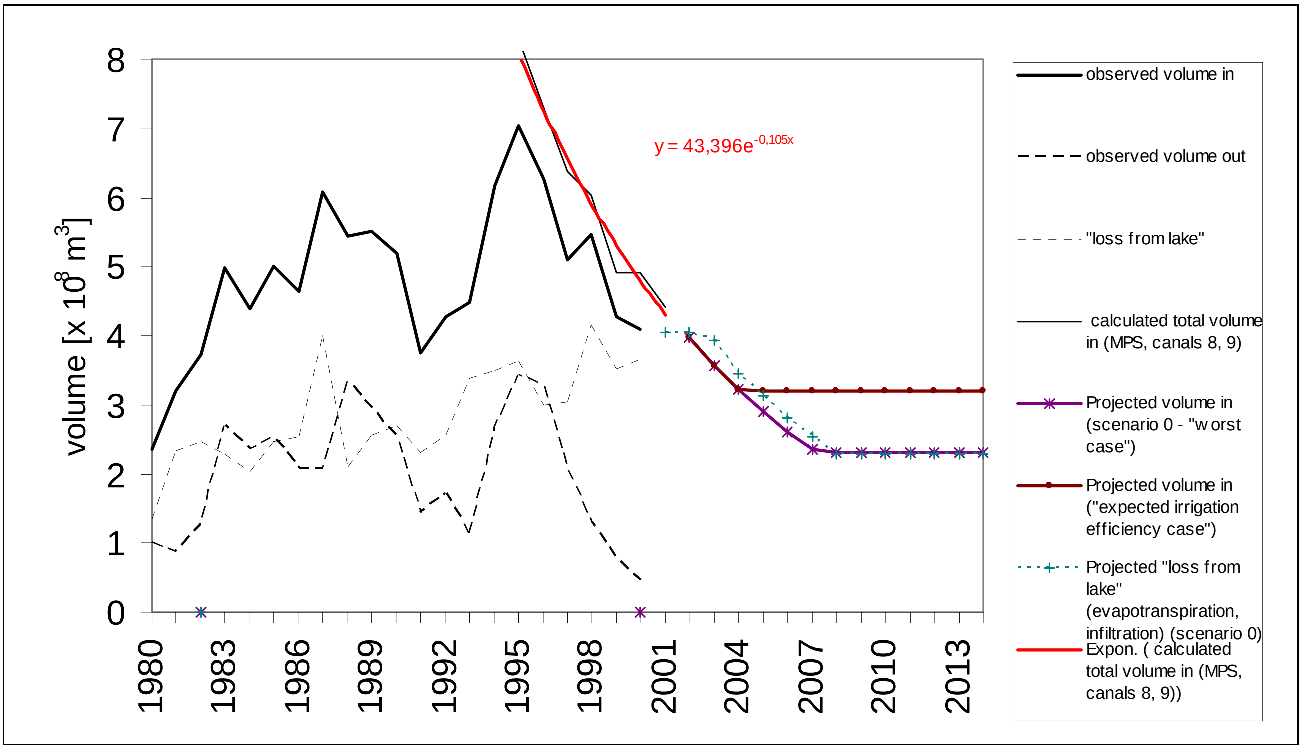


Figure 7 Scenarios for return flow to Lake Wuliangsuhai and projected lake volume.

Note: "Calculated volume in" is based on aggregation of data in the Monitoring Report for the main pumping station (MPS), canals 8 and 9.

The hypothetical nature of the exercise is obvious in that projections made based on 2001 data lead to these levels of inflow in 2005 and 2008. On the other hand longer term projections would have little basis in the available data. This underlines the importance for the Chinese counterparts of updating conclusions based on up to date monitoring data. A simple water balance model is used to predict total lake water volume based on alternative inflow. Water loss from the lake through evapotranspiration (and infiltration) is assumed to be proportional to lake area using values from the Monitoring Report for 2001 as a base year. Initital lake volume (299 million m3) is based on estimations of volume in "open water" and "reed" discussed in continuation. Due to lack of a topographical model for the lakeside we have not found it possible to make projections of increase in volume given the aim of a 1 m increase in lake level. We have therefore simply evaluated the consequence of increased return flow to the Yellow River while keeping lake level constant at 2001 levels. Given these assumptions, projections of lake volume, water purchase and outflow are illustrated in Figure 8.

Scenario 0 ("water deficit scenario")	Scenario 1 ("equilibrium scenario")	Scenario 2 ("water surplus scenario")

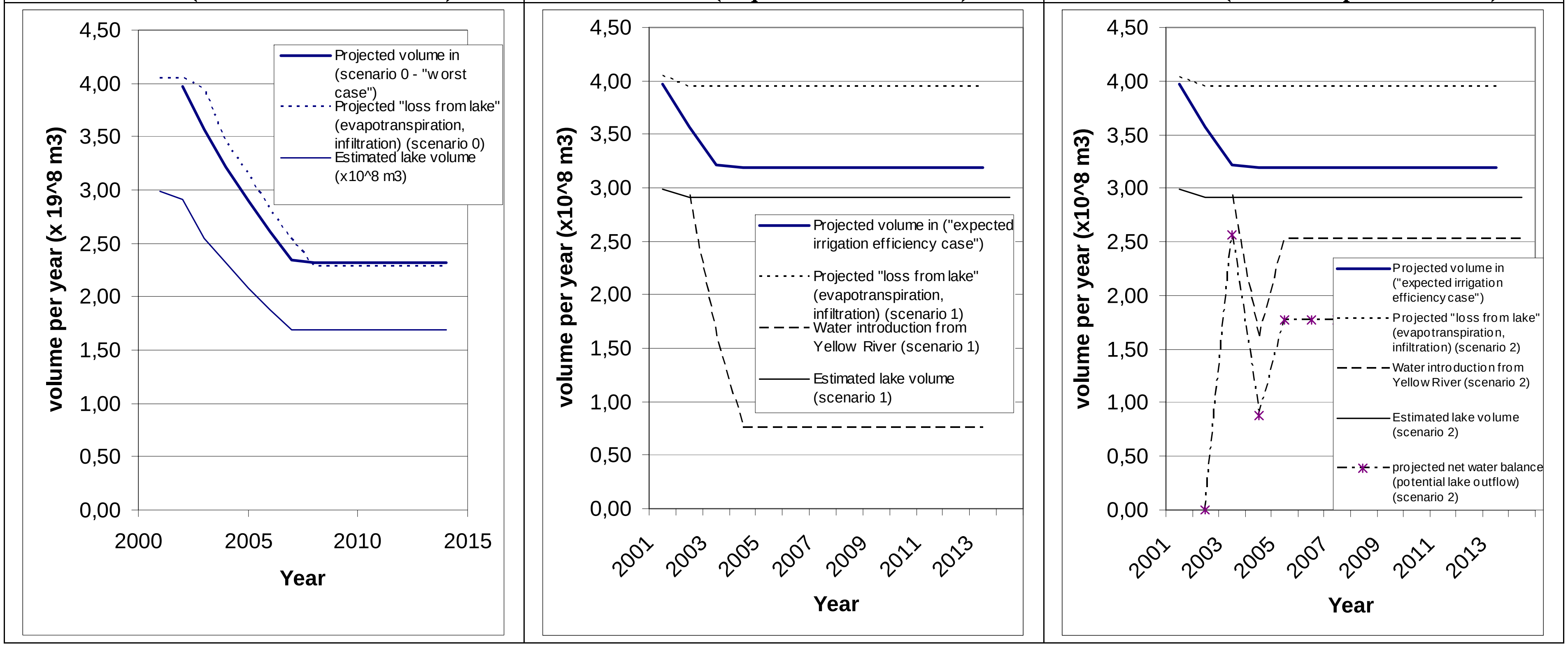


Figure 8. Scenarios – annual projections of lake water loss and hypothetical water purchases required to maintain lake volume at 2001 level

Note:. Taking into account fish farm purchases of water in 2003 and 2004 and projections of return flow from the irrigation area, a simple projections of lake volume in 2005 is 292 million m^3(scenario 1). This is so close to 2001 values for which we have hydrological and GIS data that 2001 was taken as a baseline/reference year for the economic analysis in the rest of this report.

Projections of changes in wetland, reed and open water area

Area of lake depth contours "open water"	
Depth level	Area (km^2)
0,0 m	45,09
0,5 m	4,56
1,0 m	94,94
1,5 m	16,94
2,0 m	4,55
2,5 m	1,54
3,0 m	0,02
Total	167,64
Area of reed	Area (km^2)
Farmed reed	32,18
Lake reed	146,18
Total reed	178,36
Total wetland area	346,00

Table 7 Depth-area (Monitoring Report)

Table 7 shows estimates of different land cover and depth contours that could be calculated from available depth profiles and satellite images. No representative depth profiling was undertaken within the lake reed area, so we do not know the depths at which this large and economically important resource are to be found. Given that this question is central to evaluating the impacts of upstream water use on the economic value of lake uses, we will devote some discussion to the issue here.

We observe from the map in *Figure 3* that there are large areas of open water with 0-0.5 m depth between the reed areas and the lake shore[7]; that there almost no areas with 0.5-1.0 meters depth; and then large areas with depths of 1-1.5 meters. This suggests that reed does not adapt well to areas that are dried out for parts of the year (0-0.5 meters) and that most of the reed is located in depths of 0.5-1 meter. This conclusion is partially confirmed by data from the only three sites where depths within the reed were measured (Hedelin 2000)[8]. Reed was found to dominate at the following depths at the three different sites that were sampled (95% confidence) : 0.6-1 m (Site 1); 0.8-1.2 m (Site 2); 0.7-1.3 m (Site 3) (Figure 9). According to the 37 observations from all three sites, Phragmites is found distributed 19% at 0-0.5 m, 35% at 0.5-1 m and 46% at 1-1.5 m, with a mean of 0,91 +/- 0,13 m (95% confidence). Although we know these data are not representative they are better than nothing and perhaps sufficient for the order-of-magnitude approach of impacts on reed followed in this report. These results were also confirmed during a number of manual depth measurements along the reed edge – the maximum depth at the reed-water border was close to 1,2 m (adjusted to average annual lake level = 1018,5 m asl.).

[7] This interpretation is based solely on interpretation of satelite data. For the large reed area in the north of the lake we have no observations on the ground. Estimates of open water and reed area in the rest of the report assume that it has the same characteristics as the rest of the lake, when it may in fact it may be more like a swamp than a lake with reed may predominating in depths of 0-0.5 m.

[8] Beatrice Hedelin (2000), The Effect of Reed Harvesting on the Phosphorous Budget of Lake Wualiangsuhai. Minor Field Study. Royal Institute of Technology.. All samples were collected early September 11-15[th] when recorded lake lavel was 1018,61 masl (11 cm higher than water level observed in Figure 3. Sampling at site 1 was from the lake shore and found some reed also on land indicating that sampling at least at this site accounts for reed also in the depth 0-0.5 meters. We assume samples were taken as transects, but this is not documented by Hedelin.

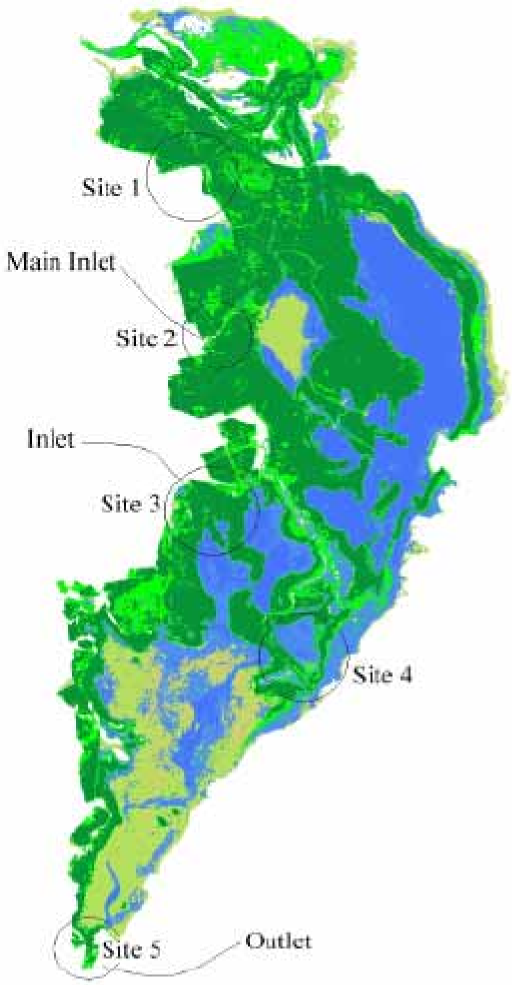


Figure 9 Sampling sites for reed (1-3) and typha (4-6)

This data indicates that the lake area-depth curve for "open water" in Figure 10 is not representative for lake depth of the profile 0-1.5 meters, and particularly 0.5-1.5 meters (the "kink" in the curve is the result of basing volumetric calculations solely on GIS interpretation of "open water" polygons). For the purposes of projecting order-of-magnitude changes in total volume of the wetland, and of lake and reed area given different water level scenarios, a better approximation is needed. We propose that this could be done by smoothing the depth-area curve from 0.0 – 1.5 meters, by assigning the % distribution of reed by depth obtained from the sampling by Hedelin (2000) (Table 8 and Table 9).

	Lake reed area (km2):		N observations
Depth	146,18	100 %	37
0-0.5	27,66	19 %	7
0.5-1.0	51,36	35 %	13
1.0-1.5	67,16	46 %	17

Table 8 Assignment of lake reed area by depth based on distribution of Phragmites depth for 37 observations at 3 sampling sites (Hedelin, 2000).

Depth level (m below surface)	Area "open water" (km^2)	Area "lake reed" (km^2)	Area "total wetland" (km^2)
0,0	167,640	146	313,820
0,5	122,547	119	241,071
1,0	117,991	67	185,155
1,5	23,056	0	23,056
2,0	6,114	0	6,114
2,5	1,566	0	1,566
3,0	0,025	0	0,025

Table 9 Estimated wetland, reed and open water area by depth

We have illustrated this allocation of reed area by depth in Figure 10.

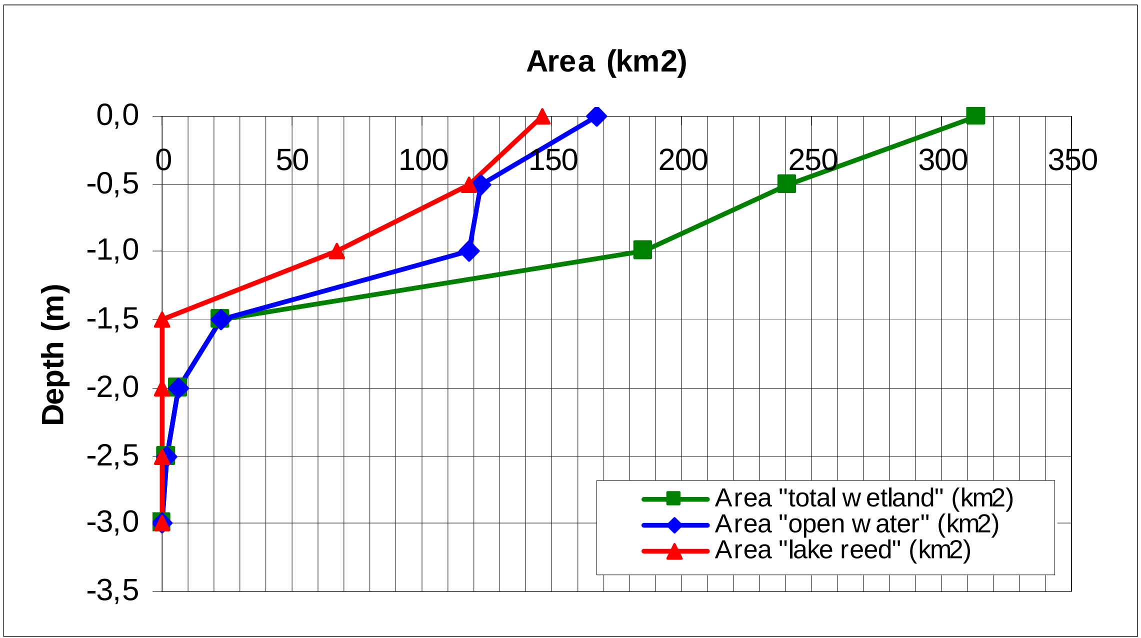


Figure 10 Lake area-depth curves.

Source: Area “Open water” (see Appendix A and Monitoring Report); Area “total wetland” based on data from Monitoring Report and Table 8 above. The reader is advised that “reed area” is indicative only as it was extrapolated based on reed-depth measurements from just 3 sites in Hedelin (2000).

This is a significant adjustment, because we know that the calculation of lake water volume based on "open water area" is then an underestimate. By assigning lake reed area to different depths we have probably overestimated lake volume somewhat, but given the large proportion of reed this should be closer to the true water volume of the lake observed in the 2001 satellite image. Figure 11 illustrates the difference in lake volumetric calculations. For impact estimates in the rest of the report, we use Figure 12 to convert volume changes due to reductions in return-flow into estimated depth changes, and then Figure 10 to convert this into changes in lake and reed area.

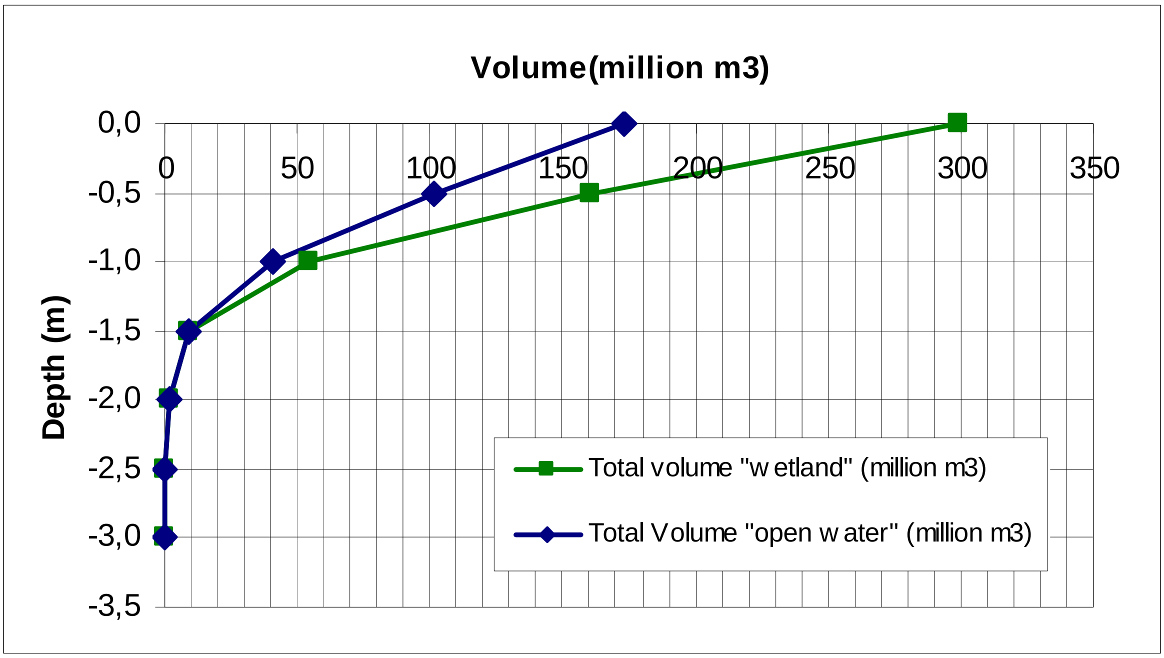


Figure 11 Theoretical depth-volume curves

Source: based on data in figure 3. The reader is advised that water volume in "reed area" is indicative only as it was extrapolated based on reed-depth measurements from just 3 sites in Hedelin (2000).

The reader must bear in mind that these are approximation based on a number of assumptions explained above. Amongst others it assumes a linear bottom profile between depth contours - although this is not true locally, it should be a decent approximation of an "average" bottom profile in a shallow lake with high rates of sedimentation (local bathymetrical variation is "averaged" both in the geological and statistical sense).

Discussion of scenarios

Reductions in lake level

It is immediately obvious from the figures above that the lake is very sensitive to changes in return-flow from the irrigation area, which in 2001 was 441 million m^3, or around 2,5 times the lake volume. With evapotranspiration and infiltration losses almost equalling return flow, any changes in irrigation efficiency in Hetao have potentially large effects on lake extent within few years.

Based on the available data a worst-case scenario might see the lake with an input of a historically low 230 million m^3 per year over several years resulting in an annual water deficit relative to evapotranspiration[9]. The scenario shows total lake volume tending from the 2001/2002 estimate of 299 million m^3 towards 169 million m^3 in about 7 years.

Assuming such a worst-case scenario for lake volume of 169 million m^3 we can use the assumptions incorporated in Figure 10 and Figure 11 to calculate the expected lake level, and in turn total wetland area, "open water" area and "reed area". Based on a simple visual inspection of the combined depth-volume-area figures in Figure 13, such a scenario would result in a reduction in lake level of about 0.5 m, and total wetland area of around 240 km^2.

The reader must bear in mind that these are approximation based on a number of assumptions explained above. While permanently dried out areas will loose reed cover, if the reduction in water level is gradual, reed will colonise new bottom areas that become available (roughly at depths less than 1.5 meters). We can therefore not make a direct reading of reed area from Figure 13. Instead two extreme cases are discussed. Case 1 with no new reed colonisation, and case 2 with rapid reed colonisation of newly available areas less than 1.5 m depth.

Case 1 assuming no reed colonisation: "Reed area" approx 120 km^2 ; "Open water area" approx 120km^2 .

Case 2 assuming full reed colonisation down to 1m depth : "Reed area" approx 220 km^2 ; "open water area" 20 km^2

These two cases are later employed in section 6 to explore the bounds for economic impacts of a reduction in lake water level under these two extreme situations.

Increases in lake level

The figure of 253 million m^3 is taken from the MCP on Introduction of Yellow River Water and *raising* the lake level by approximately 1 meter relative to June 2001: 1019,2 (April), 1019,00 masl (July and January). It is not clear how area and volume were calculated by the MCP author, given the lack of data on lakeside topography and lack of interpreted satellite images for winter lake levels (frequently above 1019 masl). For example assuming no increase in lake area relative to 2001, an increase in water level of this magnitude would require 313 million m^3 (total area cov-

[9] In our simple model evapotranspiration is proportional to lake area based on evapotranspiration/km2 lake area estimated for 2001.

ered by water is 313 km^2).

If the relationship between elevation and lakeside profile is the same for 1018,2-1019,2 masl as for the lake bottom for between -1 m and 0 m (1017,2-1018,2 masl), then an increase of 1 meter would lead to a lake area of approx 420 km^2 and a volumetric increase of approximately 370 million m^3. We know that the lake is bounded by a number of dikes and roads which means that an increase in lake depth of 1 meter probably requires a volume of more than 313 million m^3, but less than 370 million m^3 (Figure 12). With a gradual increase in lake size we can assume that reed area would increase, but this depends on data of the actual lakeside topography and more information on the colonisation biology of the phragmites reed. Data in Hedelin (2000) suggest that reed cannot endure depths of more than 1,5 meters for a whole season. If the depth-area relationship as drawn Figure 12 is valid also for the lakeside, there may only a small increase in reed area with a *permanent* increase in minimum annual lake depth of 1 meter proposed in the MCP report.

This is as far as we can take this discussion, but it illustrates the type of GIS data, biological monitoring data and ecological modelling that needed to properly conduct an economic analysis of the proposals made in the MCP reports.

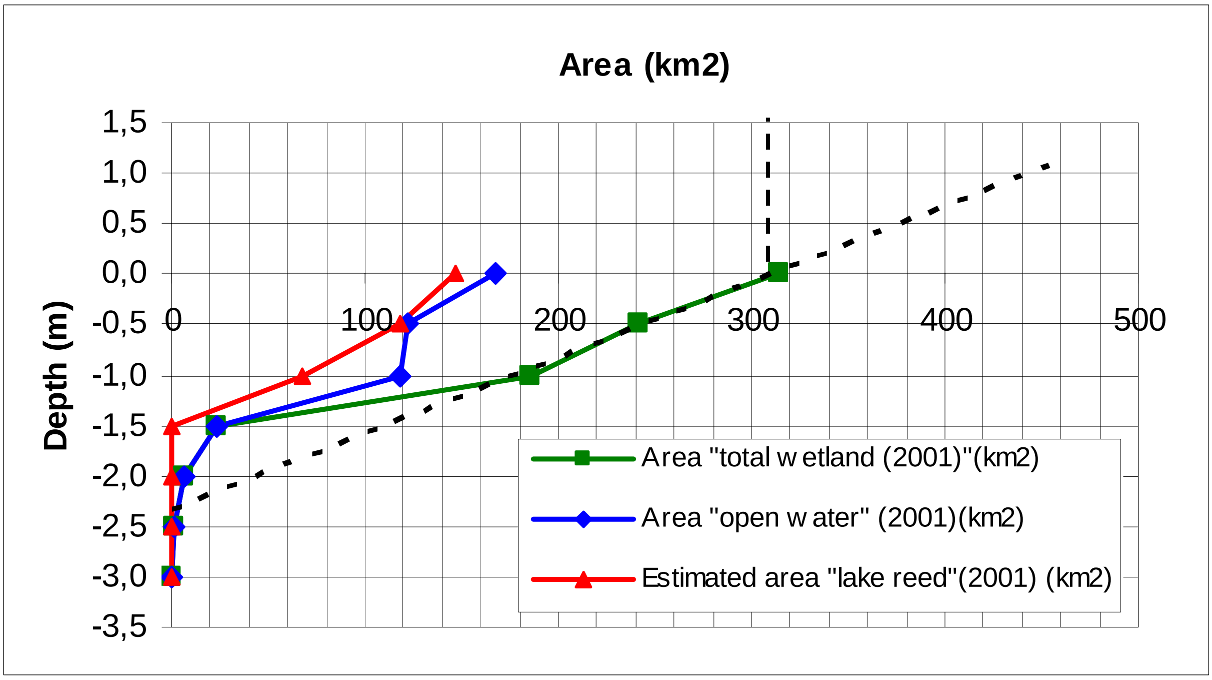


Figure 12 Reflections on hypothetical increases in lake volume and area with increases in lake level.

Note: The estimate of 253 million m^3 from the MCP report (Yellow River Water and Lake Level) is an underestimate assuming a total lake area in 2001 of 313 km^2. Assuming no increase in lake area required volume would be 313 million m^3 (vertical dashed line). Assuming a similar bottom profile as for -1 to 0 meters depth, an increase in lake level of 1 meter would lead to a lake area of approx 420 km^2 and a volumetric increase of approximately 370 million m^3.

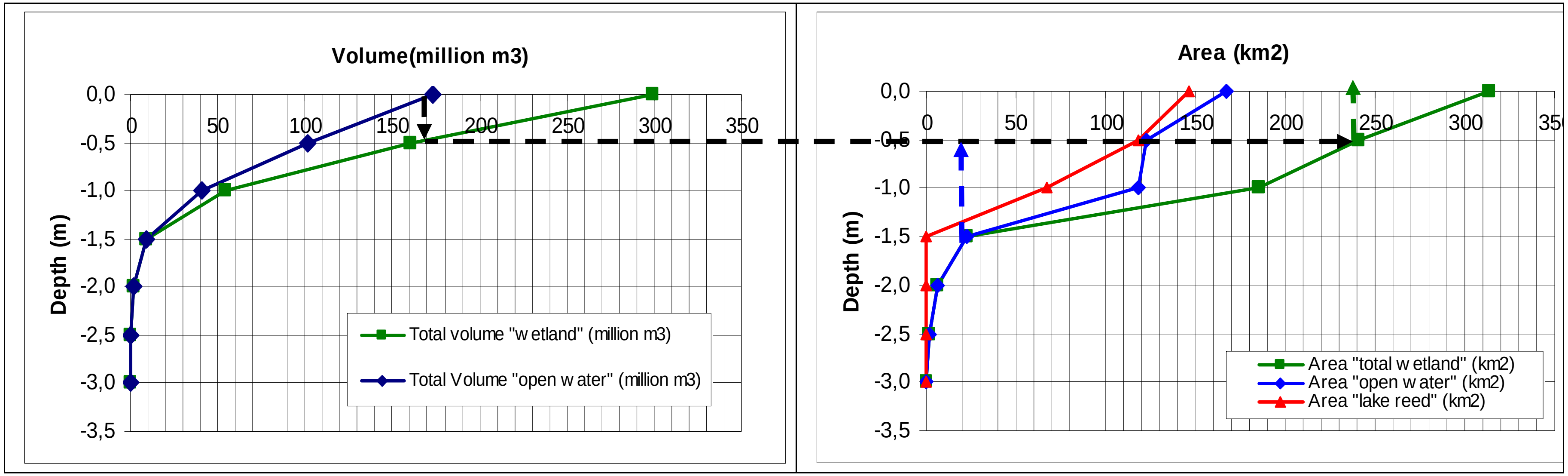


Figure 13 Theoretical estimation of impact of a lake volume of 172 million m^3 leading to a 0,5 meter water level drop on average.

Note: Total wetland area of approx. 240 km^2; Case 1 (assuming no reed colonisation): “Reed area” approx 120 km^2; “Open water area” of approx 120km^2. Case 2 (assuming full reed colonisation down to 1m depth);: “Reed area” approx. 220 km^2; “open water area” approx. 20 km^2 .

7 Costs and benefits of water use

In this section we calculate net financial returns to different water users in Lake Wuliangsuhai's catchment.

It has been generally difficult to obtain data on capital costs in the Lake Wuliangsuhai area, as depreciation of state sponsored investment before privatisation– such as by the Fish Farm - is generally not included in accounting. Where capital costs are available we use a simple 10 year useful life, or 10% p.a. depreciation rule for infrastructure, which has been adopted by businesses in the area[10]. All other operating costs have been calculated using financial prices. Net benefit figures have been adjusted to 2002 prices by the Chinese consumer price index (data is available on the internet for 1990-2002).

Lake water uses

7.1 Reed harvesting

The reed harvesting season takes place 45-55 days per year including 25-30 days for cutting and 20-25 days for transporting to the lakeshore. Historical production figures were available for the whole lake since 1996 (Figure 14).

For capital costs, and given lacking information, we assume that 50% uses ice shovels (4 wheel carts) and 50% use wood handled ice sickles and 25% use metal ice sickles. We assume transportation costs given by the Fish Farm include capital costs of vehicles (mostly tractors) used to transport reed.

No historical data on labour and transportation costs are available. Calculations of operational costs are based on constant costs of 30 Yuan/tonne labour costs and 25 Yuan/tonne transportation costs.

Accounting data on net income are very uncertain and subject to under-reporting. Fish Farm Corporations accounting data apparently show net income in e.g. 2003 of 3,019 million Yuan, while our calculations using price and production cost data provided by the Fish Farm indicate net income of 28 million Yuan. It is difficult to see how such different figures would arise. Capital costs of reed harvesting are very low as little equipment is used. Statistics show variations in production levels and labour use (Figure 15) while the Fish Farm provided data on labour costs for a single year (probably 2003). However, we have double checked these labour costs against salaries in the Fish Farm and labour costs we have used do not seem to be underestimated.

[10] Pers.com. Mr. Bai, manager, Linhe Tourist Bureau

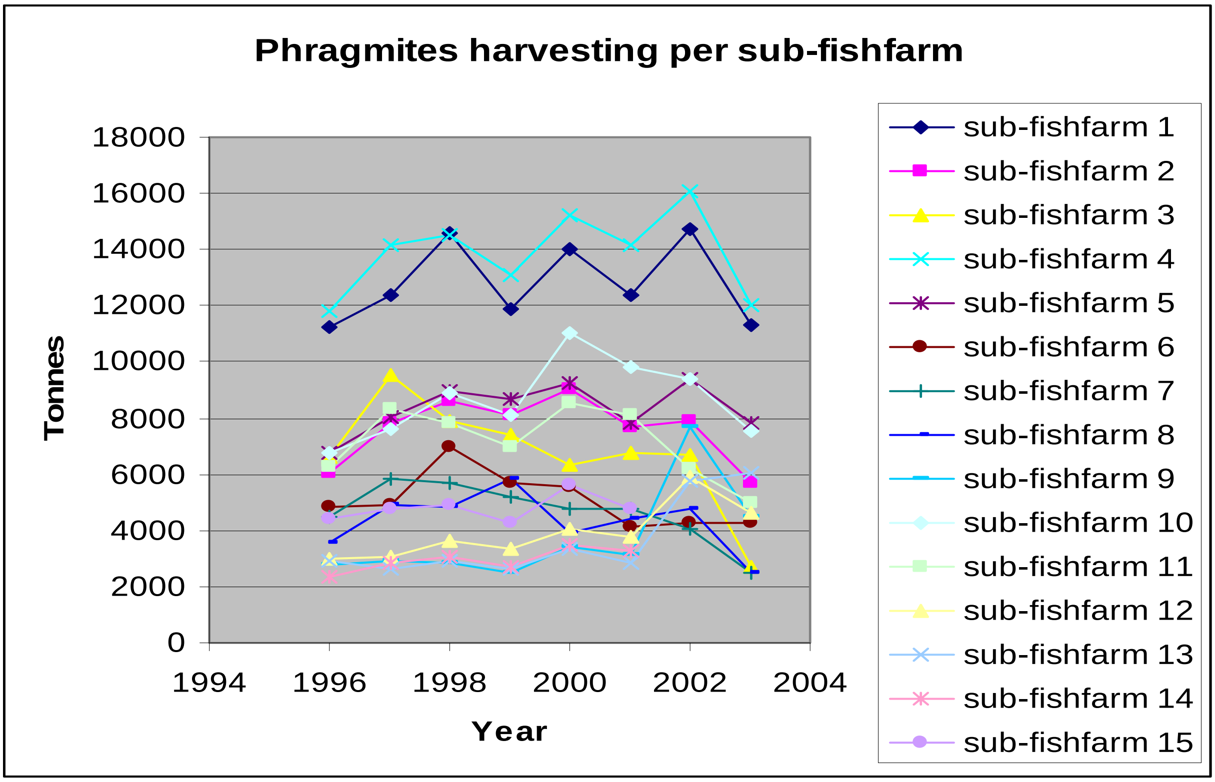


Figure 14 Reed production levels at 15 “sub-fishfarms” around Lake Wuliangsuhai

Source: Fish Farm Accountant; collected by Wenting Chen September 2004.

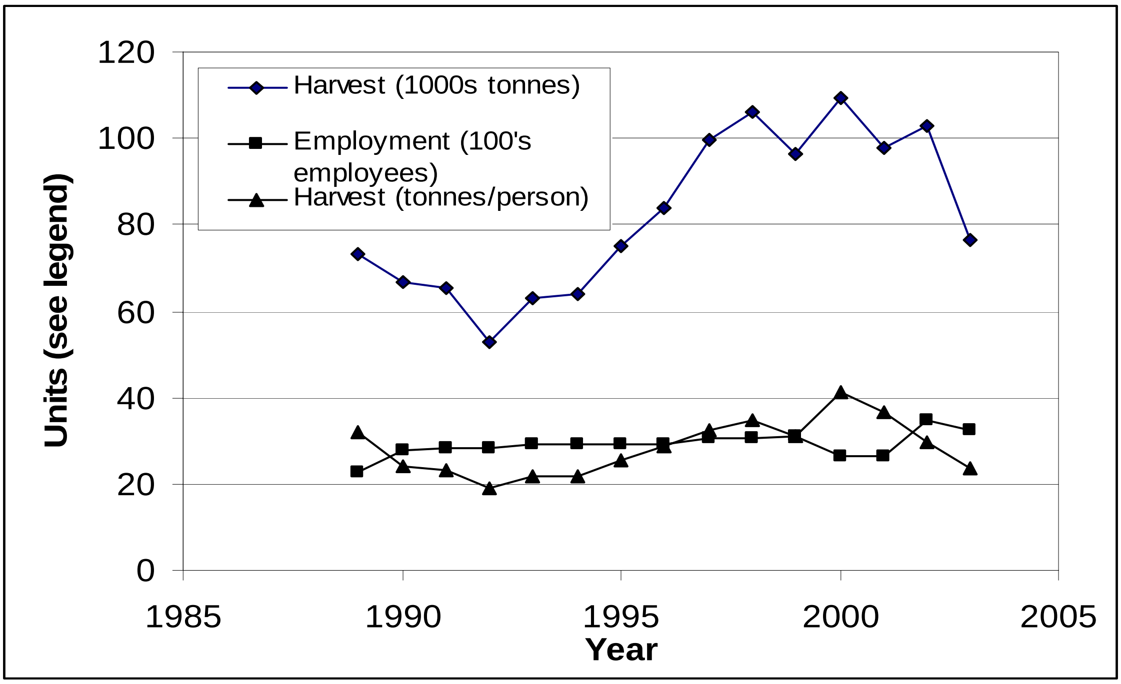


Figure 15 Variation in labour productivity for reed harvesting

Source: based on data from Fish Farm Accountant; collected by Wenting Chen September 2004.

From the Fish Farm we also know that reed harvesting lasts for about 45-55 days per year including 25-30 days for cutting and 20-25 days for transporting. We can calculate an implict daily wage based on data on labour costs per tonne of harvested reed provided by the Fish Farm. This is compared to data from Fish Farm operation of docks, hotel, restaurant and holiday village indicate that annual wages vary between 5600-8000 Yuan for full time workers (Table 10).

Labour wages	Annual(Yuan)	Daily (Yuan)
Dock	8000	30,65
Hotel	5600	21,46
Rest	7500	28,74
Holiday village	6000	22,99
Implicit wage harvesting	707	12,85
Assumptions:		
Working days	261	days
Harvest season	55	days
Labour costs	30	yuan/tonne

Table 10 Calculated wages in reed harvesting

Given high seasonal unemployment in the area labour wages in reed harvest are lower. However, we see that labour costs estimates provided by the Fish Farm are approximately what we would expect compared to other sources of employment and cannot account for the large difference we see between net income to reed reported by the Fish Farm and our calculations. In conclusion, we must assume that the net income figures we calculate are the correct order of magnitude and thereby that reed harvesting is the most important economic use of the lake by a very large margin.

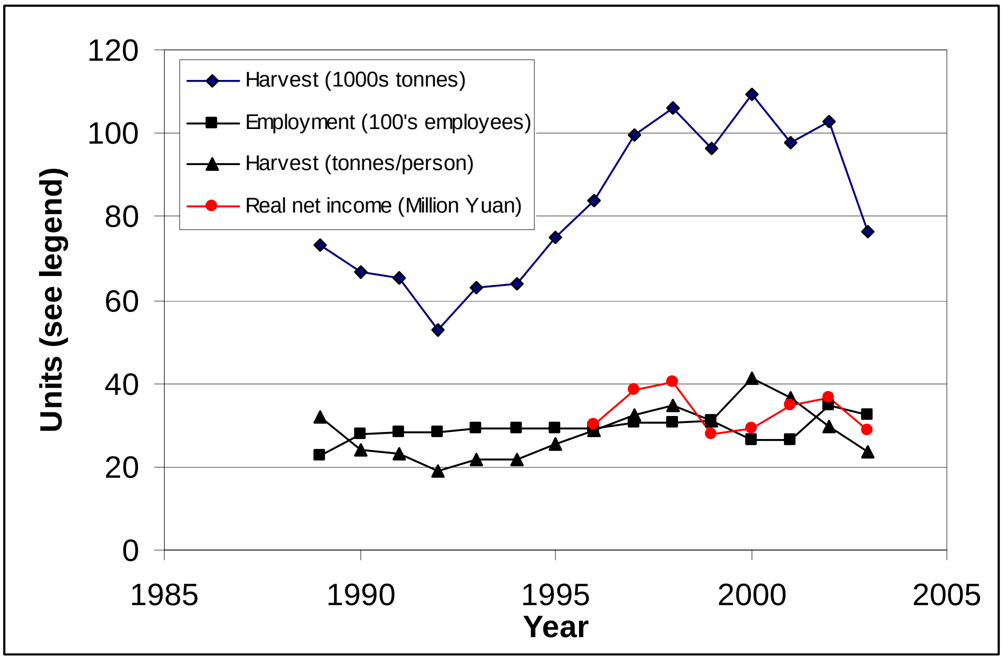


Figure 16 Real net annual income to Phragmites reed harvesting

Figure 16 shows that net income to Phragmites harvesting has varied between 28,6 and 40,5 million Yuan per year. This is equivalent to an average annual value of approx. Yuan 195 800 – 277 200 / km ^{2}, over the 146.1 km^2 of lake reed cover. We will use the low value to make an evaluation of possible impacts on reed area of a fall in lake level.

i. Typha harvesting

For Typha harvesting we only have data on production costs and prices from 2003. The only historical data available is on the number of licences given for Typha harvesting. A simple interpolation from 2003 would give the following figures for total production. In the end we have chosen to only report a single data point for Typha production for 2003. We calculate real net income per year from Typha to be about 636 000 Yuan for 2003.

Year	Typha licences	Typha production(autumn)	
	#	tonnes/year (autumn)	tonnes/year (winter)
1995	150	556*	2778*
1996	150	556*	2778*
1997	150	556*	2778*
1998	150	556*	2778*
1999	150	556*	2778*
2000	130	481*	2407*
2001	187	693*	3463*
2002	310	1148*	5741*
2003	108	400	2000

Table 11 Typha harvest estimates based on 2003 data and historical data on Typha harvesting licences.

Note : * estimate

7.2 Recreation[11]

Visitation to Lake Wuliangsuhai is the other major economic use of the lake today. The Fish Farm has registered visitation since the late 1980's. In 1997 the Linhe Tourist Bureau started operations and registering visitation. Almost all visits to the lake are through one of these two visitors' centres where tourists can enjoy restaurants, a small museum, and rent boats for lake tours. Total visitation reached a high in 1998 of 105 000 visitors total after which it has declined for a number of reasons. According to some accounts in 1999 visitors alleged poor ("smelly") lake water quality; in 2001-2002 highway construction limited travel to Lake Wuliangsuhai; in 2003 the SARS epidemic limits travel in the whole of China, also affecting this area.

Appendix 5 describes the characteristics of visitors (August-September 2004) in further detail based on the visitors survey. Seventy six percent where from Inner Mongolia, only some 5% were foreigners. For around 65% Lake Wuliangsuhai was the only destination of their trip. For around 66% this was their first trip to Lake Wuliangsuhai. Ninenty percent visited the lake for a single day. Boating and lakeshore viewing were the main activities (more than 40% of respondents' time spent at the lake), while around 7% of respondents' time was spent bird watching and around 5% in bird and fish museum.

According to operators visitors are unlikely to enter both entry points on the lake and visitation at entry #1 and #2 is additive. 2004 visitation of 41 000 total is based on projections made in September of Fish Farm visitation (16 000) and Linhe Tourist Bureau visitation (10 000) towards the end of the tourist season.

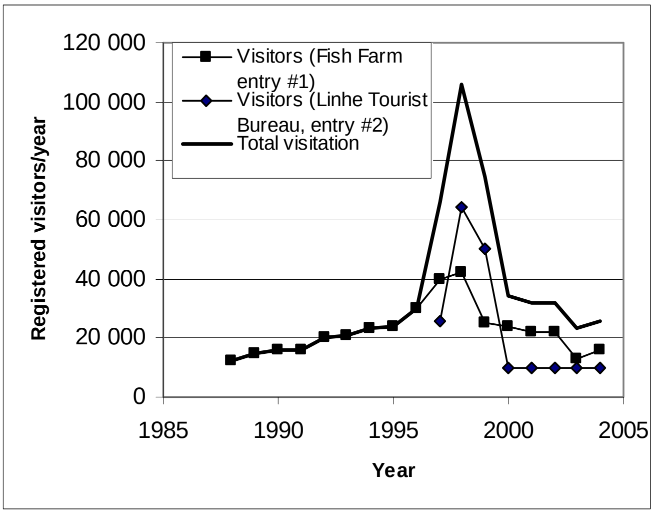


Figure 17 Historical visitation to the lake through Fish Farm and Linhe Tourism Bureau visitors centres

Source: Fish Farm and Linhe Tourism Bureau; data collected by Wenting Chen, September 2004.

[11] Data collection and regression analysis for this section have been carried out by Wenting Chen, M.Sc. student, University of Oslo.

Fish farm (entry point #1)

From Fish Farm company[12] accounts we have detailed data on income and operating costs of the visitors centre dock, hotel, restaurant and holiday village. However, no capital cost data is available.

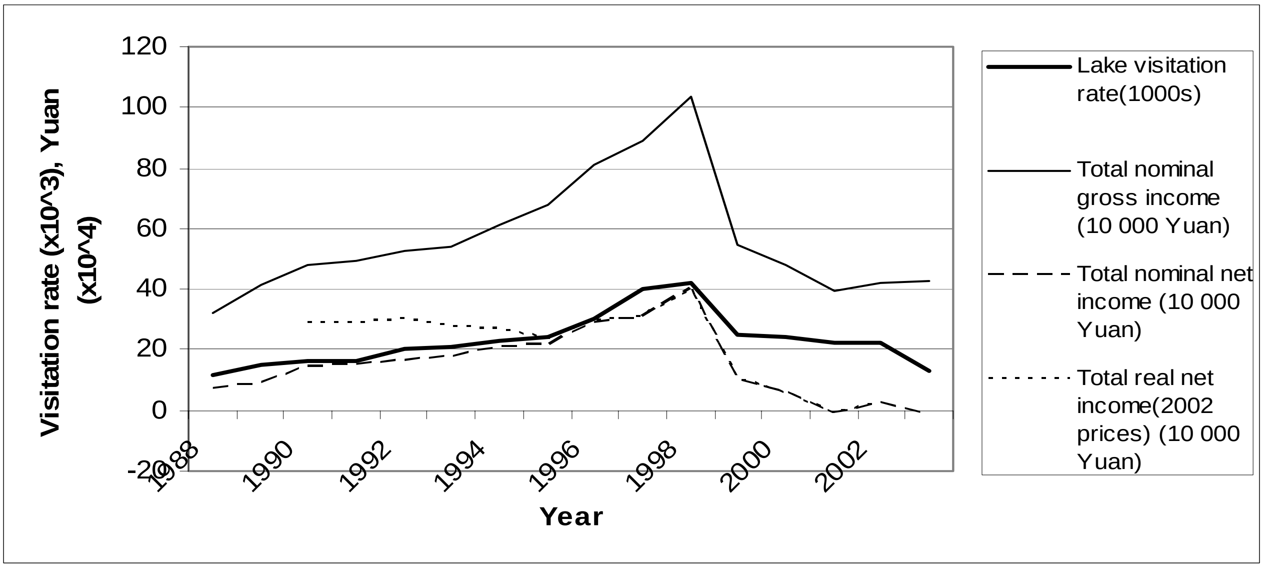


Figure 18 Returns to Fish Farm company's operation of visitors centre dock, hotel, restaurant and holiday village.

Note: real net income calculated for years with available consumer price index (1990-2002). Costs include maintenance, but not capital costs due to lack of data. Does not include boat operators on the lake which are discussed separately.

Linhe tourist bureau (entry point #2)

The Linhe tourist bureau started operation of its entry point to the lake in August 1997. In 1997-1998 it invested a total 18 138 000 Yuan in infrastructure including, dock, canal to lake, wooden house, Mongol hut, and park area. The Linhe Tourist Bureau visitation centre charges an entry fee of 10 Yuan/person. We have no data on income from the 1 large and 6 smaller restaurants at the visitors centre[13]. Based on mere observation we estimate that capacity of the small ones is 1/3 of the big one. We also assume that the big one is similar to the restaurant at entry #1. In summary we assume that Entry #2 restaurant income and operating costs are three times that of Entry 1.

Note in Figure 19 that capital depreciation costs are much larger than income net of operating costs (depreciated over 10 years). We have no such data for the Fish Farm, but expect that the

[12] Data from their accountant.

[13] According to interview, the Linhe Tourist Bureau visitor centre has "other income" of Yuan 5 000 000 per year. As this has not been specified as related to operations in Lake Wuliangsuhai it is omitted from the calculation.

same story holds true – although lake visitation has been a large income generator, investments were made in infrastructure that cannot be justified by current visitation rates.

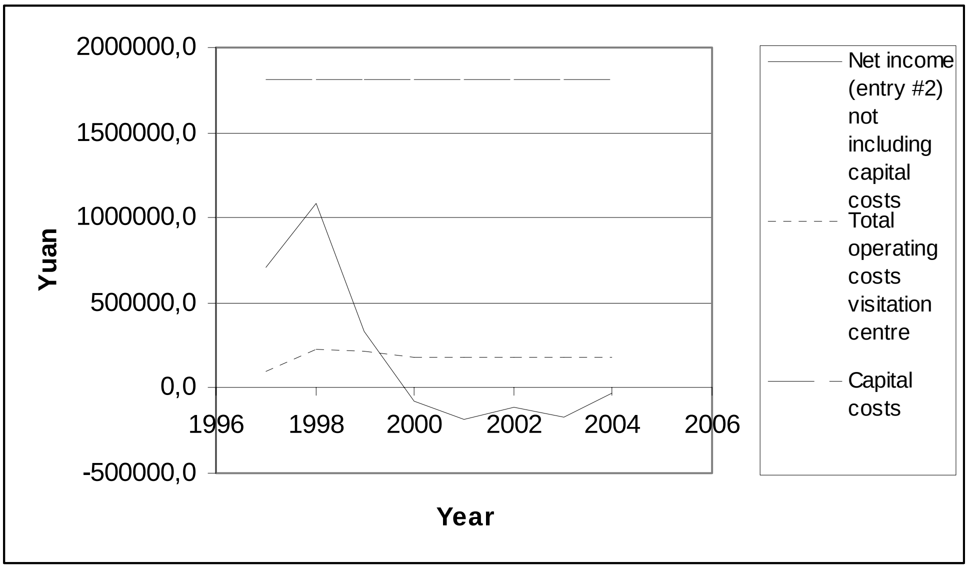


Figure 19 Net income from visitor centre operation (entry #2)

Note: capital costs not included in net income. Depreciated over 10 years.

Entry point #1 and #2 boat operations

By 1996 the Fish Farm boat operators had purchased all the 36 boats acquired for use in tourism, the first of which seems to have been purchased around 1988. Visitation peaked in 1998 at 42 000 visitors. We do not have data on when all purchases were made, but the total nominal value of the investment in boats and engines has been 1, 036 million Yuan. In the Linhe Tourism Bureau total investment in boats in 1997 was 1,33 million Yuan. We therefore assume an annual 10% depreciation cost in 1998.

Operating costs for boats are based on data from Linhe Tourist Bureau and Entry #2, due to lack of data at Fish Farm (visitation rates and type of tours are very similar). Average labour costs/month in Linhe Tourist Bureau are 500-600 Yuan/month. We assume a low end value to calculate average seasonal labour costs for boatmen (5 months work, May-September). Boatmen often have other employment and opportunity costs are probably lower than for full time employees of the tourist bureau. For capital costs we have data on when half of the boat fleet of the Fish Farm was purchased – we assume this investment plan applies to all Fish Farm boats in Lake Wuliangsuhai and adjust capital depreciation costs accordingly.

Rental for a motor boat is 10 Yuan/visitor at both entry points. According to the Fish Farm 10% of visitors visit the bird island for which boat drivers charge an addition 5 Yuan /visitor[14]. Based on these assumption average net income to boating on Wuliangsuhai, was 7.24 Yuan/visitor in 1998 (at 2002 prices). We combine capital cost data from entry points #1 and #2, and operating

[14] Described as an "entry fee" to the island.

cost data from entry #2 to calculate average costs and income per visitor used to evaluate scenarios in Figure 20.

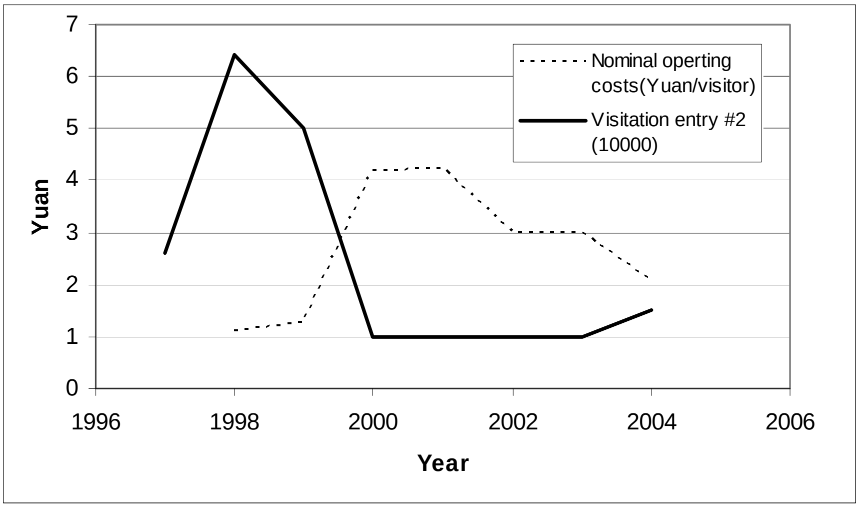


Figure 20 Boat operating costs at entry #2

Note: assumed labour costs for visitor season May-September (500 Yuan/month)

The year 1998 can be regarded as an optimum for returns after which net returns per visitor falls dramatically because the number of boat drivers and boats did not adjust proportionally to the drop in visitation (Figure 21)**.**

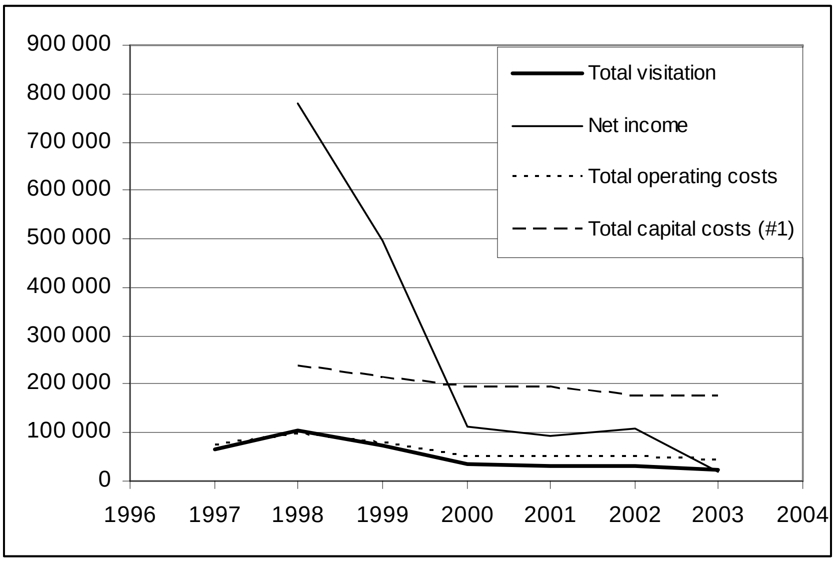


Figure 21 Net income from boating on Lake Wuliangsuhai

Tourist consumer surplus

A survey was conducted of 525 visitors to entry #1 and #2 during August 26th to 12th September 2004 to obtain personal data on travel costs and willingness to pay for increased entry fees[15]. The method employed is known as the (1) travel cost (TCM) and (2) contingent valuation methods (CVM). The aim of the methods is (1) to calculate current consumer surplus (net economic welfare after subtraction of travel expenditure) of visitors to Wuliangsuhai in summer 2004; and (2) to calculate expected increases in this consumer surplus given improvements in water quality that would make it possible to both fish and swim in Wuliangsuhai in the near future. For details of survey questions see appendix. The results from the survey discussed in this report are preliminary calculations, subject to revision.

	Use value of current visitors	Option value of current visitors	Existence value of non-users
Present lake	TCM		
Future lake with improved water quality		CVM	

Table 12 Relevance of travel cost (TCM) and contingent valuation (CVM) for estimating lake values

Table 12 illustrates that the TCM and CVM methods used here capture use values of users of the lake in its present state, as well as use and existence values for a future lake with improved water quality (for swimming and fishing). Any existence values the lake may have for populations not visiting the lake are not considered.

See appendix 2 for a copy of the survey applied to the visitors. See appendix 3 for regression results from the travel cost method under various assumptions. See appendix 4 for results from the contingent valuation questions of the visitors survey. Regression analyses have been carried out as part of Wenting Chen's M.Sc. thesis and is "work in progress". The results are preliminary and subject to further quality control.

[15] The survey was carried out by Wenting Chen, University of Oslo as part of M.Sc. thesis fieldwork. Initial regression results have been taken from a preliminary version of Chen's thesis.

Consumer surplus for lake visitation (travel cost method results)

Monthly statistics of visitation were not available from the Fish Farm. However, Table 13 provides an estimate of the distribution of visitation in a "typical" year. The daily estimate implies an overestimate of visitation in 2004, which was expected at the time of the visitors survey in September 2004 to be about 26 000/year .

Estimated visitation rate	Daily	Monthly
May	150	4650
June	400	12000
July	400	12400
August	400	12400
September	150	4500
October	150	1050
Estimated total		47000

Table 13 Visitor projections for 2004 by Fish Farm.

Source: pers.com. Fish Farm Director

A number of different specifications were tried for travel cost regression models (see appendix 3). A number of assumptions had to be made in order to use travel cost data to calculate consumer surplus from visits:

- functional form (log, semi-log);
- definition of opportunity cost of travel time (60% or 100% of average wages);
- treatment of travel costs when the trip had multiple purposes[16] (counting only additional trip costs to Lake versus a fraction of total travel costs),
- whether respondent's claimed or the researchers estimated travel costs were employed (calculated for each of the 43 zones for which there were visitors). In the survey, about 67.43% of the respondents report that the trip is the single purpose trip while the rest 32.57% reported that the lake is not their only purpose.

The travel cost function has the form shown in Figure 22. As travel costs increase (log) visitation rate per zone decreases. The consumer surplus is calculated based on an expected visitation rate per travel zone (i.e. # of observed visitors / population of the zone).

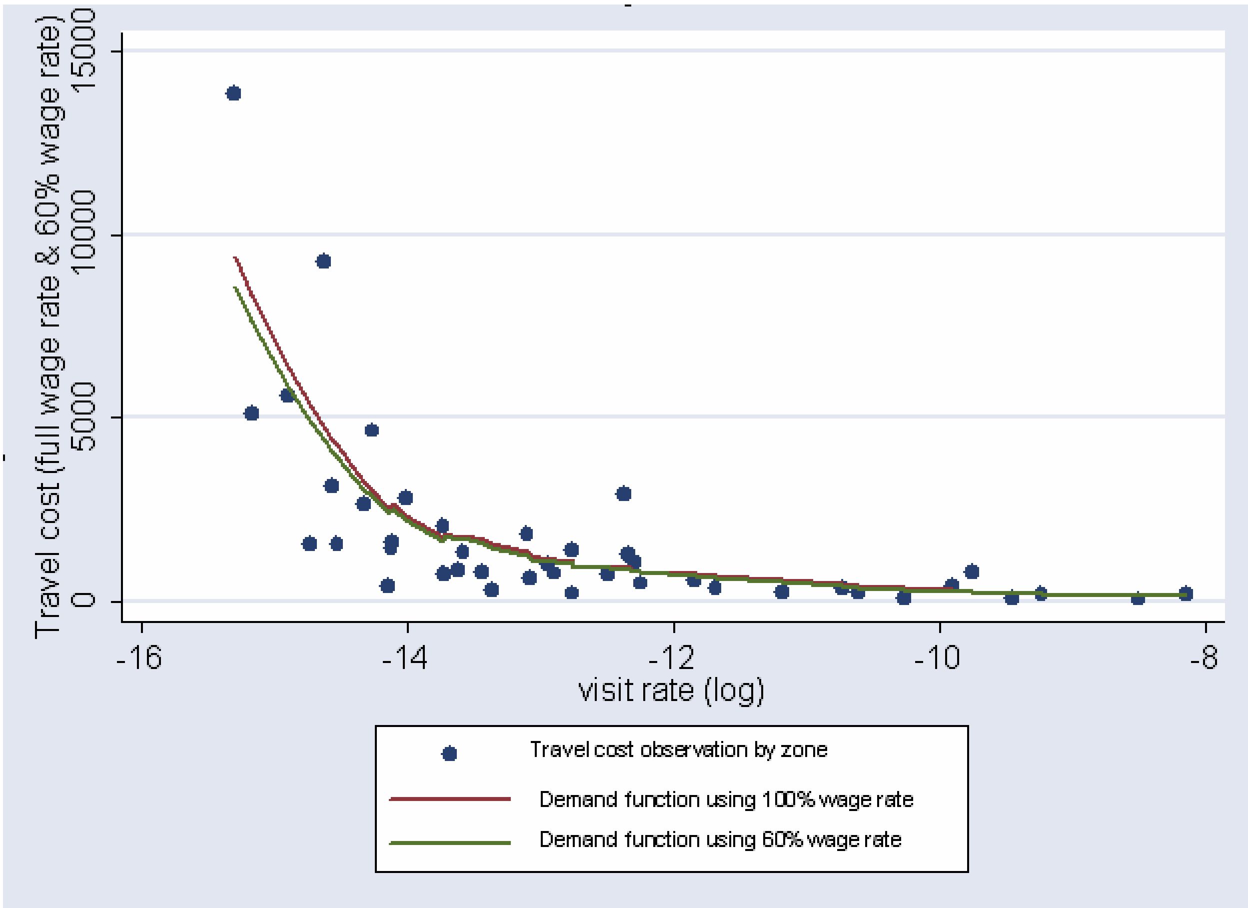


Figure 22 Travel cost and visitation rates by zone (43 zones)

As an illustration of the results in appendix, in the log linear model (Model 2), the coefficient for travel cost ("lntotalcost") is -1.149016 which indicates that 1% increase in the travel cost will lead to an average 1.149016% decrease in the visit rate across zones. The consumer surplus is calculated by estimating the area to the left of the predicted travel cost curve (by integration)[17].

Consumer surplus estimated using the travel cost method has weaknesses due to the large number of assumptions that are required. For calculations here two separate functions were estimated; one for local visitors (<500 km travel distance) and for non-locals (>500 km) travel distance, under the assumption that consumer surplus would be lower for locals[18].

Table 14 shows estimates of consumer surplus and the great uncertainty involved in predicted expected total consumer surplus for visitors to Lake Wuliangsuhai. Consumer surplus by travel zone is based on the sample visitation rate observed during 26th August to 12th September for 525 visitors. This represents 1,3 % of the estimated 41 000 visitors in 2004[19]. Calculated surplus per re-

[17] A rough approach used in this preliminary draft is to calculate average consumer surplus for all zones and multiply by the number of zones. This is work in progress as part og Wenting Chen's M.Sc. thesis.
[18] Results in appendix show that this is not the case. In future revisions of this work a single travel cost function will be used to estimate consumer surplus.
[19] Using unconfirmed statistics of 26 000 visitors to the Fish Farm and 15 000 to the Linhe Tourist Bureau entrance point.

spondent is multiplied by total visitation to obtain an aggregate annual estimate of consumer surplus. Given uncertainty in data collected annual consumer surplus is between Yuan 8,8 million and Yuan 54,6 million with 95% confidence.

Model	# travel zones, respondents	Mean consumer surplus per zone (Yuan)	Total expected consumer surplus (Yuan)	Total consumer surplus (97,5%) (Yuan)	Total consumer surplus (2,5%) (Yuan)
Non locals (60% of time costs)* (>500 km)	31	7722	239 382	377 841	100 923
Locals (60% of time costs)** (<500 km)	12	13893	166 716	321 089	12 343
Total (26 August-12 September)			406 098	698 930	113 266
Consumer surplus / respondent	525		774	1 331	216
Annual visitation	26 000				
Total annual			20 111 520	34 613 700	5 609 340

Table 14 - consumer surplus estimated using travel cost method

Source: visitor survey by Wenting Chen (August-September 2004)
Note: * calculated using function in Figure 22. **calculated using linear demand function

In further analysis we use the lower bound, i.e. we are 97,5% sure that annual consumer surplus is 8,84 million or greater per year for the total 41 000 visitors.

Willingness to pay for swimmable and fishable water (contingent valuation results)

Respondents protesting to the survey or stating WTP=0 was 7,5% of sample. Response rates were high, but few proposed explanatory variables were significant. The following are significant variables with the expected signs (see appendix 4). A 1% increase in income would lead to around a 0.16% increase in WTP to pay a higher entrance fee. Respondents expressing environmental attitudes will to pay about 0.1% more than those who don't express such opinions in the survey(“enconcern”). Willingness to pay is positively correlated to the number of visits to the lake in the last five years (“Nov5yf”). The larger the group of visitors the respondent was part of the lower WTP (*Noigroup*), illustrating “free rider” characteristics.

Table 15 WTP higher entry fee for improved lake water quality

	Sample size	Mean	Std. Dev.	Min	Max
Lowerbond WTP(witout outliers)	**511**	**54.87671**	**32.01284**	**0**	**150**
Mid point WTP(without outliers)	**511**	**65.63405**	**46.11979**	**14**	**325**

A conservative estimate of mean willingness to pay for an increased entry fee is around 54 Yuan (52-58 Yuan with 95% confidence). This is the maximum entrance fee an average visitor would pay for a repeat visit to a lake with improved water quality (see scenario), without deciding to go somewhere else. Given the current entrance fee of 20 Yuan/visitor, we can attribute an average consumer surplus for an improved lake above what is already paid of 32-38 Yuan/visitor.

None of the variables relating to perception of water and lake environmental quality were significant. While we have little additional evidence that WTP is specifically for improved water quality, significant variables seem to confirm that WTP can be related to tourists who make repeat visits and express environmental concern in general. We interpret this to mean that stated WTP may represent an expression of option value for future use of the lake. Although it cannot be specifically tied to future improved water quality, there seems to be evidence that current visitors would pay more for the opportunity of future visits to a lake with improved water quality. We therefore think that consumer surplus from the contingent valuation survey (option value) can be added to consumer surplus from the travel cost survey (current use value).

Summary of future recreational value of lake water

For purposes of comparison with upstream values of water it is necessary to compare, and if possible aggregate, the different components of recreational use value of Lake Wuliangsuhai. This is slightly problematic as our survey data is for 2004, while accounting data from the various lake visitation businesses is no more recent than 2002-2003 (at different levels of visitation). Using 2002 as a base year we assume that the consumer surplus figures observed in 2004 are proportional to visitation. The summary of lake recreational values is shown in Figure 24.

An immediate question is whether to value water in Lake Wuliangsuhai according to potential value, current value, or minimum value. The problem resides in the fact that the value of lake uses depends on the efficiency of businesses that depend on the lake. At low visitation rates, excess infrastructure and personnel lead to negative financial returns. Assuming that lake visitation of around 106 000/year (1998) represents the potential of the lake (before SARS, highway construction and reported problems with lake water quality reduced visitation), future lake recreational value would be in the order of 25 million Yuan/year. If we add the additional willingness to pay stated by visitors for improved lake water quality, potential future recreational value is around 30 million Yuan/year. Given that valuation is for the purpose of benefit-cost analysis of future values of water; given that future visitation is likely to rise if lake water quality and lake area do not deteriorate further; and given that the purpose of the scenarios for water use is to maintain/improve lake quality, this seems a reasonable assumption.

For the purpose of simple benefit-cost analysis later in this report we will make the assumption that visitation is proportional to open lake area in 2001 (168 km^2). We would then get recreational values of at least 148 000 Yuan/km^2 per year. This is assuming no further change in water quality (.i.e. a conservative estimate). The problem with such average values is that tourism value of the lake is associated with specific visitation sites. This is discussed further in the section on benefit-cost analysis of scenarios.

7.3 Fishing

Detailed data was available regarding historical fish catch of different species. However, no such data was available on fishing effort or prices. Despite a concerted effort using Chinese M.Sc. students it was not possible to find anyone at the Fish Farm with statistical data on these issues. Part of the problem may be that fishing has largely ceased in the lake, with the exception of 2002-2003 data for Golden Carp. 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 fishereies 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.

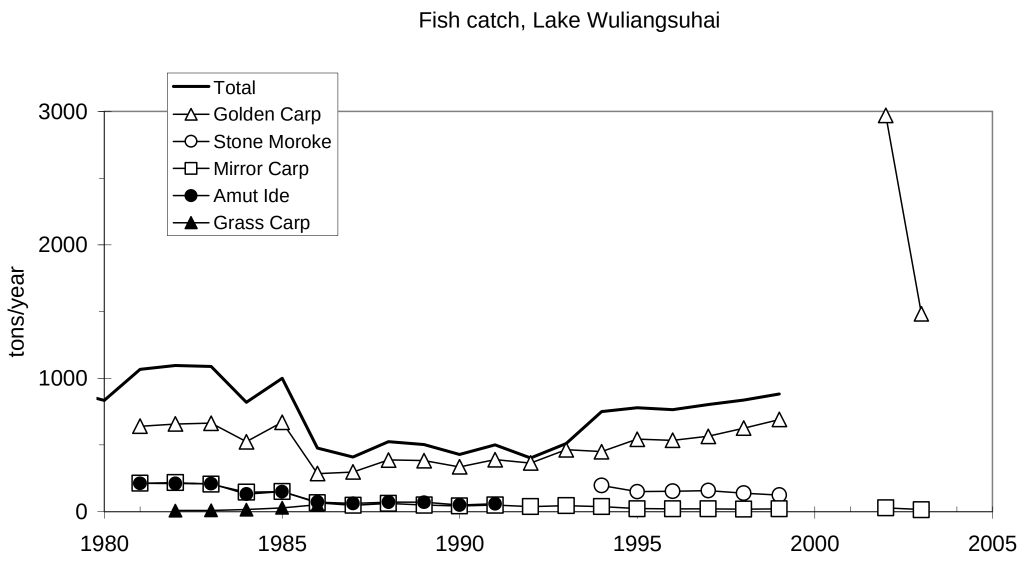


Figure 23 Commercial catch of different fish species 1981-2003. In 2000 and 2001 fishing was prohibited

Source: Monitoring Report

The data on catch, effort and prices in the lake fishery in the following section is taken from the Monitoring Report and interviews with retired fishermen in 2002. Fishing is allowed from May to November. Between ice breaking usually in March and season start in May, the fish is spawning and therefore forbidden to catch. The volume of fish caught is carp and golden carp. Golden carp is the dominant species. The size of the fishes is small, 46 in a kilo (22g each), which is sold for 1 RMB/kg. The next category fish size (medium) is 6 carps to the kilo, which is sold for 4 RMB/kg. A few times big fish up to 2.5 kg is caught. An average catch, which can last from one to three nights for the team of eight fishermen, is 250 to 300 kg. From this total the big fish constitute about 7-8 kg, the medium sized fish about 20 kg and the rest is small fishes (46 fish /kg)[20].

For the economic calculations we therefore use a weighted price for the distribution of an average catch. We assume that the price data obtained from the 2002 interview is for the same year. Fishermen state that fish prices rose steadily with the scarcity of fish. We have not historic price data. Since the catch of Golden carp was so great in 2002, prices are probably lower than for previous years. Based on this assumption, applying this price to historical fish catches probably leads to an underestimate of the value of historical catch (we don't know by how much). We have no price data on other species and so apply this price to all fish (78% of catch in 1999 and 99% of catch in 2002-2003 consisted of Golden carp).

There are considerable amount of shrimps in the lake, which are quite popular. Since 2000 these are forbidden to catch. When they were caught they were sold for 5 RMB/kg after being cooked in the home of the fishermen. A normal yearly catch could be 2000 kg pr team (no data on effort available). The reason for the shrimp-pause is to provide the carp with more food – to increase the fish production. Illegal shrimp-ruses are still employed in drainage canal no 9. [21] For economic calculations we use this price and registered catch. While the price leads to somewhat of an overestimate of the value of the catch, the lack of data on illegal fishing probably means that the values calculated for registered shrimp catch (5% of total catch by weight) are underestimates.

For fishing effort we have one data point regarding the returns to fishing of a 1-3 night sortie for an 8 man team[22]. Catch per unit of effort (CPUE) lies between 12.5 – 31,25 kg/man/night: we use an average of 17 kg /man/night in our calculation. We have no such data for shrimp, applying the same CPUE as for carp. Although this is patently wrong, applying an arbitrary value will help to avoid over-estimation of net value. Given that shrimp constitutes 5% of total catch the overall error should be relatively small.

We calculate labour costs using the implicit labour cost obtained from reed harvesting (12,5 Yuan/day). By coincidence average labour cost/kg estimated using our one data point is the same as the weigthed price/kg for carp, suggesting the subsistence nature of the fishery (no profits). Given that there is no reed harvesting and few other employment opportunities in summer, this is probably an overestimate of the opportunity cost of labour.

While subsistence lake uses with net financial returns close to zero make no impact on the financial value of the lake, in an economic analysis a more correct estimate of economic opportunity cost of labour is needed. Data on the nutritional value of fish and the proportion of catch consumed by households is also absent, but would be another way of internalising the economic value

[20] Excerpts from interview in Fishing Village no. 15 april 21, 2002. Report on Historical Development (this project)
[21] Interview in Fishing Village no. 15 april 21, 2002. Report on Historical Development
[22] Interview in Fishing Village no. 15 april 21, 2002. Report on Historical Development

of the subsistence fishery. This issue will be further evaluated in ongoing M.Sc. thesis work[23].

For capital costs we account for depreciation of boats and nets. No nets where used until the eighties. Now ruses of fairly small mesh-widths are used. The Fish Farm managers state that some 35 small wooden boats and 7 larger steel hulled fishing boats are currently operational, as well as some 200 nets[24]. Assuming 20 year lifetimes for boats and 10 year lifetimes for nets we obtain an annual capital cost of Yuan 49 000 for the whole fishery.

7.4 Animal feed production from pondweed harvesting

One of the management and control measures proposes the harvesting of pondweed (Potamogeton pectinatus) in the lake for the production of animal feed. According to the authors of this measure harvesting a 5000 hectare area within an area of 75 km^2 could produce 50 000 tonnes dry-weight of feed stuffs per year with annual gross value of 20 million Yuan. The annualised investment and operating cost is about 11,2 million Yuan with an estimated 8,8 million Yuan net income projected from such an activity. This project would require "open water" non-reed areas where Potamogeton may grow. Complex processes of lake hydrology and competition for nutrients and light with phytoplankton make the prediction of the productivity and profitability of pondweed harvesting very difficult. Although this level of harvesting seems technically possible based on small scale experiments, the ecological impacts of large scale harvesting have not been explored fully. Limnologists have suggested (Monitoring Report) that restrictions should be placed on the total harvestable area (25 km^2) and the mode of harvesting (strips) in order to avoid algal blooms due in harvested areas. The original financial calculations would have to be recast in this light and coupled to modelling of the likely algal bloom effects of different harvesting schedules.

About the only thing that can be said with certainty is that there would be no harvesting potential in areas without water. Due to successional effects in lake vegetation, it is difficult to say whether reductions in pondweed extent will be proportional to reductions in lake area, even when nutrient levels are kept constant

7.5 Fertiliser production from dredging

Another proposed management and control measure that has considered includes producing fertiliser from dredged materials from the lake. The prime purpose of dredging is to open canals for circulation and transportation, while the dredged mud is collected and dried and sold as agricultural fertiliser. Assuming fertiliser prices at 500 Yuan / tonne and 50 000 tonnes of dredging per year the authors expect gross income per year of 25 milllion Yuan . Annualised capital and operating costs are about 8, 07 million Yuan. The management and control plan does not evaluate whether this is a sustainable dredging level. We expect that such dredging would not take place every year, but no information is available on the periodicity of the measure.

[23] M.Sc. thesis by Tianyi Shen
[24] Data collected by Wenting Chen, September 2004.

We have left both projected production and sale of animal feed and fertiliser out of the analysis given these uncertainties. There is certainly a potential for income generating activities, but we do not have sufficient information to say whether it could be sustained in time at the levels suggested in the MCP reports. Figure 24 summarises the different financial returns to lake uses. The calculated values may be observed in Appendix 1.

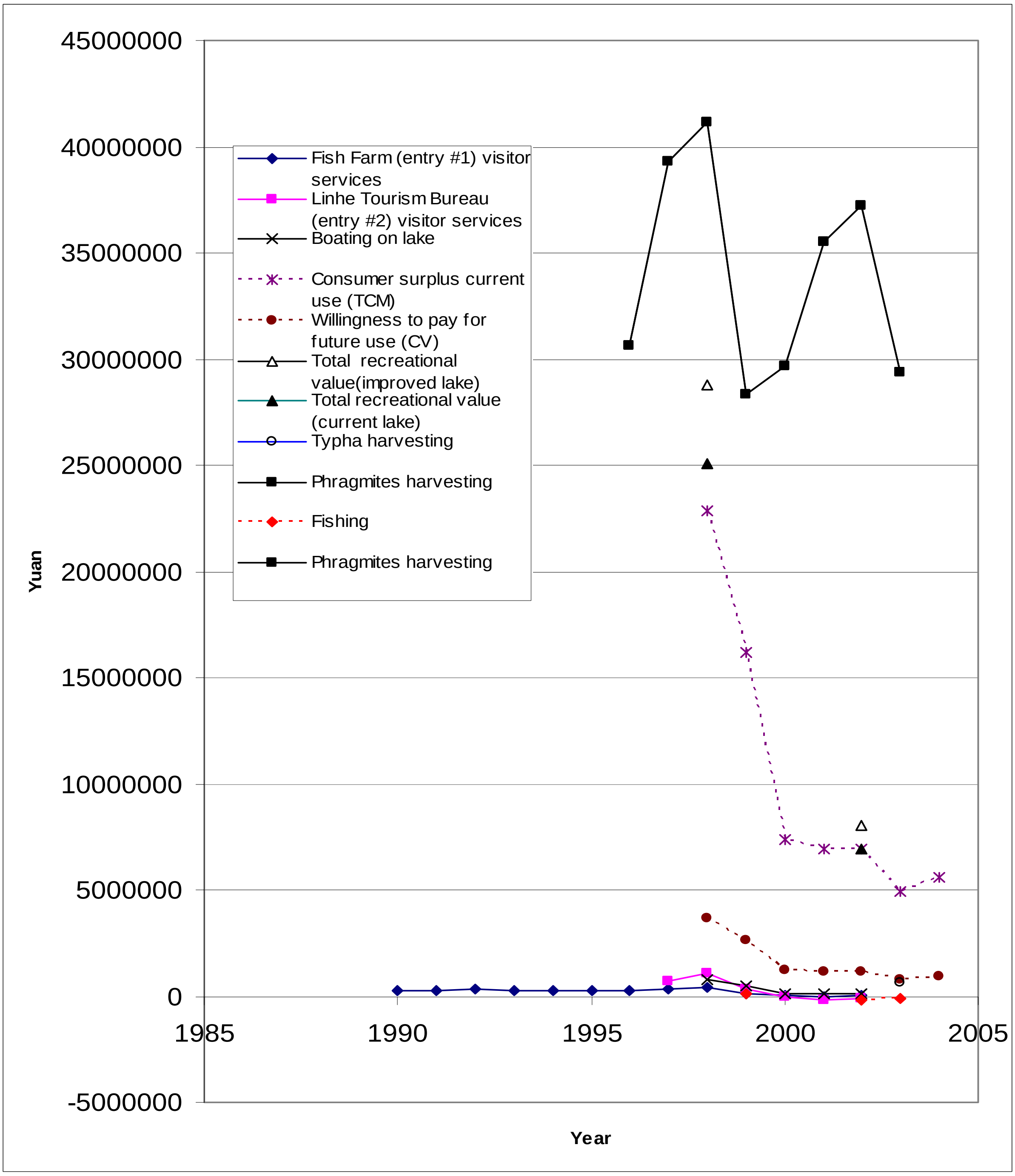


Figure 24 Comparison of economic values of lake uses.

Note: dashed lines are interpolations based on historical visitation and production statistics, but where unit values are calculated at prices available for 2004 (visitation) or 2003 (typha). Single data points (total recreational value) represent two interpretations of value. In 2002 is the last year for which we have complete data for values of all recreational uses, a year in which visitation was near a low point, and tourist installations were (probably) operating with a loss. In 1998 visitation was at a historic high of more than 100 000 visitors. Recreational value in this year may be interpreted as "potential" and compares favourably to the value of reed production.

Basin water uses

7.6 Agricultural water uses[25]

Section 4 provided an overview of the extent and types of irrigated agriculture in the Hetao Basin and resulting water use. In this section we estimate average returns to land and water use by type of crop. Production costs and prices are obtained from five years of data in the Cost-benefit Analysis Report for agricultural products (1999-2003) published by the Bayannaoer Agriculture Bureau. Crops included in the calculations are wheat, maize, sunflower, oil plant, inteplanted wheat and maize and forest, orchards and grazing grass. We thus have financial data for 85,1 % of total cropping area in Hetao and for an estimated 93 % of total irrigation water use.

Figure 25 illustrates that total production costs have fallen in Hetao in recent years. Correspondingly, agricultural profits net of irrigation fees have risen (Figure 26). Total expenses on irrigation and drainage fees have fallen since 1999 in Hetao (Figure 27), while fees per m^3 have remained constant in the same time period, indicating greater water use efficiency in the period 1999-2003. This may be the cause of the observed reduction in lake input from the drainage cannals observed for 1995-2000. In that case greater water use efficiency is coming at a cost to Lake Wuliangsuhai.

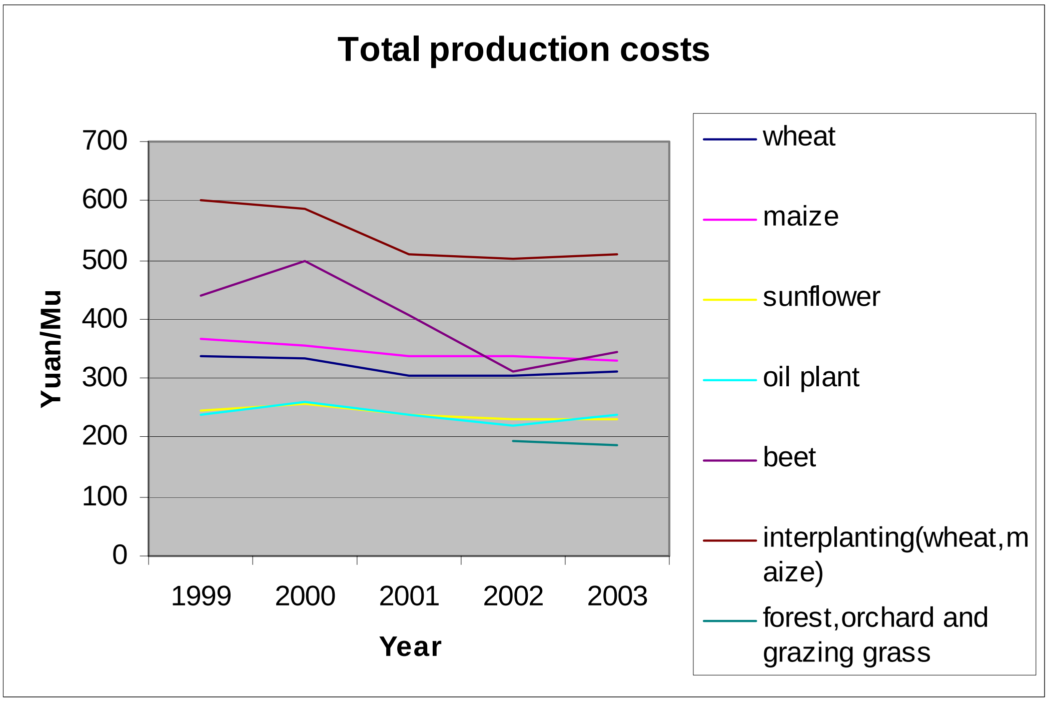


Figure 25 Average production costs by irrigated crop type in Hetao Basin.

Note: 1 Mu = 0.067 hectares

25 Data for this section have been collected by Tianyi Shen, M.Sc. student, University of Oslo.

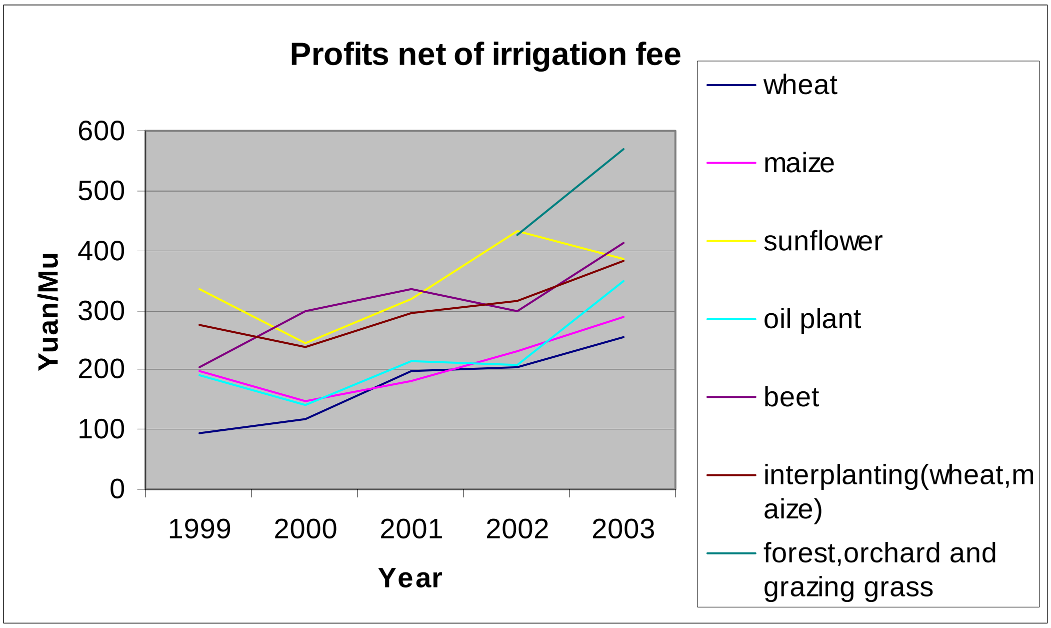


Figure 26 Profits by irrigated crop type in Hetao Basin. 1 Mu = Chinese area measure

Note: 1 Mu = 0.067 hectares

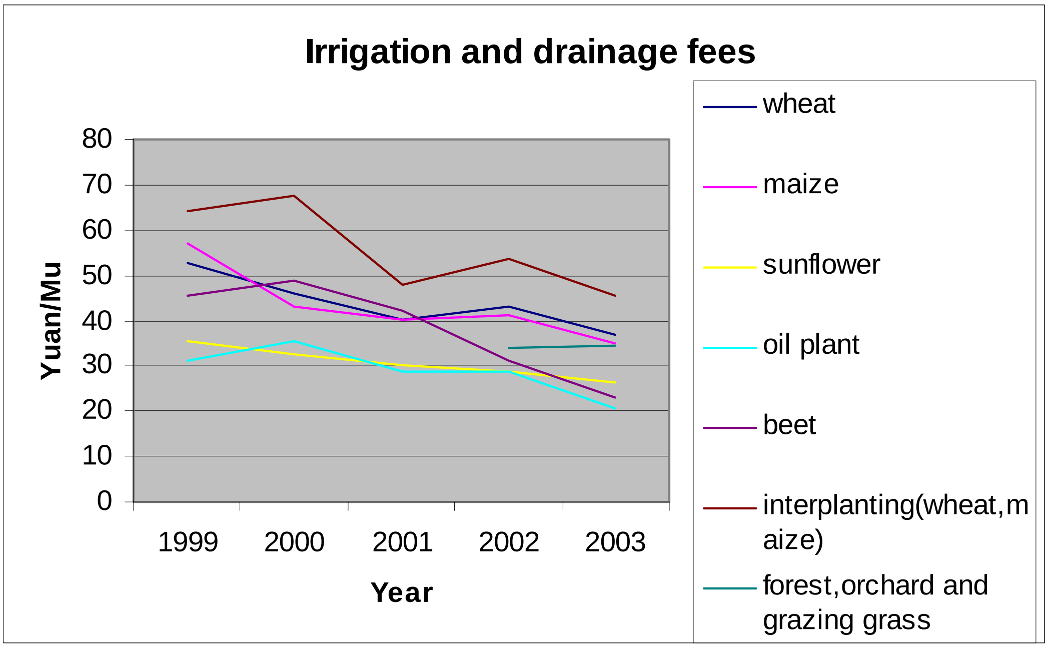


Figure 27 Average irrigation and drainage fees by crop type

Note: 1 Mu = 0.067 hectares

Figure 28 illustrates data on financial returns to crops, taking into account the variation observed in the period 1999-2003. Combined with water use by crop type, this information is in turn used to construct a water demand curve for irrigated agriculture in the Hetao Basin in Figure 31.

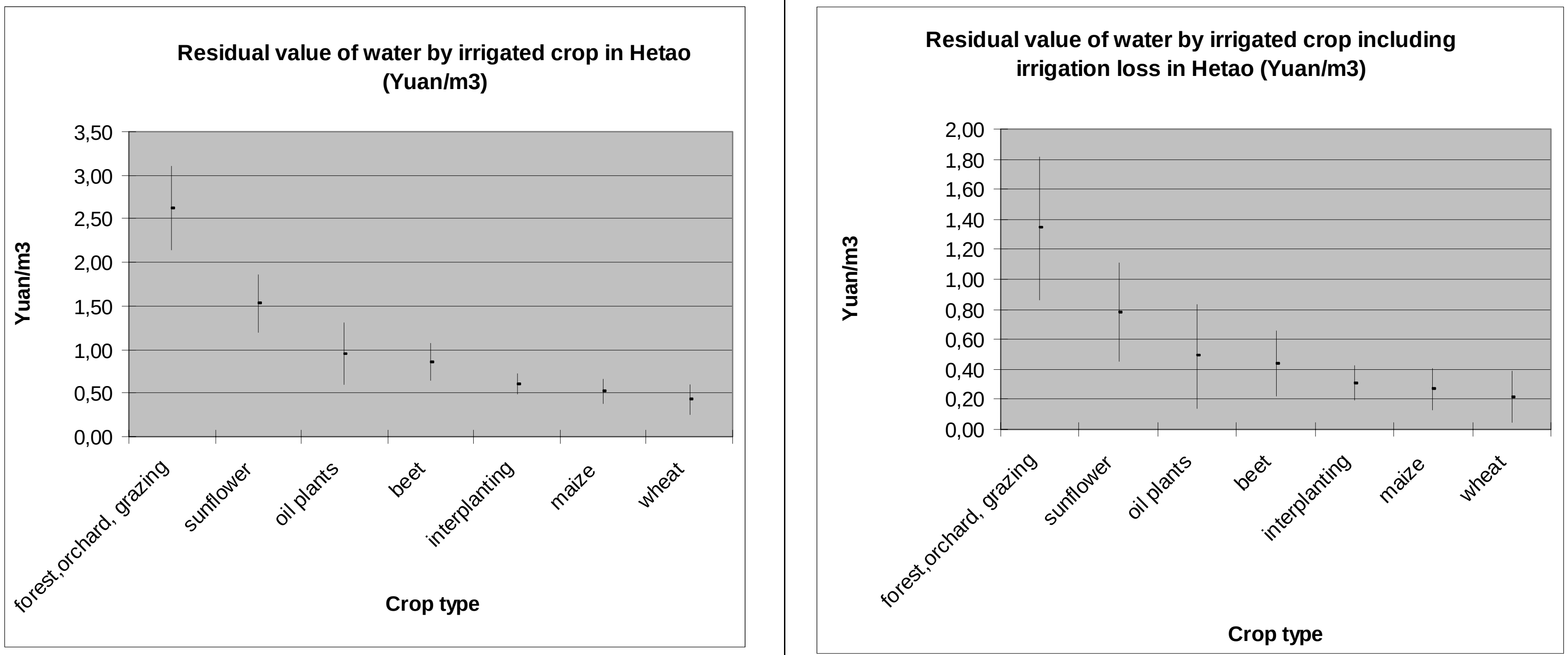


Figure 28 Residual value of water by crop type in Hetao with and without irrigation loss

Note: net income per m^3 of water used (minus irrigation fees).

Sources: Calculations based on: production cost and price data: Cost-benefit Analysis Report for agricultural products, Year1999-2003, Bayannaoer Agriculture Bureau; Crop water needs data: Experiments and actual measurement carried out by water research institute of Hetao Irrigation Bureau, Shahao Experiment Station, Yichang Yonglian Experiment Station, Inner Mongolia Hetao Irrigation Bureau; irrigation water loss data: Yellow River Inner Mongolia Hetao Irrigation Area Water Saving Project Planning Report (Year 99 Planning for short), passed by Water Ministry of China in year 2000, Year 2000, Inner Mongolia Autonomous Region Water Reconnaissance and Design Institute

8 Benefit-cost analysis of scenarios

8.1 Hetao irrigated crops versus lake uses

Summing values across all lake users for 2001/2002 we arrive at total annual value of approximately 45 million Yuan (we have data on all uses for one or the other of those years). If we do the same for 1998/1999 when reed harvest and visitation were at their highest, lake uses generated producer and consumer surpluses of a total 70 million Yuan. To accept this figure one must accept the assumption that consumer surplus per visitor was the same per visitor in 1998 as was observed in the TCM/CVM surveys conducted in 2004. Annual water inflow to Lake Wuliangsuhai in 2001 was 440 million m^3, while in 1998 it was 638 million m^3. Based on these figures the average annual value of return flow to Lake Wuliangsuhai from Hetao Basin was 0.11 Yuan/m^3 in 1998 and 0.10 Yuan/m^3 in 2001 (Table 16)[26].

Year	Inflow (Monitoring Report) ($10^6 m^3$/year)	Total value of lake uses (Yuan/year)	Average value of lake uses (Yuan/m^3)
1996	829		
1997	728		
1998	638	70 030 257	0,11
1999	603		
2000	492		
2001	440	45 150 926	0,10

Table 16 Average value of water inflow to Lake Wuliangsuhai

Source: see Appendix 1 and Monitoring Report

However, for benefit-cost analysis of water allocation between agricultural and lake water uses we need to know the *marginal* value of water. In other words, which uses will suffer, when and how much as return flow from Hetao Basin is reduced. As stated previously the evaluation of scenarios for lake depth area and volume were based on few observations, albeit with conservative assumptions. We would have to make further assumptions in order to construct a function for the marginal value of water for lake uses. This is attempted in the following.

It seems reasonable to assume that for gradually falling water levels, and rapidly colonising reed, reed area may not be severely impacted until water levels drop below -0.5 m level relative to the 2001 lake level. At this point further drops in water level make less new area at appropriate depth available for colonisation, than is lost to a receding shoreline (see Figure 10). Further reductions in water level will lead to corresponding reductions in open water area. Assuming that a drop in water level is slow enough for reed colonisation to take place as new areas of lake bottom are

[26] Using mean consumer surplus from the TCM and including willingness to pay estimates from the CV study average value of water to the lake rises to 0.11 Yuan/m^3 (2001) - 0.14 Yuan/m^3 (1998).

'made available' (< 1.5 m deep), open water area would all but have disappeared with a permanent 1 m drop in lake level (see Figure 10).

Visitors to Lake Wuliangsuhai come to the area chiefly because of the recreation related to open water surfaces (chiefly boating and bird watching). At some point reduction in open water areas can be expected to lead to a threshold effect in visitation to the area, as e.g. when visitors centers or prime attractions are no longer accessible due to reed encroachment or innavigable depth. For access to the bird station from the Fish Farm visitor centre's harbour, this would probably be the case if average annual lake levels drops permanently more than 1.0 m. In this case more than half the distance to the island would have to be dredged judging by the map in Figure 3. For the Linhe Tourist Bureau ("Tourist Station Park",) there would be access to navigable open water perhaps even at lower water levels, but probably not to the bird station. Reductions in visitation would probably happen before this as word was spread of reductions in lake level, reed rapidly filled remaining open water areas, and as less and less dilution of nutrients getting to the lake led to increased growth of pondweed, making transportation on the lake progressively more difficult.

Because reed areas might even expand with falling water levels of 0.5-1.0 meters, less water to the lake may for a short while actually lead to increased reed production, while at the same time reducing tourism visitation. With no further information it is certainly difficult to even entertain hypotheses as to the marginal short term value of water to Lake Wuliangsuhai.

On the long term we can note that a permanent supply of water to the lake generates as much as 0,15 Yuan/m^3 in wetland values, mainly from reed harvesting and visitation/recreation. This is more than than the 0,0274 Yuan/m^3 paid by the Fish Farm in their latest purchase of 78 million m^3 Yellow River water in 2004 . Could the marginal value of water for lake users be lower than what the Fish Farm is paying for water from the Yellow River? Recall the two extreme cases that were conceivable with a drop in lake level of 05 m (section 6).

For the purpose of simple benefit-cost analysis later in this report we will make the assumption that visitation is proportional to open lake area in 2001 (168 km^2). This is assuming no further change in water quality[27]. We would then get recreational values of at least 148 000 Yuan/km^2 per year. The problem with such average values is that tourism value of the lake is associated with specific visitation sites, and tourism value of the lake probably has some important thresholds.

Until sites such as the bird island and visitation centre harbours are innavegable no dramatic reduction in visitation numbers can be expected. With a 0.5 meter drop in lake level this will not be the case, unless reed colonisation was so aggressive that open water areas all but disappeared. In both cases we would expect a smaller lake to have a lower landscape values which is why we hypothesise that average lake value for recreation is proportional to area of open water. In the second case discussed in section 6, average values are probably conservative as a lake area of only 20 km^2 would probably lead to all but a disappearance of visitation (and economic value derived from it). For reed it is much easier to assign average harvest values per unit of reed area, which we calculated to Yuan 195 800 – 277 200 / km ^{2} per year.

[27] i.e. using a conservative estimate of 25 million Yuan/year not including willingness to pay for lake water improvements.

Table 17 summarises the results of the discussion above where we attempt to place economic impact values on the consequences of both extreme cases. If we assume aggressive reed colonisation as lake level drops, we obtain a conservative value of 0.081 Yuan/m^3 (last lin of the table). This is the value of incremental inflow which avoids a 0.5 meter lake drop in lake level relative to 2001 levels. If we assume no reed colonisation economic impacts are proportionally greater for reed, but less so for visitation, resulting in a value of 0,134 Yuan/m^3. Further discussion of the usefulness of this result is made below under Policy Conclusions.

	Case 1	Case 2
	(assuming no reed colonisation)	(assuming full reed colonisation down to 1m depth);:
2001 inflow (million m3)	441	441
"Worst case" inflow (million m3)	230	230
Change in long term average annual inflow relative to 2001 (million m3)	-211	-211
Change in average water level (m)	-0,5	-0,5
New average lake volume(million m3)	172	172
New total wetland area (km2)	240	240
Reed area 2001 (km2)	146	146
Reed area worst case (km2)	120	220
Change in reed area(km2)	-26	74
Open water area 2001 (km2)	168	168
Open water area worst case (km2)	120	20
Change open water area (km2)	-48	-148
Average value reed area (Yuan/km2)*	195800	195 800
Average recreational value open water area (Yuan/km2)**	148000	148000
Change reed income (proportional to reed area) (Yuan)	-5090800	14489200
Change visitation income and consumer surplus (proportional to open water area) (Yuan)	-7104000	-21904000
Net change in surplus	-12194800	-7414800
Net unit value of avoiding change in annual flow (Yuan/m3)	0,06	0,04

Table 17 Two extreme scenarios for economic impacts of a permanent reduction in average lake level by 0.5 meters relative to 2001.

Note: * lowest estimates of average value per unit area

8.2 Opportunity costs for downstream uses in the Yellow River – possible value of hydrological services of Lake Wuliangsuhai

Monitoring Report data show that the return flow to Lake Wuliangsuhai from water used in irrigation is virtually all lost to evapotranspiration and infiltration in the lake. Does water abstraction for Hetao irrigation impose opportunity costs on downsteam uses in the Yellow River? This has not been the focus of the study, but some isolated pieces of information provide some indication of the opportunity costs of water.

In May 2000 the Hetao irrigation area abstracted about 80% of the average flow in Yellow River for that month (Figure 29). This is the month in which the Yellow River flow downstream of Wuliangsuhai is at its lowest, or about 300 million m^3. We also know that one of the largest immediate downstream water users is Batou City, which consumes an average 542 million m^3/year. Given that 63% of water abstraction is for irrigation, abstraction in May at Baotou is probably higher than the average 45 million m^3/month. At any rate we can see that a significant portion of the remaining flow immediately downstream of Hetao is abstracted in May. Seasonal water scarcity is therefore a relevant issue to discuss when evaluating the allocation of water to Hetao irrigation area and the role of Lake Wuliangsuhai.

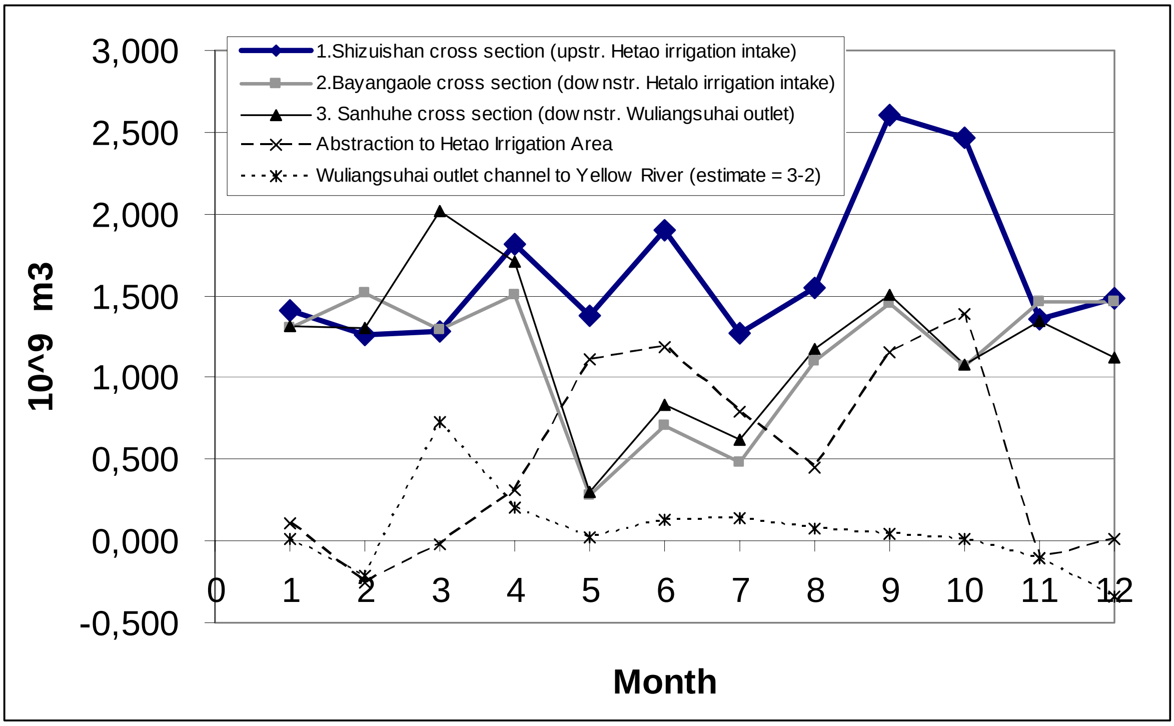


Figure 29 Hydrological data for Yellow River upstream and downstream of Lake Wuliangsuhai

Source: The collection of irrigation and drainage information in Hetao Irrigation Area (1998-2002) , The statistics of monthly flow at Shizuishan,Bayangaole and Sanhuhe cross sections from 1960-2000, p17-20, Hetao Irrigation Bureau.

	million m^3	
total water introduced from Yellow River	542,41	100 %
irrigation use	340,8	63 %
industry use	168,12	31 %
domestic use	33,49	6 %

Table 18 Baotou City Water plant abstraction from Yellow River

Source: Baotou Water Resources Bureau

With a calculated wetland water volume of 299 million m^3 in 2001, the storage capacity in Wuliangsuhai is about equivalent to the remaining flow in the Yellow River in May downstream of Hetao irrigation area. Without changing lake level, residence time in the lake for an additional 300 million m^3 would be about a month. In other words by diverting about this amount of water directly to Lake Wuliangsuhai in March/April when irrigation demands in Hetao are more modest, using the lake/wetland as short term storage, the flow in Yellow River could probably be duplicated in May.
In this manner Lake Wuliangsuhai could provide a valuable hydrological service to downstream uses, increasing its economic importance for the watershed.

We do not know which uses are affected by possible water shortages downstream, nor as a consequence what the incremental value of this water storage service could be worth. However, some further data on opportunity costs of water from the lower reaches of the Yellow River is presented in the following.

According to Chen et al. (n.d.) opportunity costs of water use in Yellow River for a multi-purpose dam at Xiaolangdi, lower Yellow River are in the range of 0,3-0,5 Yuan/m^3 [28]. This is the value of lost water uses downstream of the reservoir in the lower Yellow River when water there goes to consumptive uses such as irrigation. Given that Yellow River water is used for drinking water, irrigation and hydroelectric production at several locations between Hetao and Xiaolangdi – amongst others Baotou City - this is a very conservative estimate of opportunity cost of water use in Hetao[29].

[28] CHEN Xiaoguo, SHI Chunxian, ZHANG Huiyan, Summarization on planning and study about Yellow River water resources development and utilization, YRCC.
[29] M.Sc. thesis by Tianyi Shen,UiO, will try to generate more complete data on opportunity costs of Yellow River water use.

Figur 30 Hetao irrigation area (red circle) and location of multi-purpose dam at Xiaolangdi (green box).

Source: CHEN Xiaoguo, SHI Chunxian, ZHANG Huiyan, Summarization on planning and study about Yellow River water resources development and utilization, YRCC (no date).

We use this conservative estimate of opportunity costs of water in the Yellow River in the next section on policy recommendations where we try to place Hetao Irrigation Area and Lake Wuliangsuhai in a bigger context[30].

Finally, for the sake of argument, if we use 0,3-0,5 Yuan/m^3 as representative of the marginal value of water to users in downstream areas with water shortage; and if we assume that there is water shortage somewhere in the lower reaches of the Yellow River when flow is as low as 300 million m^3 in May at Sanhuhe, then Lake Wuliangsuhai's water storage service could be worth as much as 90-150 million Yuan every spring.

When we compare this hypothetical value of this environmental service with the value of direct uses of the lake (conservatively estimated at 45-70 million Yuan/year) it is striking to see the potential economic importance of environmental services versus direct uses.

It places the other estimates in this report in a new light, particularly considering that the value of ecosystem/habitat support services for fish and birds has not been included in the study.

[30] Work in progress in Tianyi Shen's M.Sc. involves obtaining better estimates of the opportunity cost of water downstream of Hetao amongst others for domestic uses in cities like Baotou.

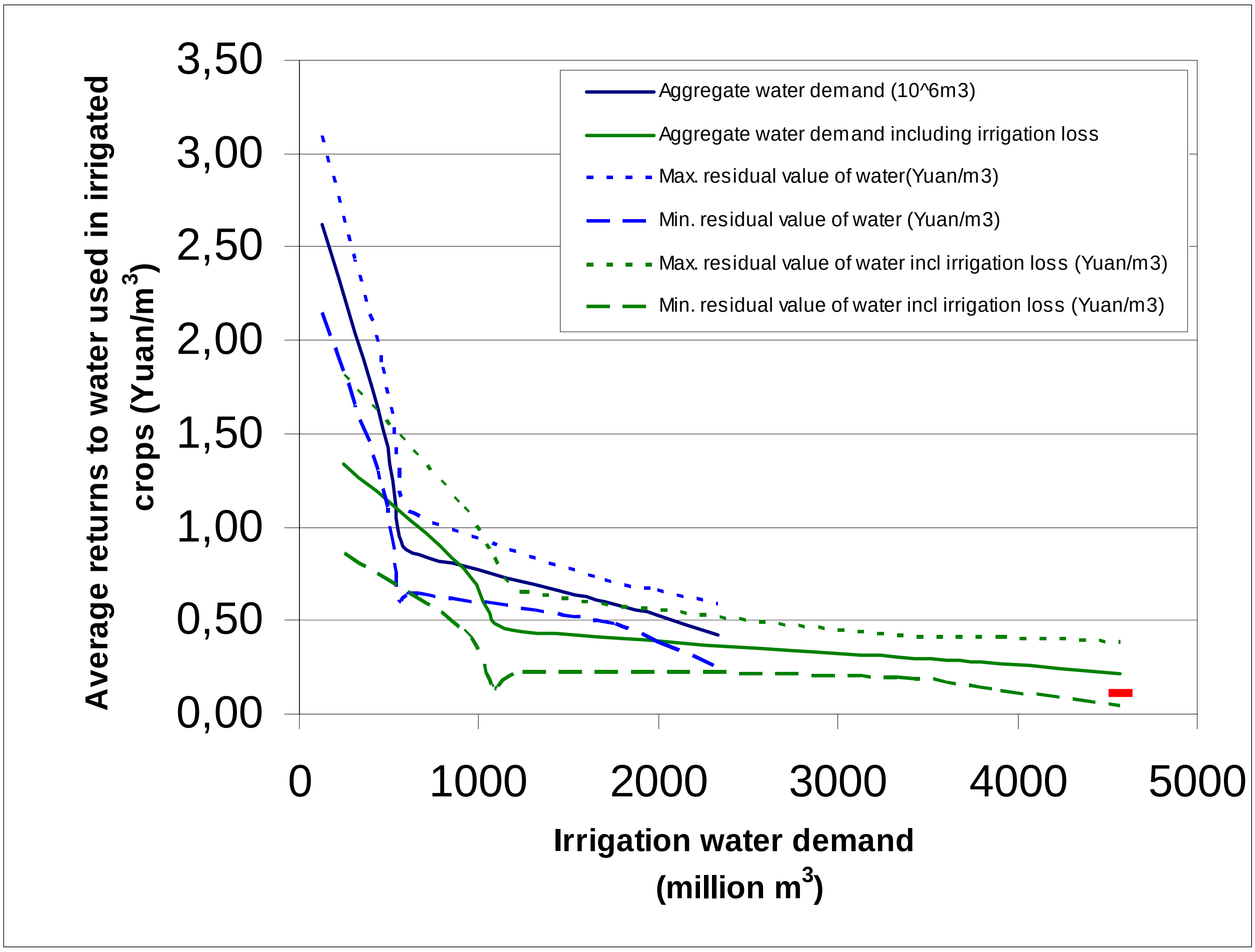


Figure 31 Returns to use of water in agriculture (1999-2003), average opportunity cost in Yellow River (grey line), conservatively estimated marginal value of lake water uses (short red line lower right hand corner).

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 Yuan/m^3 (638 million m^3 = 1998 return flow); 0.10-0.11 Yuan/m^3 (440 million m^3 = 2001 return flow) and 0.04-0.06 Yuan//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.

9 Policy conclusions

Given all the assumptions made above what can we say about the values in Table 17 Average economic values per unit area of reed and open water are lowest estimates given all the assumptions in this report. For reductions in water level there is a trade-off between visitation and reed production if we assume aggressive reed colonisation. This produces the most conservative estimate of the value of additional water to the lake to avoid a 0.5 m drop in water level. This is still higher than the 0,0274 Yuan/m^3 the Fish Farm paid for about 78 million m^3 in 2004. We can quite safely conclude that the Fish Farm's purchase of Yellow River water at the 2004 terms had net benefits from a longer term 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, while current (2001) income from tourism was very low (almost all value comes from consumer surplus to visitors).

We must keep in mind that no values have been assigned to biodiversity conservation, nor to the potential value of a healthy fishery in the lake, and that we have used conservative recreational values. Furthermore, no value is assigned to water stored in Lake Wuliangsuhai and released to the Yellow River during the dry season. In 2001 this was 366 000 m^3. At 0,3-0,5 Yuan/m^3 as opportunity cost in the Yellow River, the current (2001) value of the reservoir services provided by Lake Wuliangsuhai are small. We have in no way pretended to evaluate the potential of such reservoir services given the lack of topographical data, but they would seem to be limited and inferior to impacts of large seasonal changes in water level on reed harvesting and especially visitation.

Putting Lake Wuliangsuhai and Hetao Basin in a wider context we can make some simple comparisons in Figure 31. If irrigation water losses are removed we see that the value of water in irrigated water in Hetao is higher than values with irrigation losses observed in 1989[31] . Increase in the water value of economically marginal crops such as wheat may be as much as 0,5 Yuan/m^3. This is more than our most conservative value of water for lake uses. Based on this reasoning water savings in wheat should be pursued aggressively assuming that the increased value to wheat production would be greater than (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 using an estimated 670 million m^3 /year including irrigation loss proportional to its cultivation area. Depending on which year is used the average residual value of water to irrigated wheat varies between 0.05 Yuan/m^3 (1999) – 0.39 Yuan/m^3 (2003) (Figure 28). Even with the very conservative estimates of the marginal value of lake water uses calculated in Table 17 we see that an economic case could also be made for reallocating water from the least productive areas under wheat to maintenance of Lake Wuliangsuhai.

From the perspective of downstream uses in the Yellow River, even a very conservative estimate

[31] SHI Yaohua, LIU Huizhong, Wu Tongshun, The Study of Water Saving in Hetao Irrigation Area, paper collection edited by China Water Academy Association, (1999). Data from experiments conducted in 1989.

of opportunity costs of downstream water uses of 0,3-0,5 Yuan/m^3 at Xiaolangdi (Chen et al, n.d). 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. Notice that this conclusion would also be true even after eliminating all irrigation losses. Part of 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 likely at their highest downstream.

This simple analysis does not take into account social costs of reducing agriculture in Hetao Basin, but the differences in financial returns to different uses of water in irrigated agriculture and downstream - even with very conservative assumptions - are so striking that we feel such a conclusion is justified.

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 we add 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.

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Appendix 1: Estimated returns to lake water uses

Year	Visitors (Fish Farm entry #1)	Visitors (Linhe Tourist Bureau, entry #2)	Total visitation	Fish Farm (entry #1) visitor services	Linhe Tourism Bureau (entry #2) visitor services	Boating on lake	Consumer surplus current use (TCM)	Willingness to pay for future use (CV)	Total recreational value(improv ed lake)	Total recreational value (current lake)	Typha harvesting	Phragmites harvesting	Fishing	Total wetland value	Comments
1988	12 000		12 000												
1989	15 000		15 000												
1990	16 000		16 000	286 173											
1991	16 000		16 000	286 468											
1992	20 000		20 000	302 034											
1993	21 000		21 000	277 615											
1994	23 000		23 000	267 190											
1995	24 000		24 000	233 647											
1996	30 000		30 000	293 396								30 641 900			
1997	40 000	26000	66 000	306 330	697 290							39 284 391			
1998	42 000	64000	106 000	393 873	1 066 739	768 973	22 868 848	3 697 280	28 795 712	25 098 432		41 153 681		70 030 257	
1999	25 000	50000	75 000	104 786	331 904	498 226	16 180 788	2 616 000				28 313 521	80 865		affected by lake smel
2000	24 000	10000	34 000	58 263	-72 912	111 236	7 336 291	1 186 920				29 674 336			highway construction
2001	22 000	10000	32 000	-10 973	-179 534	90 931	6 903 803	1 116 160				35 542 720			
2002	22 000	10000	32 000	22 000	-118 000	109 924	6 903 803	1 116 160	8 033 888	6 917 728		37 222 362	-161 646	45 150 926	
2003	13 000	10000	23 000				4 962 108	802 240			636000	29 341 986	-105 323		affected by SARS
2004	16 000	10000	26 000				5 609 340	906 880							

Appendix 2: TRAVEL COST AND CONTINGENT VALUATION QUESTIONNAIRE

Interview Location:______________________
Respondent is: arriving / leaving the lake

NOTICE:
We are conducting a survey of visitors to Lake Wuliangsuhai on behalf of the "Fish Farm" company. Your answers will help the company and the authorities improve the services offered to lake visitors. Your answers are completely confidential.

PART I: Lake Visitor Survey

1.1 What is your home Country__________
1.2 What is your home County____________
1.3 What is your home Zip code_________

2. Is the lake your only destination on this trip? (destination: the main aim of your trip)
A. YES
B. NO (If NO, please specify all the other destinations for this trip
2.1.____________________________________
2.2What's your departure place for Lake Wuliangsuhai?_________________________
2.3What's the next place you are going to visit___________________

3. Are you visiting the Lake for one or several days? (CHECK ONE)
____ One-day trip (Go to Box A) _____Multiple-day trip (Go to Box B)

<u>BOX A: ANSWER THESE QUESTIONS ONLY IF THIS IS A ONE_DAY TRIP</u>

4.1. How many hours do you want to / did you spend in the following activities respectively?
_____Boat sightseeing
_____Bird watching (bird island)
_____Enjoying the water by the lakeside
_____Bird and fish museum
_____Camel riding
_____Other(Specify)_____________________
_____Other(Specify)_____________________

GO TO BOX C

<u>BOX B: ANSWER THESE QUESTIONS ONLY IF THIS IS A MULTI-DAY TRIP</u>

4.2. Where did you / are you planning to stay at night (CIRCLE ONE)
A. Hotel near the lake
B Hotel in Wulatequanqi
C. With family
D. Other (specify:)_______________________

4.3 How many days do you plan to visit the lake area?
_______(days)

4.4 How many hours do you want to / did you spend in the following activities during day-time respectively?
_____Boat sightseeing
_____Bird watching (bird island)
_____Enjoying the water by the lakeside
_____Bird and fish museum
_____Camel riding
_____Other(Specify)_____________________
_____Other(Specify)_____________________

GO TO BOX C

PLEASE TURN OVER

BOX C: For either one-day or multiple-day trips, please answer the following questions:

5. How did you come to the lake?
  a. Train
  b. Bus
  c. Car
  d.Plane
  e.Any combination of the way mentioned above___+___+____+____

6. How long it take you to come to the lake from your home? __________hours

7. How many people travel with you on this trip? __________

8. Is this the first time you have been to Lake Wuliangsuhai?

a. Yes →→ 9. How many times have you visited Lake Wuliangsuhai in the last 5 years?
___0 ___1-2 ___3-4 ___5-6 ___7-8 ___9-10 ___ more

b. No

10. How many times do you think you will visit Lake Wuliangsuhai **in 2005**?
___0 ___1-2 ___.3-4 ___5-6 ___7-8 ___. 9-10 ___more

11. Have you visited **other** lakes or rivers in the **past 5 years** to do similar activities?

a. Yes →→12. How many times in the last have you visited **other** lakes or rivers to conduct similar activities as this time **this year**?
___0 ___ 1-2 ___3-4 ___5-6 ___7-8 ___9-10 ___more

b. No

13. Approximately how much money did you spend **in total** for this trip? _______Kr

14. On your way to Lake Wuliangsuhai, how much money did you spend on
  14.1 transportation for this trip? _______RMB
  14.2 food en route__________RMB
  14.3 lodging en route________RMB

15.Here at Wuliangsuhai, how much will you / did you spend on: How much did you
  15.1 entrance fees _________RMB
  15.2 boat rental____________RMB
  15.3 food ________________RMB
  15.4 lodging ______________RMB
  15.5 other _______________RMB (please specify:______ __________________)

PART II : Lake Perception Survey

The next questions concern your experiences and perceptions of Lake Wuliangsuhai
A=Agree
D=Disagree

The next 5 questions relate to your decision to spend time at lakes and rivers in general

16) Water quality affects your decision to visit lakes/rivers	A	D
17) Boat sightseeing affects your decision to visit lakes/rivers	A	D
18) Being able to watching wildlife/birds affects your decision to visit lakes/rivers	A	D
19) Being able to fish affects your decision to for to visit the lake	A	D
20) Facilities for visitors (e.g., visitor centre) affect my decision to go to the lake	A	D

The next questions relate to your perceptions of Lake Wuliangsuhai

21) The water in the lake is very clear	A	D
22) The water in the lake has a disagreeable smell	A	D
23) Surrounding area of the lake is clean and well maintained	A	D
24) This lake is too congested or crowded.	A	D
25) I enjoy boat sightseeing on the lake	A	D
26) I enjoy watching the birds on the lake	A	D
27) Visitors throw too much rubbish on the ground / into the lake	A	D
28) I would visit the lake more often if the water quality became better	A	D
29) I would visit this lake more often if it was less crowded here	A	D
30) I would visit this lake more often if it had better facilities.	A	D
31) I would visit the lake more often if there was less rubbish in the surrounding area	A	D

Part Three: Willingness to Pay Survey

Lake Wuliangsuhai has until the 1980's provided visitors with a place to enjoy lake sightseeing, boating, bird watching, fishing and swimming. But during the last 20 years, the lake's water quality has become steadily worse so that today it is **not recommended to fish or swim** in the lake. The poorer water quality is due to pollution from fertilizers from agriculture, and waste water from industry and households in the Hetao Basin. The lake is also becoming smaller due to the water pollution (sedimentation and growth of reeds) and water originally for the lake being used for irrigation in the Hetao agriculture. If no action is taken now, in 10 years it will **not be possible to do boating or bird watching** at the lake.

The Fish Farm company, in cooperation with local authorities and industries, want to invest in actions to guarantee continued boating and bird watching, and make it possible to swim and fish in the lake in 10 years time. The actions include:

- industry and cities investing in wastewater treatment to avoid bad smelling water, allow swimming and fishing in 10 years
- FishFarm company buying water from the Yellow River Commission to maintain lake level
- FishFram company dredging channels and cutting back reeds around lake to ensure continued boating

33. Would you be willing to pay a higher visitor fee on your next visit to the lake to contribute to these improvements? Keep in mind that industry and cities will pay their fair share, but the actions cannot be undertaken without contribution from lake visitors also.
1. yes, I would pay a higher fee
0. no, I would not pay a higher fee (GOTO35)

The Fishfarm wants to make sure they do not charge too much for these improvements in future lake quality.

34. How high would the visitor's fee have to be before you would no longer be willing to visit the lake and would go somewhere else? Keep in mind that you will continued to be able to boat sightseeing and see birds and in 10 years you will be able to fish and swim as well. Keep in mind the other travel expenses you will have on your next trip.

Would you still visit the lake if the fee was..? (CHECK AMOUNTS STARTING FROM LOWEST)
___8+20=28 RMB
___11+25=36 RMB
___14+30=44 RMB
___17+35=52 RMB
___20+40=60 RMB
___25+50=75 RMB
___30+70=100 RMB
___50+100=150 RMB
___more.(Please specify)________________

35Why are you not willing to pay a higher visitors fee?____

____________________(recode this to close ended answers in main survey)

Part Four Household Information

36. Gender
    a. Male   b. Female

37 How old are you? _____

38..1 How many children do you care for in your household?
a. 0   b. 1   c 2   d. more than 2
38.2. How old are they?   _________________________

39. What is the highest level of education you have completed?
    a. Primary school
    b. Junior high school
    c. Senior high school
    d. Bachelor
    e. Master
    f. Ph.D.:

40. What is your occupation:________________________________

41. Please indicate on this card the **total** monthly income in your household (SHOW CARD. INCLUDES YOURSELF AND MEMBERS OF YOUR FAMILY):
___< ¥1,000   ___¥1,000-¥2,000 ___¥2,000-¥3,000   ___¥3,000-¥4,000
____¥4,000-¥5,000 ___¥5,000-¥6,000 ___¥6,000-¥7,000   ___¥7,000-¥8,000
____¥8,000-¥9,000 ___¥9,000-¥10,000 ___¥10,000-¥11,000 ___ > ¥11,000
42,If you go to a tourist attraction that is extremely dirty, what will you do then?
A.Complain and decide never to come back
B,Throw rubbish every where
C,Keep the nature tidy and keep it as nature
D Become a member of environmental organization and advocate others to protect nature

Appendix 3: Travel cost results

Table 19 Results from different specifications of a zonal travel cost model (work in progress)

Lnvisit rate		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Totalcost	Coefficient			-0.0004161*					
	t-value			-3,76					
	p-value			0,001					
Lntotalcost	Coefficient		-1.149016*						
	t-value		-7,67						
	p-value		0,000						
Totalcost2	Coefficient				-0.0004595*				
	t-value				-3,77				
	p-value				0,001				
Lntotalcost2	Coefficient	-1.132089*							
	t-value	-7,44							
	p-value	0,000							
totalcost(claimed)	Coefficient					-0.0004443*			
	t-value					-2,05			
	p-value					0,047			
lntotalcost(claimed)	Coefficient						-0.4800396*		
	t-value						-2,30		
	p-value						0,027		
totalcost(oneaim)	Coefficient							-0,0003493	
	t-value							-0,46	
	p-value							0,650	
lntotalcost(oneaim)	Coefficient								0,1146982
	t-value								0,48
	p-value								0,634
Householdmonthlyincome	Coefficient	-0.0000532*	-0.0000531*	-0.0000836*	-0.0000817*	-0,0000306	-0,0000347	-0.0000883*	-0.0000891*
	t-value	-1,81	-1,84	-2,15	-2,10	-0,59	-0,71	-1,94	-1,95
	p-value	0,078	0,073	0,038	0,043	0,557	0,481	0,061	0,058
Gender	Coefficient	-0,1437264	-0,0647532	-0,7847271	-0,7980202	-1,5264250	-1.806822*	-2.00128*	-2.080075*
	t-value	-0,19	-0,09	-0,77	-0,78	-1,38	-1,69	-1,75	-1,84
	p-value	0,852	0,932	0,449	0,440	0,177	0,099	0,088	0,075
Age	Coefficient	0,0201022	0,0205682	0.05189905*	0,0530175	-0,0135118	0,0047054	0,0042581	0,0033058
	t-value	0,93	0,97	1,65	1,68	-0,41	0,15	0,13	0,10
	p-value	0,357	0,338	0,011	0,101	0,687	0,883	0,901	0,923
Education	Coefficient	0,0355334	0,0020653	0,0083529	0,0308323	-0,0411775	-0,0434237	-0,1044487	-0,0952877
	t-value	0,59	0,04	0,10	0,36	-0,45	-0,49	-1,13	-1,04
	p-value	0,562	0,972	0,920	0,719	0,654	0,628	0,264	0,305
Constent	Coefficient	-5.998652*	-5.385721*	-12.92549*	-13.26425*	-9.721133*	-7.79172*	-9.137181*	-9.846685*
	t-value	-4,40	-3,95	-6,52	-6,54	-5,01	-3,87	-4,45	-4,20
	p-value	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Adj-R2		0,6258	0,6391	0,3240	0,3244	0,1610	0,1825	0,0708	0,0713
F		F(5,37)=15,06	F(5,37)=15,87	F(5,37)=5,03	F(5,37)=5,03	F(5,37)=2,61	F(5,37)=2,87	F(5,37)=1,64	F(5,37)=1,65
Sample size		43	43	43	43	43	43	43	43

Note: models 1 and 4 use 60% of hourly wage as opportunity cost of time. “Oneaim” indicates the use of fractional/additional travel costs to Wuliangsuhai for multipurpose trips.

Table 20 Consumer surplus for foreigners and non-locals (>500 km for Wuliangsuhai) for various assumptions about function form, opportunity costs of time, multi-purpose trips and type of travel costs (work in progress)

	Variable	Obs	Mean	Std. Dev.
1)	CS(full t cost)	31	8527.727	14011.13
	CS(hut full t cost	31	18739.09	29132.89
	CS(*ln*full t cost)	31	53488.75	119057.8
	CS(hut*ln*fulltcost)	31	48672.63	69399.68
2)	CS(60% t cost)	31	7722.279	12687.77
	CS(hut 60% t cost)	31	17032.71	27061.45
	CS(*ln*60% t cost)	31	58465.27	132581.5
	CS(hut*ln*60% t cost	31	51932.74	74050.67
3)	CS(claimed cost)	31	7986.466	13121.83
	CS(hutclaimed)	31	18210.88	23816.04
	CS(*ln*claimed)	31	-9332.575	17438.5
	CS(hut*ln*claimed)	31	-12316.39	19632.3
4)	CS(fullt cost multi)	31	4210.073	6647.124
	CS(60% t cost multi)	31	3812.43	6019.301
	CS(claimed multi)	31	3942.857	6225.227
	CS(*ln*fulltmulti)	31	24380.03	37965.59
	CS(*ln* 60%t multi)	31	26060.63	42095.99
	CS(*ln*claimedmulti)	31	-3658.825	5476.225
	CS(hutfullt multi)	31	11532.24	17054.86
	CS(hut60% t multi)	31	10627.06	16088.45
	CS(hutclaimedmulti)	31	9912.357	10484.94
	CS(hut*ln*fulltmulti)	31	25494.74	25507.48
	CS(hut*ln*60% t multi	31	27067.92	27558.49
	CS(hut*ln*clamedmulti	31	-5582.424	7663.358

Table 21 Consumer surplus for locals (<500 km) (work in progress)

	Variable	Obs	Mean	Std. Dev.
1)	CS(linearf)	12	13893.79	22737.83
	CS(linear60%)	12	13893.79	22737.83
	CS(linearfhut)	12	8414.848	10029.84
	CS(linear60%hut)	12	8367.262	9889.314
2)	CS(linearfmulti)	12	10978	17737.17
	CS(linearfhutmulti)	12	6796.243	8127.965
	CS(linear60%hutmulti	12	6756.205	8002.113

Appendix 4: Contingent valuation results

Table 22 The sampling and data treatment for willingness to pay higher entrance fee for improved water quality (work in progress)

	Number	Percentage
WTP protests	6	1,14%
WTP consistent outliers	8	1,52%
WTP consistent zeros	33	6,29%
WTP coding error/missing	0	0
Total sample size	525	
Sample reponse rates	100,00%	
WTP>0	486	92,57%
WTP=0	33	6,29%
WTP protests	6	1,14%

Definition of “enconcern” dummy variable: 1 if respondent chooses C or D; 0 if A or B to the following multiple choice.

If you go to a tourist attraction that is extremely dirty, what will you do then?
A.Complain and decide never to come back
B,Throw rubbish every where
C,Keep the nature tidy and keep it as nature
D Become a member of environmental organization and advocate others to protect nature

Table 23 Log linear model of WTP using the midpoint willingness to pay without outliers (work in progress)

lnWTPmidpoint	Coef.	Coef.	Coef.	Coef.	Coef.
lnhouseholdincome	.1609219	.1619385	.1638903	.1587258	.1622834
(monthly)	(5.72***)	(5.76***)	(5.79***)	(5.66***)	(5.78***)
Gender	.0828553	.0808058	.0883919	.0755386	.078463
	(1.74**)	(1.70*)	(1.83*)	(1.59)	(1.64)
Age	-.0030709	-.0029201	-.0030099	-.002692	-.0028743
	(-1.63)	(-1.56)	(-1.61)	(-1.44)	(-1.53)
Education	-.001982	-.0008982	-.0014452	.0004424	-.000952
	(-0.27)	(-0.12)	(-0.20)	(0.06)	(-0.13)
enconcern	.1120519	.1099349	.1090395	.1079629	.1093391
	(2.37**)	(2.33**)	(2.30**)	(2.29**)	(2.31**)
noigroup	-.0036954	-.0037429	-.0037648	-.0037796	-.003707
	(-1.73*)	(-1.75*)	(-1.76*)	(-1.77*)	(-1.74*)
nov5yf	.0147154	.0148845	.0153715	.0143914	.0148931
	(1.73*)	(1.76*)	(1.81*)	(1.70*)	(1.76*)
waterqualityd	.0203283				
	(0.38)				
Sightseeingd		-.0291516			
		(-0.60)			
Fishingd			-.0300155		
			(-0.69)		
Facilityd				-.1122878	
				(-1.84*)	
Wildlifed					-.0472176
					(-0.81)
perception1	-.0263812	-.0307304	-.0313981	-.0288731	-.0299832
	(-0.56)	(-0.66)	(-0.67)	(-0.62)	(-0.64)
perception2	.0031275	.0055172	.0054191	.0091087	.0060122
	(0.09)	(0.17)	(0.17)	(0.28)	(0.18)
perception3	-.0112435	-.0067226	-.0071643	-.0079607	-.0046331
	(-0.25)	(-0.15)	(-0.16)	(0.748)	(-0.10)
perception4	-.0303755	-.029888	-.027438	-.0304124	-.0332952
	(-0.32)	(-0.32)	(-0.29)	(-0.32)	(-0.35)
perception5	-.0711654	-.0622329	-.0621284	-.078025	-.054137
	(-0.43)	(-0.37)	(-0.37)	(-0.47)	(-0.32)
Constant	2.918949	2.919167	2.89915	3.013325	2.92862
	(9.30***)	(9.31***)	(9.21***)	(9.51***)	(9.33***)
Number of obs	478	478	478	478	478
F(13, 464)	4.04	4.06	4.07	4.32	4.08
Adj R-squared	0.0765	0.0769	0.0772	0.0829	0.0775

Appendix 5 – Characteristics of visitors to Lake Wuliangsuhai

Table 5-1

Provinces	Number of visit	Percentage
Anhui	3	0,57 %
Beijing	31	5,90 %
Fujiang	1	0,19 %
Gansu	3	0,57 %
Guangdong	2	0,38 %
Henan	8	1,52 %
Heilongjiang	1	0,19 %
Inner Mongolia	400	76,19 %
Jiangsu	1	0,19 %
Liaoning	5	0,95 %
Ninxia	3	0,57 %
Shengyang	1	0,19 %
Sweden	14	2,67 %
Taiwan	10	1,90 %
USA	3	0,57 %
Zhejiang	5	0,95 %
Hebei	8	1,52 %
Shaanxi	5	0,95 %
Shangdong	6	1,14 %
Shanghai	6	1,14 %
Shanxi	7	1,33 %
Sichuan	1	0,19 %
Xinjing	1	0,19 %
Total	525	1

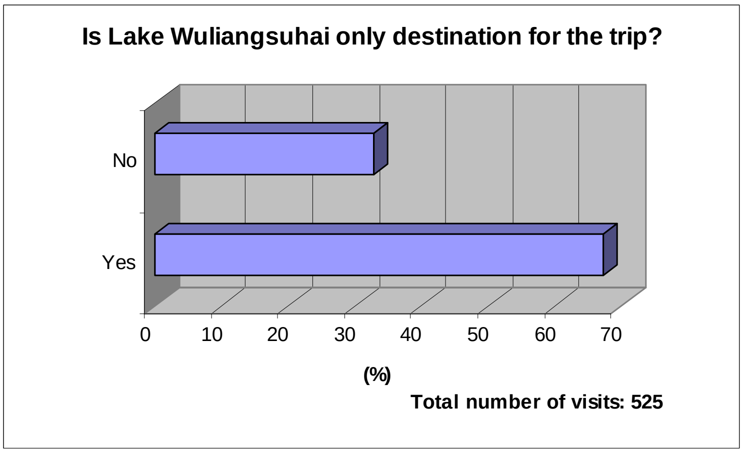


Figure 5-1

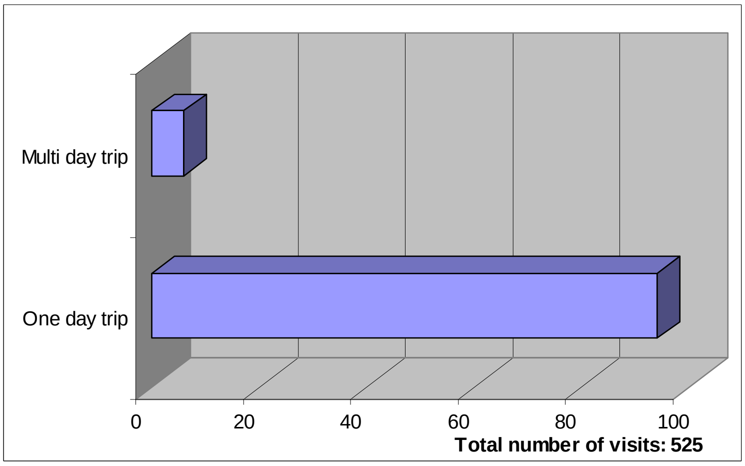


Figure 5-2

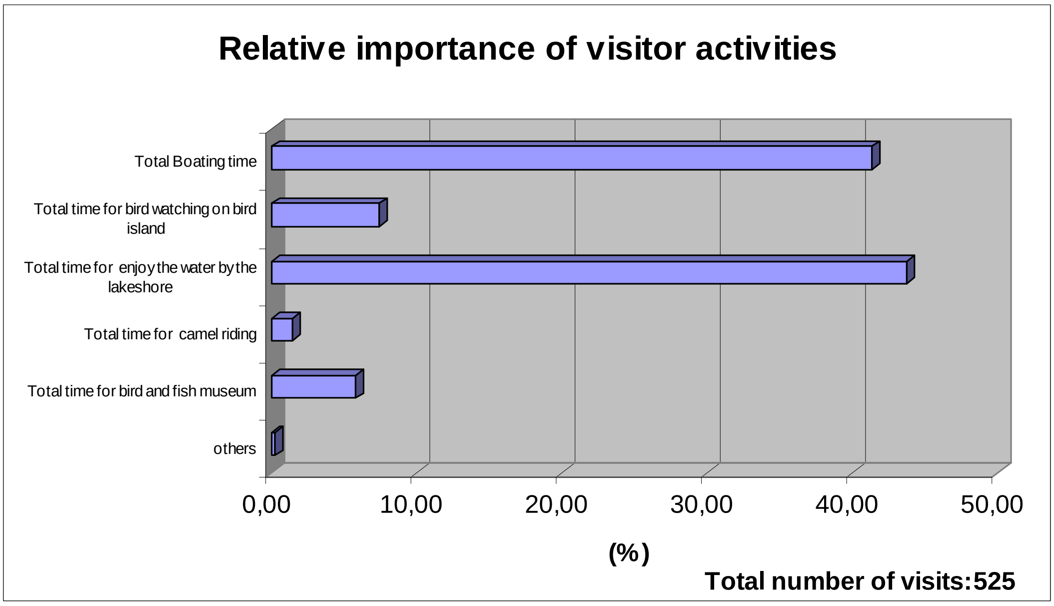
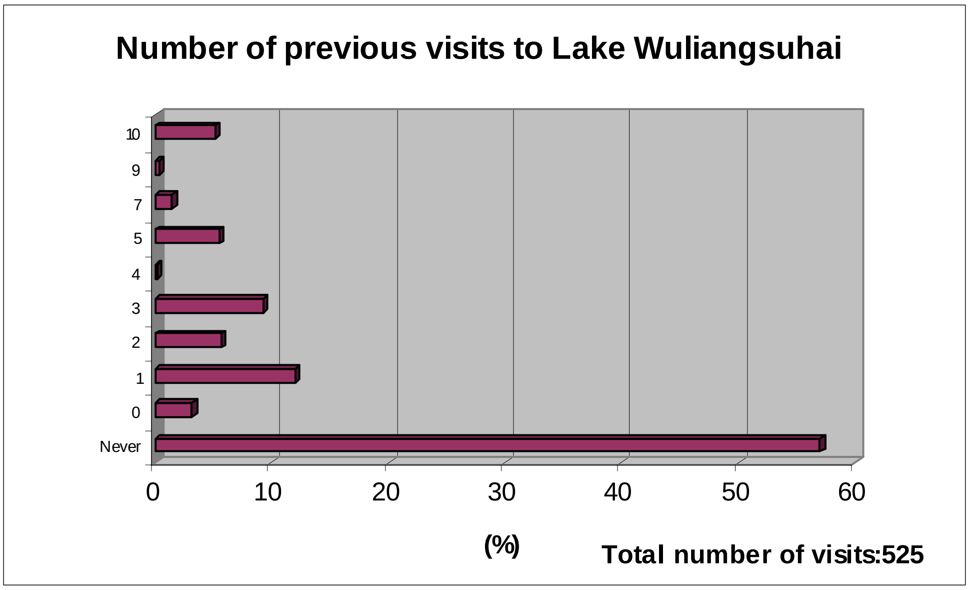


Figure 5-3



Number of previous visits to Lake Wuliangsuhai
10
9
7
5
4
3
2
1
0
Never
0
10
20
30
40
50
60
(%)
Total number of visits:525

Figure 5-4