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Upstream-downstream cooperation approach in Guanting Reservoir watershed

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Abstract: A case study is introduced and discussed concerning water dispute of misuse and pollution between up- and down-stream parts. The relations between water usage and local industrial structures are analyzed. Results show it is important to change industrial structures of the target region along with controlling water pollution by technical and engineering methods. Three manners of upstream-downstream cooperation are presented and discussed based on the actual conditions of Guangting Reservoir watershed. Two typical scenarios are supposed and studied along with the local plan on water resources development. The best solution for this cooperation presents a good way to help the upstream developing in a new pattern of eco-economy.

Keywords: watershed; cooperation; upstream-downstream; industrial structures; Guanting Reservoir

Introduction

Water is one of the most precious resources in the world. According to recent study, by the year of 2050, about 66 counties and 2/3 of the world population will face moderate to severe water scarcity. Water crisis is basically found in river basin. Upstream and downstream conflicts about water quantity and quality often occured there. This was the focus of a seminar organized by Stockhom International Water Institute/International Water Resources Association in Stockhom in August 1999.

China is also facing water crisis. Since 1980's, there have been some 400 cities in water shortage. Water conflicts (Editorial, 2000) often occur regionally. These conflicts are mainly on aspects such as: (1) Different governmental department have different policies or schemes towards developing the same river basin. Water quantity and quality are managed by different government agencies, for example, water conservancy agency is in charge of water quantity and environmental protection agency is responsible for water quality. (2) Water rights are not clear, especially in the watershed of river. Upstream and downstream conflicts occur regularly. In this situation, people in the upstream are in the favorite position and can take advantages of geographic location to use water resources without any interference, while people in the downstream have no choice to take in any results arising from misusing of water by the upstream, especially the water is in poor quality. This kind of problem is commonly met both for international and national river basins. (3) Because of unclear water rights, water allocation and distribution along the river are certain to be unfair. People in the upstream have the priority to use more water than the downstream. (4) Riparian people are another factor that should be paid more attention. Different education level of the people can lead to different results. Perfect regulations or laws concerning water resources may not been implemented in this situation. As a common idea, water is free and can be used at any time, place and any amount. This is especially the case in the rural area of China.

In fact, these are the main forms of conflicts in river watershed (Peter, 1999). Each river may have its own conditions and characteristics. The solution to solve the problem may be different. In Guanting Reservoir watershed, a total different scheme of tackling upstream and downstream conflicts will be introduced and studied in this paper. It is urgent and tough task to solve the pollution in the reservoir. The fundamental countermeasures should be as following: changing the scale to measure economic growth in the upstream area, changing present unreasonable industrial structures in the basin, changing present pattern of economic development into a sustainable one.

1 Present situations

Located in middle reaches of Yongding River and 80 km Northwest of Beijing, with a total volume of 4.16×10^9 m^3, Guanting Reservoir is one of two biggest surface water resources in Beijing. The reservoir was built in 1950s and reconstructed in late 1980s. Its functions are flood control, domestic water supply, hydro-power supply and irrigation. From 1980s, water supply has become a major task for the reservoir, especially domestic water supply to the west part of Beijing. The reservoir controls an area of 43402 km^2 and has three main breaches of Sanggan River, Yanghe River, and Guishui River, respectively. Basic engineering parameters are shown in Table 1.

Table 1 Basic engineering parameters of Guanting Reservoir

Item	Value	Item	Value
Site location	Guanting Village of Huailai County, Hebei	Controlled area	43402 km^2
River name	Yongding River	Average runoff over years	8.80×10^8 m^3
River system	Haihe River	Average sand income over years	34.26×10^6 t
Designed flood volume	19.81×10^8 m^3	Average precipitation over years	426 mm
Designed flood table	484.35 m	Controlled irrigation area	920 km^3
Dead table	476.00 m	Total volume	41.60×10^8 m^3

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From 1997, Guanting Reservoir has stopped supplying water for domestic use to Beijing because of its poor water quality (Beijing Metropolis Government, 2001). The latest monitoring results showed that water quality in the inlet section (No.8 bridge) and in the reservoir are in a state of exceeding V class and IV class respectively. Therefore, one quarter of population in Beijing has been affected. Continuous drought in the past three years (1999—2001) in Northern China has made the situation even worse. To meet the increasing water demand, more ground water has been developed in north and west parts of Beijing. According to statistics from hydrogeological survey, from 1961—1995, an accumulated volume of 3.965×10^9 m^3 of ground water was overdeveloped (Chen, 1999). A series of geological problems have been reported in recent years such as ground subsidence, ground water contamination.

From 1950s to 1990s, water inflow in the reservoir declines rapidly (Fig.1). Water inflow in 1990s is only 1/5 of 1950s. Two reasons were found, one is declining of precipitation in these past years, the other is increasing water consumption in the upstream. From 1973 to 1999, three periods were divided according to inlet water quality of reservoir. First period of 1973—1979, water quality in the reservoir was under control and gradually became better after a rather long period of serious pollution because of wastewater discharged from the upstream. Second period of 1980—1985, water quality was stable, but there has been a tendency of eutrophication. In the third period of 1986—1999, as the economy of the upstream area increased, water consumption grew rapidly, and wastewater was discharged directly to the river without treatment. COD_{Mn}, total P and total N were accumulated in the reservoir. Water quality in the reservoir became class V. In 1997, the reservoir was stopped supplying domestic water to Beijing.

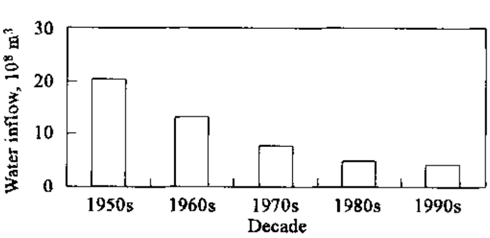

Fig.1 Average inflow in the past decades of Guanting Reservoir

The past experience shows that, to some extent, water quality of a rather long period in the reservoir reflects the situation of economic development in the upstream. When the water quality becomes poor, the economy in the upstream will get developed in a short time. When the related laws and regulations were carried out by the enterprises, factories and governments at different levels, the water quality will become better. In economy, there is a view that economy development leads to pollution. The relation of economy and pollution can be described with inverse letter U (Zhang, 1998). To avoid all these passive methods of water pollution control in the Guanting Reservoir watershed, it is suggested to combine water resources with the industrial structures in the watershed.

Previous studies lead to the results that water pollution in Guanting Reservoir is mainly caused by waste water from Zhangjiakou area of Yanghe River watershed, because of block of Cetian Reservior, water flow from Sangganhe River has little effect to the quality of water in Guanting Reservoir, therefore, the upstream concerning in this paper covers an area of 16.4×10 km^2 in Zhangjiakou region.

2 Water resources and industrial structures in the upstream

In this area (Institute of Water Resources Sciences of Hebei, 2002), economy is less developed compared with the downstream of Beijing. In 1999, the total population is 3.08×10^6, of which, 67.3% is farming population. GDP output is 1.73 billion RMB Yuan (Table 2).

Table 2 Compare of industrial structures of different levels (%, 1999)

	Agriculture	Industry	Service sector	GDP per capita RMB Yuan	Engel coefficient
China	17.3	49.7	33	6517	-
Beijing	4	38.9	57.1	19803	0.395
Upstream	13	51	36	5180	0.44

Water resources and agriculture: In this area, agriculture is concentrated in traditional sectors such as farming, forestry, stock raising and fishery, which was formed by 58.8:5.9:45.4:1.0 in 1999. Extensive farming manner and over-development of stock raising are two main causes lead to water and soil erosion. In 1982, there was an erosion area of 10602 km^2. After 17 years comprehensive management and control, there has been 4396 km^2 left. Water and soil erosion brought great amount of soil and sand into reservoir, by the end of 1999, 640×10^6 m^3 volume of reservoir has been filled up. The functions of reservoir are influenced and can not be operated as designed before.

Water consumption in agriculture is increasing. In 1999, there is a total area of 1756 km^2 irrigation land in the region. Water consumption is 718×10^6 m^3/a, which accounts 56% of average volume over years of total water resources in this area. Based on the analysis of statistics of 1999, an average water production rate is 0.96 kg/m^3, which is smaller compared with 2.0 kg/m^3 of that in Beijing. Water pollution from agriculture is the other factor to be paid attention to. According to recent calculation, about 876 t/a of COD and 992 t/a of NH_3-N eluviated in the upstream area are brought down to the reservoir and lead to water pollution. Water resources and industry: of 367 investigated enterprises, 88 are large-medium size enterprises. Production value of 20 big enterprises accounts for 70% of total industrial production. This kind of enterprises is mainly related to consumption of resources or energy. They are mainly belonged to tobacco industry, food industry, paper making industry and chemical industry.

In 1999, water consumption of 367 enterprises was 783×10^6 m^3, of which 143×10^6 m^3 was fresh water and 640×10^6 m^3 was circling water. According to water usage, industrial fields can be ordered as: power industry, metallurgy industry, chemical industry and food industry. In 1999, waste water discharged from industrial sector reached 78.4×10^6 t. The principal pollutant COD is 34.7×10^3 t. Wastewater from industry of Zhangjiakou and Xuanhua areas is regarded as main reason of polluting the reservoir.

Water resources and service sector: Water use in this sector can be stable and seen steady increase in recent years. In 1999, it is about 52.5×10^6 m^3. The sewage water from service sector is about 42.7×10^6 m^3 with a COD content of 19.1×10^3 t.

Based on analysis, it is clear that agriculture is a large water user and water input-output ratio is lower, industry is a large discharging source of wastewater and should be responsible for reservoir pollution. Water resources management should be started from solving these problems arising from misuse of water.

3 Assessment on industrial structures

To understand the industrial structure and its relation with regional water resources, an assessment should be made at basin-wide scale. Many methods can be used to do so. Here, a new approach of fuzzy optimal selection is introduced in this paper.

3.1 Fuzzy optimal selection model(Chen, 1994)

Suppose n objectives to be selected optimally, there are m indictors reflecting structures of objectives, which form indicator set x_{ij}

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdot & \cdot & \cdots & \cdot \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} = (x_{ij}). \qquad (1)$$

To deal with indicators specifically, for known m indicators, if the bigger the indicator is, the more favorable to industrial structure, then its relative membership degree is bigger, therefore

$$r_{ij} = \frac{x_{ij}}{\bigvee_i x_{ij} + \bigwedge_i x_{ij}}. \qquad (2)$$

If the bigger the indicator is, the smaller the relative membership degree of the indicator with respect to the "superior" of industrial structure. Therefore

$$r_{ij} = 1 - \frac{x_{ij}}{\bigvee_i x_{ij} + \bigwedge_i x_{ij}}. \qquad (3)$$

with Equations (1), (2), (3), a matrix of relative membership degree for n objectives is obtained as

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdot & \cdot & \cdots & \cdot \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} = (r_{ij}). \qquad (4)$$

Where: x_{ij} is the eigenvalue of No. j indicator of No. i objective, r_{ij} is the corresponding relative membership degree. $\wedge$, $\vee$ refer to choosing "big" or "small".

Suppose u_i is the relative membership degree of No. I objective with respect to the "superior" of industrial structure. Weight victor of m indicators is expressed as $W = (w1, w2, \cdots, w_m)^T$, satisfying $\sum_{j=1}^{m} w_{ij} = 1$. According to fuzzy set theory, the weighted broad sense space can be obtained as following:

$$D(r_i) = u_i^p \sqrt{\sum_{j=1}^{m} (w_j \mid r_{ij} - 1 \mid)^p}. \qquad (5)$$

To make optimal value of u_i, an objective function is established

$$\min\{F(u_i) = u_i^2 \left[\sum_{j=1}^{m} (w_j \mid r_{ij} - 1 \mid)^p\right]^{2/p} + (1 - u_i)^2 \left[\sum_{j=1}^{m} (w_j \times r_{ij})^p\right]^{2/p}\}, \qquad (6)$$

with $\frac{dF(u_i)}{du_i} = 0$, then

$$u_i = \frac{1}{1 + \left[\frac{\sum_{j=1}^{m} (w_j \mid r_{ij} - 1 \mid)^p}{\sum_{j=1}^{m} (w_j \times r_{ij})^p}\right]^{2/p}}. \qquad (7)$$

Equation (7) is so called fuzzy optimal selection model.

Objectives and indicators: Based on situations of water resources and industrial structure of the upstream area, there are 6 indicators of 11 sectors representing the studied system. According to statistics of data of 1999, these indictors are obtained and listed in Table 3.

Table 3 Indictors for assessment on 11 industries of the upstream area in 1999

	Water consumption of 10000 RMB Yuan production, m^3	COD discharge of 10000 RMB Yuan production, kg	Relating coefficient of industries	Reusing rate of water resources, %	Pollution loading ratio	Energy consumption of 10000 RMB Yuan production, tc
Power	345	1.8	2.618	97	1.79	5.84
Machine	42	2.8	2.1	65	0.98	1.19
Metallurgy	144	3.1	2.407	92	1.52	13.95
Chemical	318	20.6	3.19	90	41.45	8.07
Textile	133	3.0	1.739	6	0.08	1.87
Paper making	300	740.9	2.065	35	18.3	2.93
Excavate	71	153.1	2.323	54	5.64	3.62
Building material	123	0.6	1.76	64	0.05	5.87
Food	92	80.1	1.371	54	28.18	2.43
Leather	107	12.1	1.953	0	0.06	0.51
Others	261	0.01	1.569	68	0.04	1.15

3.2 Calculation and evaluation

After calculation using fuzzy optimal model, the industrial sectors can be rearranged with the "superior" degrees in order from big to small(Fig.2). With this optimal result, it can be drawn a conclusion that the structure of current industrial sectors in this region is not suitable for sustainable use of water resources. Food, textile, and chemical industries are listed behind for their large volume of wastewater discharge and should be implemented some reforms both for enterprises themselves and the outer environment such as corresponding laws and regulations about watershed management.

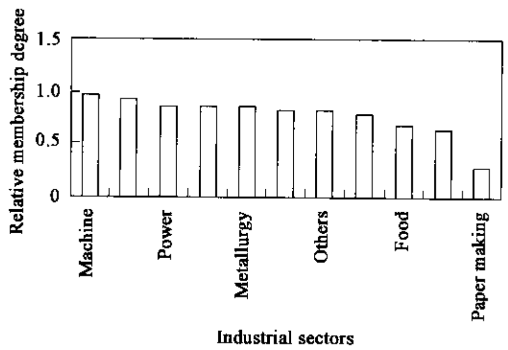

Fig.2 Industrial sectors ordered by "superior" degrees

4 Alternatives for upstream-downstream cooperation

Based on the analysis mentioned above, some alternatives are developed to try to answer the conflicts of upstream and downstream for reasonable use of water resources in the watershed.

4.1 Cooperation objectives

The objectives of cooperation between up and down stream are: (1) to change the industrial structure in the upstream area so as to improving water quality and quantity in the watershed; (2) to quicken the steps of opening and reform in the upstream area so as to gradually improve people' s living standards and to find a way of becoming wealth for the farmers; (3) to achieve the goal of sustainable use of water resources(including other natural resources) for ever.

4.2 Possible ways of cooperation

After a series of analysis on actual conditions of Guanting Reservoir watershed in view of both economy and water resources science, there are many ways of up and down stream cooperation to be studied and tested (Hu, 2000). They are basically classified into three categories including policy dominant type, economy dominant type and technology dominant type.

The policy type is referred to enhance the cooperation between up and down stream by depending upon the implement of laws and regulations on water resources issued by central and local governments. Also some agreements are included among involved parts between up and down stream concerning water rights and water resources distribution. In the agreements, special measures of stimulating the involved parts should be paid attention to in the process of cooperation. This kind of cooperation means different for macro-management on basin-wide scale and lays a sound foundation for solving conflicts of up and down stream.

The economy type is referred to find a suitable and sustainable economic development patterns for up and down stream areas(Daniel, 2000). In this aspect, it also includes some compensation in fund and policy. Generally speaking, living standard of riparian in the up stream is lower than that of people in the down stream, while the former has priority to use fresh water resources and to discharge waste water into water system without considerations on its pollution to the water environment. The later may have more money and make his economy well developed, but it has to accept the bad results coming down from the up stream, as the case happened to Guanting Reservoir. Economic measures may work along with the implement of corresponding regulations and agreements. Two steps have to be implemented. One of them is to build a stimulating system of compensation so as to safeguard the interests of the involved parts, i.e. to use the fund from down stream to where and what it deserved. The other step is to gradually change the current industrial structures and economic increasing pattern in the upstream area, so as to remove completely the source of causing water misuse and pollution. It can avoid re-occurrence of reservoir pollution, and to go into the strange circle of pollution and control as happened in Guanting Reservoir in 1970—1980's.

The technical type is referred to some technical measures of both engineering and non-engineering used to deal with the conflicts of water use in the basin (Malin, 2000). It is difficult to distribute water resources as equally as planed because of the complicated situations in these dispute areas. Technical measures are often used to study the history of water consumption and simulate the relations of water users in both up and down streams by use of a kind of model. In most cases, some relative optimal schemes will be proposed. A scheme accepted by all parts will be selected at last. In this case, water technicians and scientists can play an important role in the whole process.

As for Guanting Reservoir watershed, some scenarios can be added to enhance the up and down stream cooperation. Two special ones are discussed here.

Scenario Ⅰ: In a short period of time, by keeping the state of the current industrial structure in the upstream area, some passive methods can be used to solve the problems, including adding waste water treatment plants, strengthening the implement of laws and regulations in all sectors. For the upstream part, there are some basic steps to do so as to: (1) control contents of pollutants in discharged waste water, especially for the 367 investigated enterprises; (2) strengthen the education on water environment protection through out society; (3) use the compensation system to get fund and low interests loan from down stream of Beijing and use fund for control water and soil erosion etc. For the down stream part, some measures may be concentrated to: (1) provide technologies to help the up part to build waste treatment plants; (2) provide fund to help the up part to do this; (3) give suggestions in the process of water pollution control engineering. According to plan, in next 5—10 years, some wastewater treatment plants will be built along the river in the upstream. Total treatment capacity will be 102 million tons of wastewater. 34 projects of point source control will be implemented. The area of irrigation of water saving will be 440 km^2. There will be 2130 million RMB Yuan to spend on these projects.

Scenario Ⅱ: To completely change the situations in the basin wide and control water pollution, a sustainable economic development pattern is needed, i.e. to reform the current pattern of economic growth and change the current industrial structures in the upstream area(Jan, 2000). For the upstream part, there are some suggestions to be considered. (1) It is important to change scales of measuring economic development. At the beginning, a satellite account can be set up to calculate the losses from damages of natural resources and environmental pollution. (2) It is a good choice to build for an eco-economy in the region. Some corresponding regulations can be approved locally. For the down stream part, with a support of central government, Beijing can do more perfect concerning cooperation with up stream areas. The cooperations include: (1) Using its advantages at fund and technology, Beijing should play an active role in making schemes and doing researches on water issue along with the up part. (2) In the process of water resources allocation and water pollution control, Beijing should take the responsibility to monitor water quality in the inlet of reservoir and make suggestions to the up part according to bilateral agreement.

5 Conclusions

Conflict in watershed is a universal problem that met in most rivers worldwide. The cooperation between upstream and downstream is considered to be the useful and effective way to solve water issues in watershed. A successful cooperation can be focused on:

- a full awareness of local conflicts about water issue including up and down stream areas;
- a compensation system reached by the involved parts including up and down stream areas;
- a supporting system of technical, economic and political made by involved departments to implement various schemes of dealing with water issue in the watershed;
- a complete new pattern of economic development in the upstream area, suggested here is to build for sustainable eco-economy in Guanting Reservoir watershed.

However, some problems concerning the cooperation of upstream and down stream are to be studied and analyzed in the future. For the case study, the problems may be:

- an agreement on water issue should be made by the up and down parts in short time;
- a watershed management organization should be established as soon as possible;
- the allocation of water resources in watershed should be made by a certain manner;
- the third part in the cooperation is important. Its function and status are to be discussed detailed later.

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