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Water Security Situation in Haihe River Basin after South-to-North Water Transfer Project

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Abstract The over-exploitation of water resources in the Haihe River Basin (HRB) has now become a serious problem. This is clearly evidenced by the fact that many local rivers and lakes are drying up and the total amount of over-exploited groundwater has reached over $1000\times10^8 m^3$. It is important to note that the exploitation of water resources in HRB was reasonable before 1979. After 1980, however, over-exploitation happened with an annual average amount of $40\times10^8 m^3$. Both the dry season and rapid economic growth in HRB took place at the same time. Therefore, the over-exploitation of water in HRB was actually the negative result of the conjunction of a continuous dry season and rapid economic growth. So the over-exploitation would not be as serious as it is today if either of the above two stopped. After the first stage of south-to-north water transfer project, the water shortage problem in HRB could be eased for the following reasons: firstly, water transfer project will bring to the Basin $60\times10^8 m^3$ water resources; secondly, a wet season will come back eventually according to natural law of climate variability; finally, its agricultural and industrial use and total water consumption all have decreased from the peak value, so that the groundwater table will raise certainly and ecological water in rivers and lakes that were dried-up will be partly restored. In the future, the main problem of water resources security in HRB will include water pollution, operation risk of the south-to-north water transfer project, groundwater pollution and engineering geological hazards that may be brought by groundwater rise. The proposed countermeasures are as follows: keeping strengthening water demand management, raising water price as well as subsidies for the low-income family and improving other water related policies, preventing and dealing with water pollution seriously and getting fully prepared for the operation of south-to-north water transfer project.

Keywords Haihe River Basin, south-to-north water transfer project, water resource security

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1. Phases and reasons for over-exploitation of water resources in the Haihe River Basin before the south-to-north water transfer project

1.1 It is after the year 1980 that the over-exploitation started

The phenomenon of water resources overdraft in the Haihe River Basin (HRB) has been increasingly obvious since the 1980s. As to its surface water, there is a saying, "most rivers have dried up while the rest has been polluted". Actually, 60% of the plain rivers in HRB have dried up and 70% have been polluted (Haihe River Commission, 2005). The groundwater in the Basin has almost been used up and the cumulative amount of overdraft was more than $1000\times10^8 m^3$ by 2006. To be specific, the overdraft mainly occurred during the decade from 1980 to 1990 with a cumulative amount about $800\times10^8 m^3$ and an annual average amount about $40\times10^8 m^3$.

There is one thing that should be noticed here: the groundwater exploitation amount in HRB didn't exceed its recharge capacity before 1980. According to the long-term data of groundwater level from typical observation wells in the region, groundwater level saw no significant changes at that time (Haihe River Commission, 2005). That is to say, the over-exploitation happened after 1980.

1.2. Reasons for over-exploitation after 1980

1.2.1 Continuous dry period happened synchronically with rapid economic growth

As shown in Figure1, the cumulative precipitation anomaly, which equals to the difference between annual practical value and average, in HRB was on a rising trend from 1956 to 1979. That was because precipitation anomalies were mostly positive during that time, which means precipitation in a single year was more than average annual precipitation and it was a high-flow period. The cumulative precipitation anomaly began to plummet after 1980 and a low-flow period came. The average annual precipitation in the 1980s was 90% less than that of multiple years.

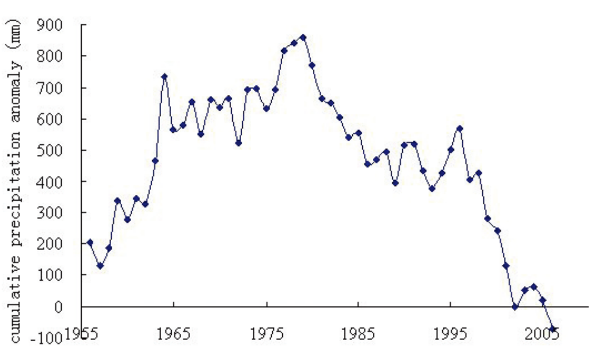

Figure 1 A cumulative precipitation anomaly curve in Haihe River Basin.

Moreover, it was just in this period that China started a three-decade-long rapid economic growth since 1980. The average annual economic growth rate in HRB was more than 10% and accordingly the total water use in the region increased sharply from less than $380\times10^8 m^3$ in the 1970s to more than $400\times10^8 m^3$ in the late 1990s with the maximum being as high as over $430\times10^8 m^3$ (see Figure 2).

Via a comparison between the cumulative precipitation anomaly curve and the water use curve in HRB, it is reasonable to believe that the serious over-exploitation and the water resources crisis in HRB during the period from 1980 to 1999 were caused by the overlaping of a peak period of water consumption and a low-flow period. If they had not happened at the same time, which means total water use wasn't at the peak (no more than $380\times10^8 m^3$) when low-flow period came or it was normal flow year when peak water-use period came, it might have been possible to strike a balance between the supply and demand of water resources in HRB and the situation that annual average exploitation amount of $40\times10^8 m^3$ would not have occurred in the case of other conditions remain unchanged.

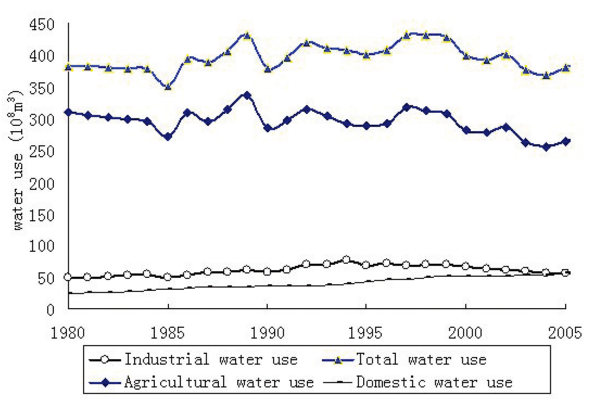

Figure 2 Variation of water use in Haihe River Basin.

1.2.2 Low utilization efficiency of water directly led to over-exploitation

As illustrated in Figure 3: the irrigation quota in HRB has shown a significant downward trend since 1980; the average was over 4500 m^3/ha. before 1990 and less than 3825 m^3/ha during the period from 2003 to 2006. If water-use efficiency during the 1980 – 2000 period reached the average of the recent 5 years, then the irrigation water use during that period would be less than $690\times10^8 m^3$. This means that 86 % of the groundwater overdraft there, or about $800\times10^8 m^3$, was caused by low efficiency of irrigation water use.

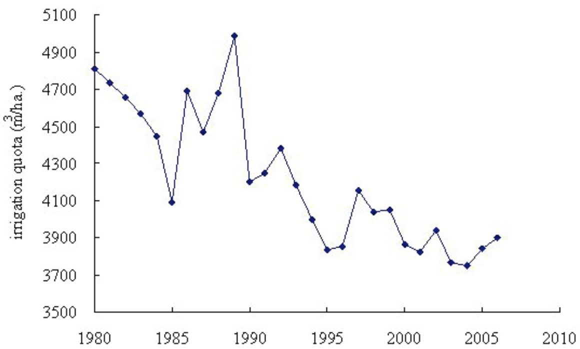

Figure 3 Variation of irrigation quota in Haihe River Basin.

The industrial water quota decreased faster than irrigation quota in HRB. Using the same assumption and calculation as above, one could find that industrial water overuse caused by low utilization efficiency amounted to more than $600\times10^8 m^3$. But considering the rise of commodity prices, this estimation seems to be too high. Total industrial water use in HRB was $1,287\times10^8 m^3$ during 1980 and 2000 and if the percentage of industrial water overuse was conservatively estimated as 10%, then the amount of industrial water overuse would be about $129\times10^8 m^3$.

Apparently, the low utilization efficiency of agriculture and industrial water resulted in water overuse of $819\times10^8 m^3$ ($690\times10^8 m^3$ plus $129\times10^8 m^3$), which was even bigger than the total amount of groundwater over-exploitation in the same time period. Therefore, it can be concluded that although over-exploitation of groundwater during 1980 and 2000 happened at the same time as continuous dry period and rapid economic growth, the main cause for serious water shortages in the region was the low utilization efficiency of water resources.

1.2.3 Irrational industrial distribution

There are two typical examples for irrational industrial distribution here. One is a large area of paddy fields in HRB, where water shortage problem was serious. The other was a number of companies with high water use and high pollution were located at the foot of the Taihang Mountain Range and in the windward and upriver area, such as Yanshan Petrochemical Company, Capital Iron & Steel Group, Handan Iron & Steel Company and Xingtai Iron & Steel Company.

Figure 4 shows a soaring trend for industrial water use in HRB before 1994. One of the significant reasons behind it was that high water use industries like iron & steel and petrochemicals developed extensively and fast to fulfill the demand of rapid economic growth (Jia *et al*., 2003). After that, although there was another round of rapid economic growth during 2002 – 2007, industrial water use didn't rise significantly with the increasing production of steel and iron. That was because the economic growth mode had changed and water-saving facilities and technology had been used widely. A very convincing example was that the Steel-Making Plant of the Capital Iron & steel Group moved to the Caofeidian District in Tangshan, Hebei, where it is suitable to use seawater as cooling water to save freshwater and making full use of the port to import iron ore from abroad in order to solve the problem of raw material shortage.

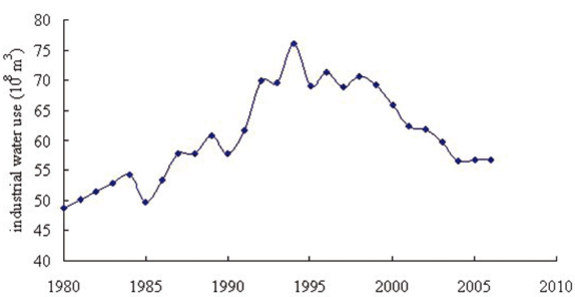

Figure 4 Variation of industrial water use in Haihe River Basin.

2. An estimation of water supply and demand in HRB after South-to-North Water Transfer Project (SNWTP)

2.1 Water resources in HRB will increase notably after SNWTP

According to the plan, water transferred to the north of the Yellow River via the middle and the east routes of the program will amount to $50\times10^8 m^3$ and $10\times10^8 m^3$, respectively ($60\times10^8 m^3$ in total) after the first phase of SNWTP. Although the completion time of the first phase, which was due in 2010 according to the original plan, has been deferred for 4 years, water transfer to HRB by SNWTP can be expected soon. The fact is the water transfer route from Hebei to Beijing had been finished and used for emergent water dispatch between the two places since September 18, 2009.

2.2 A wet season will come back soon

An analysis of a long-time series of precipitation data (1870 – 1981) reveals that the precipitation cycles in North China range from 20 years, 10 years to 5 years and so on(Chen *et al*., 1982). An analysis of monthly precipitation data during 1957 – 1994 by Yang (1999) suggested that the main precipitation pattern in North China featured oscillation periods of quasi-3, 5, 6, 7 years. From the figure of wavelet analysis (Mexican Hat) of precipitation in HRB during 1965 – 2006 (Figure 5) and frequency variance, it can be known that the precipitation cycles in HRB are 3, 5, 7, 15 years and so on. According to the precipitation cycle of 15 years, it was a wet season in the 1950s, a dry season in the late 1960s and the early 1970s with 1969 as the center, a wet season in the late 1970s with 1976 as the center, a relative dry season in the early 1980s with 1983 as the center, a relative wet season in the 1990s with 1994 as the center, and a dry season in the 2000s. To be specific, it was also a wet season, according to the precipitation cycle of 7 years, in the mid-1990s and so it was an extremely wet year in 1996 marked by a flood in August. Based on precipitation cycle theory mentioned above, it is supposed to be wet years soon.

From the dialectical point of view, as long as HRB still lies in the temperate semi-humid monsoon climate zone, the dry period, which has lasted for more than 28 years since 1980, will end and a wet season will be back eventually. The theory that the dry period in HRB will last forever is of the viewpoint of metaphysics, which treats everything like they are static and unchanged. Proponents of this theory are irrational, as they are scared of the temporary difficulties and fail to think in a scientific and dialectical way.

2.3 Water use has reached its peak and tends to decrease

Due to the decrease of agricultural water use in HRB, its total volume of water use has dropped steadily from the high point as shown in Figure 2. It is noteworthy that domestic water use has increased, and will keep growing with the increase of population, urbanization level and life quality. However, it is only a minor part (about 15%) of the total amount of water use at present, and considering the decrease of agricultural and industrial water use, its growth will not change the downward trend of total water use.

There were two main reasons for the decrease of agricultural water use in the region. First, the acreage of irrigated area remains stable, as the available arable land was limited. The second, irrigation quota is reduced sharply because of the extensive popularization of water-saving technologies and low water consumption crops. Currently, this trend is to maintain.

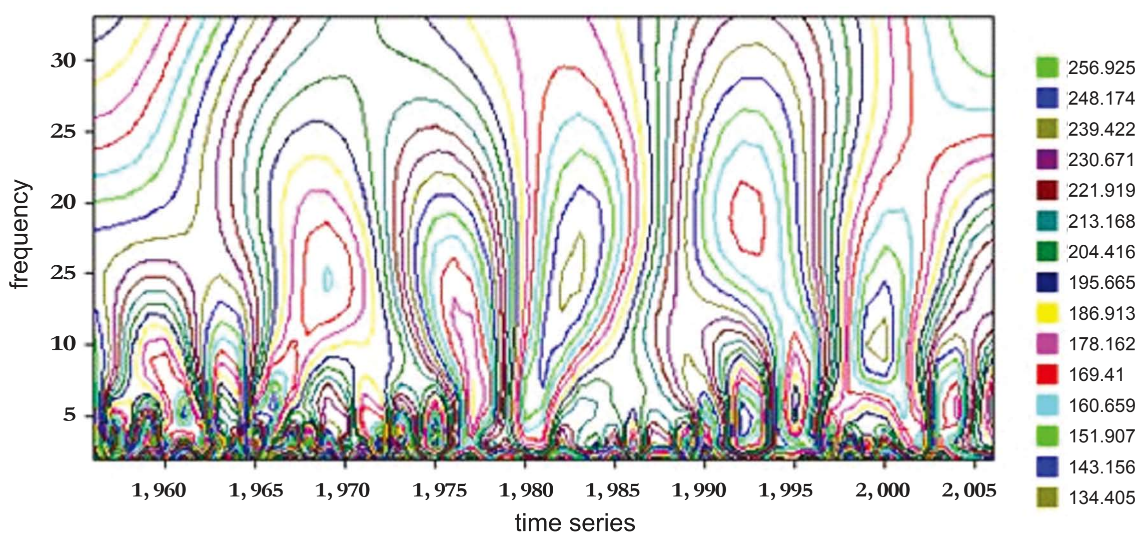

Figure 5 Wavelet analysis (Mexican Hat) of precipitation in Haihe River Basin (1956-2006).

From the macro point of view, the industrial water use in HRB has been reduced recently and it can be displayed in the frame of Kuznets Curve with the development of economy (Jia 2001a; Jia *et al*., 2004, 2006). Theoretically, because of industrial structure upgrade, environment protection and water price regulation, industrial water use will not keep raising but drop after it reaches the peak point(Jia *et al*., 2000). As illustrated in Figure 4, it has already happened in HRB. And in the future, industrial water use would not increase substantially as water prices go higher and the restriction of wastewater discharge becomes stricter.

It is reasonable to conclude that agricultural, industrial and total water use in HRB are decreasing and will maintain a downward trend in the coming years. Whenever it comes to water demand in HRB, this should be known clearly and not be doubted.

2.4 Imbalance between supply and demand of water resources will be redressed

In the next two or three decades the situations of water resource supply and demand in HRB will be much better than it was during 1980 – 2007 because the amount of available water resources will grow thanks to SNWTP. A continuous dry season will be over and total water use will start to decrease after reaching the peak. It can be expected that the long-term over-exploitation of groundwater will end and groundwater will be recharged and groundwater level will rise gradually; at the same time, water for ecological use in natural rivers and lakes will increase substantially and ecological conditions will be improved. To make these happen, there are still several things to do: to strengthen water demand management, to raise water prices further to a reasonable level, and to spare no efforts to treat and regulate wastewater discharge strictly.

3. Main problems and countermeasures of water resources security in HRB after SNWTP

3.1 Main problems

3.1.1 *Per capita* possession of water resources remains at a low level

Although SNWTP will ease the imbalance between supply and demand of water resources in HRB, water scarcity is still a serious problem for the region in comparison with water-rich areas. Its water occupancy per capita is, and still will be, at the lowest level (about 300m^3/person) in China and all over the world no matter how SNWTP goes. Its water resources will be even scarcer for high-standard water requirement, especially for ecological use.

3.1.2 Water pollution will be a major threat to water security

Two field surveys were made separately to ascertain whether water shortage affected profits of companies and

living of families in the region. The respondents of one survey were industrial companies in North China and the findings demonstrated that profits of most companies were not affected by water shortage (Zhou *et al*., 2006). In the other survey, residents in Beijing and Tianjin were interviewed randomly and the results showed that most families were not aware of water shortage in daily life, except families living in single-storey buildings without running water. On the other hand, however, almost everyone had personal understanding of water pollution. Terrible things are happening: people have to dig deeper wells because shallow groundwater is polluted; farmers don't eat the farm produce they grow because irrigation water is polluted; people get skin diseases when they wear clothes washed in polluted water; there are even "cancer villages" caused by water pollution! Water pollution has been a major threat to the security of water supply, food and environment.

3.1.3 There is a risk that SNWRP might not operate as planned

No matter how good a plan is, there will always be unexpected things to happen, such as changes in the plan's preconditions or the negligence of some factors in the plan. So there are risks in the operation that planned objectives would not be achieved. The first phase of SNWRP has not been as easy as planned and its completion time is delayed for 4 years. Even if the project would have been finished without any troubles, there still might be several uncertain issues that could hamper its planned functions. For example, a wet season might come unexpectedly, then there would be no need for water transfer and all the newly-built facilities would become idle; the price of transferred water might be too high for water users that they would look for substitutes despite of water shortage; there might be accidents during any phases of the project, and so on (Jia 2001b, 2003). All these need to be thoroughly addressed with detailed strategies in advance.

3.1.4 The rise of groundwater table might lead to some new problems

Firstly, it is no doubt that the groundwater level will rise after the completion of SNWTP. Data of typical groundwater observation wells (Hai River Commission, 2005) indicated that the flood that happened in south HRB in August 1996 made the shallow groundwater level rise suddenly by 5 – 10 meters. The precipitation of Beijing in the year 2008 was higher than the average and observation data showed that shallow groundwater level rose significantly by the end of the year. These examples reflect that groundwater recharge could be very fast.

Secondly, although groundwater recharge is a good thing, it might lead to some new problems in the other hand. China has experienced a rapid environmental pollution as well as a rapid economic development since 1980. According to statistics data, there are hundreds of landfills or disposal sites across the country, but most of them cannot meet the normal standards of related regulations and don't have proper facilities to deal with garbage leachate. If groundwater level is low and the soil layer is thick enough to filter garbage leachate, so the water will be safe. Once groundwater level rises, contaminations in soil, or even garbage might go into the groundwater directly and cause seriously pollution.

Besides that, the rise of groundwater might have negative influences on some facilities, such as water leakage in underground facilities and so on.

3.2 Countermeasures

3.2.1 To keep strengthening water demand management

Water shortage is one of the basic situations of HRB that is hard to change in a short time. Therefore, water demand management should be strengthened strictly. To be specific, we should continue promoting water rights innovation, encouraging water right transformation from low efficiency users to high efficiency ones, raising water price to a rational level to give powerful incentives for water saving, assessing the effects on water resources before starting any new construction projects, regulating water use, and avoiding unreasonable water use to make sure that total water use would not surpass available water resources any more.

3.2.2 To strik a balance between policies on water price hikes and subsidies for low-income families, and improve other related policies

Water is one of the precious natural resources. To reflect the scarcity, marginal cost and benefit of water resources, and to promote water use efficiency, water prices should be raised further. Meanwhile, other related policy tools should be formulated accordingly to eliminate the negative effects of water price rise.

For domestic water use, the standard price should rise and the ways to collect water fees should also be changed. Tier water pricing is a good idea, which means charging lower for basic water use and higher for extra. The government should also raise the minimum living standard to make sure that the increase of water rate would not affect the living of the low-incomes.

As to agriculture water use, the profits of farming are relatively low and agriculture is the key factor in food security of the whole country. So the rise of agriculture water price should not affect the income of farmers and food security. To achieve this object, subsidies should be given to farmers according to irrigation area or food production. It is a reasonable measure to improve the efficiency of water utilization and do no harm to the incomes of farmers and food security.

Additionally, the money from water fees after water price hikes should not be used entirely as wages of monopoly water suppliers, but for water resources development, conservation, research and education.

3.2.3 A deep understanding of the great potential of seawater utilization and making good use of seawater

In coastal areas, seawater should be treated as an important water source and be put into good use, including the direct use and desalination of seawater. The potential of seawater utilization might be even greater than SNWTP. Seawater utilization should become one of the basic measures of water security problem.

3.2.4 To prevent and deal with water pollution seriously

In 2008, the so-called “Milk Powder Incident” greatly shocked the whole world. It caused serious damages to the reputation of Chinese government and people. To avoid such things happen again and improve the security of drinking water, food and the environment, the government should take a positive attitude to manage water pollution without laissez-faire.

3.2.5 To get fully prepared for the operation of SNWTP

As to the garbage pollution problem that might be brought about by groundwater rise, all the landfills and disposal sites should be checked for water security risks. If there is any problem, it should be solved in time.

To the possible operation risks of SNWTP, all the possibilities need to be considered with a detailed emergency plan in advance.

Acknowledgments

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