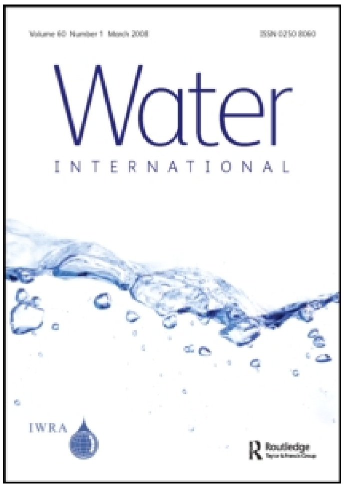

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The South-North Water Transfer Project in China
An Analysis of Water Demand Uncertainty and Environmental Objectives in Decision Making

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Abstract*: After nearly half a century of planning, the construction of the controversial south-to-north water transfer (SNWT) project in China was officially launched just before the end of 2002. This paper looks into the decision-making process of the project in the context of the country's transition from a centrally-planned economy to a market economy, rapid economic development, and severe environmental degradation. Uncertainties concerning future water demand in individual sectors are examined with reference to the latest projection prior to the launch of the project. Adjustment of project objectives and shift of the focal issues concerned over the years are elaborated. The analysis suggests a high degree of uncertainty in future water demand. The expansion of project objectives to include ecosystem recovery in the late 1990s, however, provided a decisive argument for implementing the project as no other alternative was considered available to meet the estimated ecosystem water requirement. Consequently, remaining doubts on the need for the project and concerns on adverse environmental impacts have tended to be sidelined. With the implementation of the project, the government is caught in a dilemma of keeping water prices low to substantiate the economic needs and improving water use efficiency to honor the environmental objective of the project.*

Keywords*: China, south-north water transfer, uncertainty, environmental objective*

Introduction

The idea of transferring water from the Yangtze River to northern China, the so called south-north water transfer (SNWT), was first conceived in the early 1950s by then leader Chairman Mao. During his inspection of the Huanghe (the Yellow River), Mao made a comment that "southern China has abundant water and northern China has less water." He suggested the need to "borrow some water from the south to the north" (MWR, 2002). The idea was a rather daring one at the time given the fact that such a transfer would extend over 1,000 km in distance and require an enormous capital investment that the country did not have, not to mention technical difficulties that had to be overcome. Nevertheless, since the emergence of the idea, feasibility assessment and planning of the water transfer have been carried out by relevant ministries and governmental organizations. In later years, there was some involvement of stakeholders, academics, as well as the general public in the planning process.

Over the past 50 years, population growth and economic development in China have greatly increased its demand for water. To meet this demand, many water projects have been carried out to tap rivers, and pumping equipments have been installed to extract groundwater. Since the late 1970s, annual water withdrawals in many areas in northern China, especially the North China Plain, have exceeded annual renewable water resources. The over extraction of groundwater has caused depletion of aquifers at an alarming rate (Shi, 1997; MWR, 2002; Xu, 2003). Ecosystems and the environment have been severely degraded.

The late 1970s was also the time when China launched its ongoing nationwide economic reforms. Spurred by the reforms, there has been a remarkable growth in the economy and consequently a rapid increase in national wealth. This has provided the country with the necessary financial capacity to implement the SNWT project. The ability to overcome major technical obstacles has smoothed the way for the implementation. In 2000, President Jiang Zemin stated: "In order to radically alleviate the severe water shortage in the north, it is necessary to implement the South-North Water Transfer Project" (Jiang, 2000). "Speed up the preparatory work of the project and start the construction as soon as possible" was proposed in the nation's Tenth Five-year Plan (2001-2005). Following approval of the state council, the Ministry of Water Resources set the implementation deadline for the end of 2002. The official ceremony held on December 27, 2002 marked the formal launch of the project (MWR, 2002; South-North Water Transfer Planning Bureau, 2002).

The construction of large water projects has always been an emotional and controversial issue (WCD, 2000; Yevjevich, 2001). Regarding the SNWT project, debates on its rationality and issues relating to management have been intense over the years (Liu, 1998; Wang and Ma, 1999; World Bank, 2001; WWF, 2001; Liu and Zheng, 2002; Shang et al., 2003; Berkoff, 2003). China's transition from a centrally-planned economy to a market economy, rapid economic development, and deteriorating environment and ecosystems since the late 1970s have led to continuous changes in boundary conditions concerning decision making. As a result, objectives of the project, major constraints, and issues debated have also been changing. Uncertainties and complexities involved in decision making and management of the project have greatly increased.

Validating the need for additional water is a prerequisite for the decision on a water project. It also lays the foundation on which the rationality of the decision can be judged. For this reason, validating the need has been at the center of debate on the SNWT project. Water is used for many purposes: domestic and industrial use, irrigation, hydropower generation, navigation, recreation, fisheries, and ecosystems. The water demand for any one purpose is influenced by a variety of factors relating to the state of economic development, macro and micro economic policies, the standard of living, importance of a specific sector in the national economy and society, technology, efficiency of water use and management, socio-cultural practices, and others (Biswas, 1983; WCD, 2000; Chenoweth and Malano, 2001; Clark, 2002). This makes the validation of the need for additional water highly complicated and contentious.

Difficulties also arise in validating the need for a large water project and selecting a plan among different options due to uncertainties of the factors involved. This concerns not only the water demand in the economic sectors, but also the priorities a society puts on the environment. With economic development and rising incomes, the priorities of a country and its people can change, typically to the direction in favor of environment protection (Beckerman, 1999). Changes in priorities can strengthen either support or opposition to the construction of large water projects depending on the values attached to the different components of benefits and costs. As will be elaborated in this study, the significant improvement in living standards and the increased urgency to tackle environmental problems in China have led to a broadening of objectives of the SNWT project to include ecosystem recovery. The latter has provided a strong argument for the final decision on the project.

This study examines the decision-making process of the SNWT project. Uncertainties in water demands in different sectors are elaborated in the context of continuous changes in Chinese society and with reference to the latest water demand projection conducted in China prior to the project implementation. Methodologies used in the projection and practiced commonly in China are introduced to shed light on sources of uncertainties and possible overstating of future water demand. The analysis highlights particularly how the inclusion of ecosystem recovery in the project objectives has increased the weight in favor of the project, paving the way for the final decision on implementation. Questions are raised about the risks of inflating overall gains of the project under insufficient knowledge of costs and benefits involved in ecosystem recovery and of the appropriate quantity of water required. A dilemma between keeping water prices low to substantiate the economic need of the project and improving water use efficiency to achieve the environmental goals is also addressed. The study aims to enhance the understanding of uncertainties concerning decision making on the SNWT project and the major controversies involved. The elaboration of environmental goals in supporting the final decision provides added value to the literature, where environmental concerns have mostly acted against implementing large water projects (WCD, 2000). The study, however, is not intended to judge whether or not the SNWT project should be implemented. Such a judgment requires quantification of the values of benefits and costs of all the elements involved. Political concerns, emotion, and pride that a country takes to build such a project further complicated the issue. This is beyond the scope of the current study.

Water Deficit in the North China Plain

Water Stress and Environmental Degradation

The spatial distribution of China's water resources is uneven (Figure 1). Of the nine major watersheds (basins), the Haihe (the Hai River) watershed has the lowest water availability on a per capita basis: merely 358 m^3/year given the population of 1998. In the adjacent Huanghe and Huaihe (the Huai River) watersheds, per capita water availability is also considerably low.

The North China Plain is located in three water-short river basins: Haihe, Huaihe, and Huanghe (the HHH basins hereafter). The region is dominated by a continental temperate monsoon climate. Precipitation is highly concentrated in a few months of the year. Irrigation is crucial for achieving stable and high yields (Shi and Lu, 2001). In the areas where multiple cropping is practiced, irrigation is essential. Today, about 60 percent of the crop land is irrigated, using about 70 percent of the annual total water withdrawal of the region (MWR, 2002).

The continued increase in water use has put enormous pressure on the region's water resources. Currently, the ratio of total annual water withdrawal to total annual available water resources in the Haihe basin exceeds 95

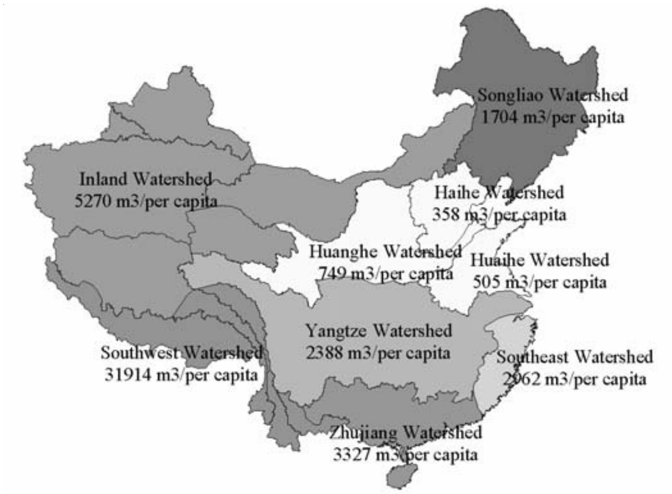

Figure 1. Per Capita Water Resources by Watersheds in China, 1998. Source: Yang and Zehnder (2001)

percent. The ratios in the Huanghe and Huaihe basins are about 75 percent and 70 percent, respectively (MWR, 2003a). At such a high level of water withdrawal, most of the rivers in the region, especially the Haihe basin, have been dried. The Huanghe has virtually become a seasonal river and has sent little or no water to the sea during the dry season in recent years (MWR, 2002). When additional surface water is no longer available, the focus has been turned to aquifers. It is estimated that the accumulated overdraft of groundwater in the North China Plain exceeds 90 billion m^3 (Xu, 2003).

Water Balance Projections for the North China Plain

Given the poor resource endowments and the increase in water use, it has been a general view that the North China Plain needs additional water. However, debates have been intense on the magnitude of water shortage at present and in the future. Since the 1980s, a number of projections of the region's water demand and supply over a time span of 10 to 50 years have been undertaken by various organizations and many individual researchers (Biswas et al., 1983; Research Group of the State Conditions, 1989; Liu and He, 1996; United Nations, 1997; Sandia National Laboratories, 1998; Wang, 1999; Zhang, 1999; MWR, 2000; World Bank, 2001; Pan and Zhang, 2001). A noteworthy trend exhibited in these projections is that the estimates for the economic sectors have been continuously adjusted downwards: the figures in the later studies are smaller than those conducted earlier. One of the latest projections prior to the project implementation was conducted by the Chinese Academy of Engineering in association with the Chinese Academy of Sciences in a key consultative project on the Water Resources Allocation in Northern China and SNWT (Pan and Zhang, 2001). This study provided a comprehensive and systematic assessment of the current and future water situation of the region. The projected future water demand is among the lowest of the existing projections. The projection from this study has been considered the most authoritative in China and has provided an important basis for the final decision on the project. The following analysis uses this projection as reference (baseline). Table 1 presents the detail.

Water uses in different sectors in the baseline projection follow the common definitions in China. Industrial water demand refers to water use for manufacturing and thermal power generation in both urban and rural enterprises. Domestic water demand consists of urban and rural household water use, municipal water use (in commercial enterprises, hospitals and schools, and for urban parks and urban hygienic needs), and water use for stall-fed animals

Table 1. Baseline Water Supply and Demand Projection for the HHH Basins (billion m^3)

		Water Supply						*Water Demand (Use)*					
Basin	*Year*	*Surface and ground-water*	*Diversion from the Yellow River*	*Diversion from the Yangtze River*	*Reuse of waste-water*	*Others*	*Supply*	*Industry*	*Domestic*	*Agriculture*	*Ecosystem minimum*	*Sum of demand*	*Water deficit*
Haihe	Current*	31.0	5.5		0.3	0.4	37.1	6.7	4.7	33.4	0.2	45.0	7.8
	2010	31.0	4.6		1.7	1.0	38.8	8.5	6.2	33.1	1.2	49.1	10.8
	2030	31.0	4.6		3.5	1.4	41.0	10.0	8.4	32.9	2.6	53.9	13.3
											(7.5)**	(58.8)	(17.8)
Huaihe	Current	56.8	3.3	8.1	0.4	0.1	68.6	9.7	6.1	52.2	0.7	68.6	0.0
	2010	59.8	4.9	9.0	0.9	0.2	74.6	14.0	8.8	53.3	0.9	77.0	2.4
	2030	64.2	4.9	10.4	1.4	0.4	81.3	16.8	12.4	53.7	1.4	84.3	3.0
											(4.4)	(87.3)	(6.0)
Huanghe	Current	4.05			0.3		40.8	5.9	2.9	34.0	0.0	42.9	2.1
	2010	42.8			0.7	0.5	44.0	8.4	4.6	34.6	1.2	48.8	4.8
	2030	43.9			1.4	1.0	46.3	11.0	6.4	35.2	2.5	55.1	8.7
											(12.5)	(65.1)	(18.8)
Total	Current	128.3	8.8	8.1	0.9	0.5	146.5	22.3	13.6	119.7	0.9	156.5	9.9
	2010	133.5	9.5	9.0	3.3	1.7	157.4	30.9	19.6	121.0	3.4	174.9	17.9
	2030	139.2	9.5	10.4	6.3	2.8	168.6	37.8	27.2	121.7	6.5	193.3	25.1
											(24.4)	(211.0)	(42.6)

Notes: * The current water demand figures refer to those of 1997; ** Figures in parentheses are the volumes taking into account required amount of ecosystem water use; Probability of precipitation: 75%. Source: Pan and Zhang (2001) in rural areas. Agricultural water demand is dominated by irrigation. Water use in forestry, animal husbandry, and fishery industries is also included in this category.

Ecosystem water demand is defined as the water required for sustaining eco-environmental systems. It includes seven components: 1) the minimum in-stream ecosystem water use, 2) urban river and lake environmental water use, 3) wetland recovery and protection water use, 4) groundwater replenishment water use, 5) water use for land conservation in hilly areas, 6) water use for sediment transport and estuary ecosystems, 7) pollution dilution water use. There are overlaps among these components. Concerning the situation on the North China Plain, ecosystem water demand is set at two levels in the projection by Pan and Zhang (2001). The first level is the water required for preventing ecosystems from further deterioration, or for maintaining the status-quo ecosystem condition of the respective river basins. It is considered as the minimum water requirement for ecosystems. The second level is the water required for not only preventing ecosystems from deterioration but also progressively restoring degraded systems through water and soil conservation, afforestation, sediment and salt balance, assurance of base flows in rivers, urban ecosystem construction, and groundwater recharge (including compensating the groundwater overdraft accumulated over the years). The second level of water demand is regarded as the amount required for maintaining healthy ecosystems. Using required ecosystem water demand for projection, total water deficit in the HHH region will be around 43 billion m^3 by 2030, substantially larger than that of 25 billion m^3 when the minimum ecosystem water demand is considered (Table 1).

Given the excessively high water withdrawal ratio in the HHH region, increasing total supply by developing local resources is limited. This is reflected in the baseline projection in which the additional water supply within the three basins is marginal, especially for the Haihe basin. In contrast, water demand will increase substantially. The projected large and widening gap between water supply and demand suggests that the North China Plain is facing a severe and worsening water deficit. Given the magnitude of deficit at present and in the coming years, it is believed that relying on water conservation measures cannot radically solve the problem (MWR, 2000; Pan and Zhang, 2001). The conclusion has been the need for the SNWT project.

Features and Major Concerns of the SNWT Project

Since the start of project planning back in the early 1950s, some 50 different routes have been proposed to convey water to the north. By the early 1980s, three routes: Eastern, Central, and Western, had been selected in principle (Figure 2) (Biswas, 1983). In the later years, the focus of the planning has mainly been on developing the detailed design, including the scale of the water transfer, the location of specific facilities and technical problems to be solved.

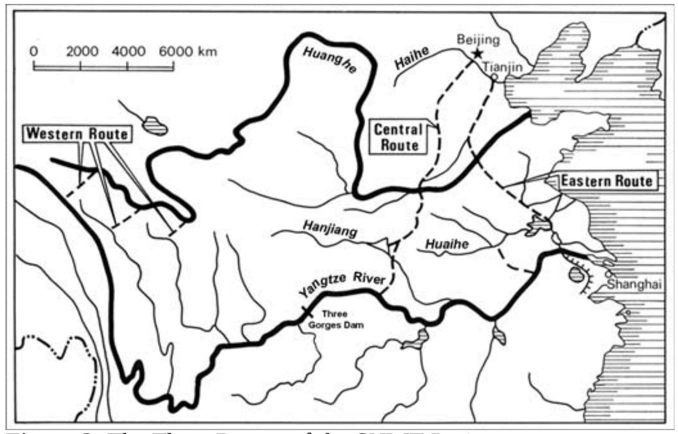

Figure 2. The Three Routes of the SNWT Project

a) The Eastern Route diverts water from the lower reach of the Yangtze River to the north along roughly the ancient Beijing-Hangzhou Grand Canal. The first phase of the Eastern Route, to be completed around 2007, will divert about 9 billion m^3/year of water. Roughly half of this amount will be transferred to the north of the Huanghe (MWR, 2002). The major concern of this route is the water quality which meets only the minimum requirement for drinking at the source and deteriorating steadily northward due to the influx of the untreated wastewater from many small and mostly rural factories along the route. There is much concern that the Eastern Route could transfer unusable water to the north (Qian, 2001; Liu and Zheng, 2002).
b) The Central Route mainly serves domestic and industrial water uses in Beijing, Tianjin, and some cities in Hebei, Henan, and Hubei provinces. The first phase of the Central Route, to be completed around 2010 (perhaps even before the 2008 Beijing Olympic Games), will transfer 9.5 billion m^3 of water across the Huanghe (MWR, 2002). The major concerns about this route are the limitation of water resources at the origin of the diversion and the large displacement of people due to the need to raise the Danjiangkou Dam on the Hanjiang, a tributary of the Yangtze. The average annual surface runoff of the Hanjiang catchment is only 38.5 billion m^3 with two-thirds coming during the rainy season. Records have shown that in very dry years, runoff can be as low as 18.8 billion m^3 (Liu and Zheng, 2002). The diversion of 9.5 billion m^3 of water will have significant impacts on the economy and ecosystems in the source area. In addition, some 300,000 people will have to be moved due to the inundation of land according to the official estimation (MWR, 2002). The real number, however, could be much larger.
c) The Western Route diverts water from three upper-reach tributaries of the Yangtze River to the upper reach of the Huanghe. The route goes through the remote Qinghai Plateau and northwestern arid and semi-arid areas where economic development has lagged far behind the eastern part of the country. The route car-

ries the objective of boosting the local economy. Meanwhile, the increase in flow of the Huanghe will help recover the ecosystems and transport sediment in the river. The direct benefits of this route to the North China Plain are relatively modest. As the main part of the route is located 3,000 to 4,500 meters above sea level, many technical problems remain to be solved. The construction cost is deemed to be very high.

The three routes have been designed independently and can be built and operated separately. At the end of 2002, the construction of the Eastern Route was officially commenced. The implementation of the Central Route was followed shortly after. The Western Route remains under detailed planning and construction is unlikely to begin before 2010. The whole project is envisioned to be completed in the middle of this century with a total diversion capacity of 45 billion m^3 through the three routes (MWR, 2002). This amount roughly compensates the projected water deficit in the HHH region. The total volume of water to be diverted is about 5 percent of the average annual runoff of the Yangtze River, which is 951 billion m^3/year.

Uncertainties in the Water Demand Projection

The projected growing water deficit in the HHH region has been the basis underlying the decision on the SNWT project. A question that needs to be asked is how sound this basis is. This section examines uncertainties of future water demand with reference to the baseline projection provided in Table 1 and the trends exhibited during the past two decades. Methodologies used in the baseline projection are common practices in China. They are provided to shed light on sources of uncertainties and on the possible overstating of future water demand.

Systematic and historical data on annual water use in different sectors are incomplete in China. Before 1997, the water use data for different sectors at the river basin level were available only for 1980 and 1993. Starting from 1997, the data at the provincial, and river basin level have been published annually by the Ministry of Water Resources.

Industrial Water Demand Projection

In the baseline projection, total industrial water demand was based on water quota assigned to per unit product value (i.e., m^3/10,000 yuan) with consideration of growth rate of water use, demand elasticity, and per capita water use. This resulted in an increase in total industrial water demand from 22.3 billion m^3 in 1997 to 30.9 billion m^3 in 2010 and to 37.8 billion m^3 in 2030 for the HHH basins. The pace of increase is almost the same as that during the 1980s and the early 1990s in the region. Figure 3 illustrates a scattered trend in industrial water use between 1980 and 2002 in conjunction with projected demand for the year 2010.

Between 1980 and 1993, a significant increase in industrial water use was seen in all the three river basins,

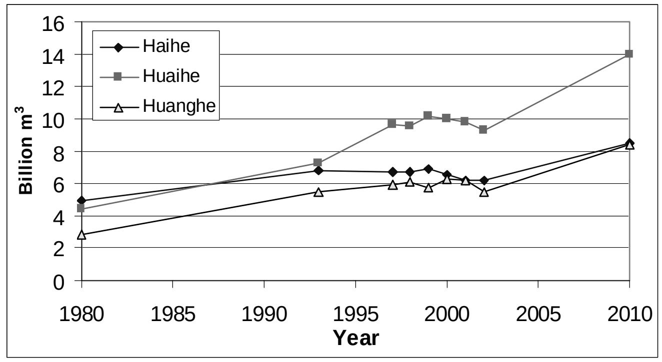

Figure 3. Industrial Water Use in the HHH Region, 1980-2010. Data for 1980 are from UN (1997); data for 1993 are from Zhang (1999); data for 1997-2002 are from MWR (2003a); and the projections for 2010 are from Pan and Zhang (2001)

though the magnitude varied. Since then, the pace has slowed down. Between 1997 and 2002, changes were minor in the Huaihe and Huanghe basins. In the Haihe basin, there was a slight decline.

Currently, water use efficiency in China's industrial sector is low. The average recycle ratio was about 60 percent in urban industries and merely 15 to 30 percent in township and rural industries in the HHH region (Pan and Zhang, 2001). The low efficiency implies a high potential for water saving. Faced with aggravating water stress, recent years have seen progressive implementation of water saving measures and market-based policies (Boxer, 2001; Wang, 2002; Thomson, 2003; Lasserre, 2003). In the North China Plain, this has contributed to an acceleration of structural adjustment in the industrial sector and a shift to the tertiary sector (Jia, 2000; Jia et al., 2004). This, together with technological progress, is likely to slow the pace of increase in future industrial water use in comparison to that experienced in the 1980s and early 1990s. The projected increments, therefore, could have been overstated though the exact extent of overstating is difficult to estimate.

Domestic Water Demand Projection

The increase in domestic water use is determined by population growth and the amount of per capita water use. The latter is closely related to the level of income and the rate of urbanization (which leads to a more water-use lifestyle). During the past two decades, the North China Plain has experienced rapid population growth, urbanization, rising incomes, and consequently, a large increase in domestic water use (Figure 4). As the forces driving the increase in domestic water demand remain strong in the coming years, it is expected that the domestic water use will continue to increase. The question, however, is: by how much?

Domestic water demand in the baseline projection is based on quota assigned to each person multiplied by the projected total population with respect to urban and rural residents in each of the river basins. In the Haihe basin, a quota of 190 L/person/day for urban residents is assigned

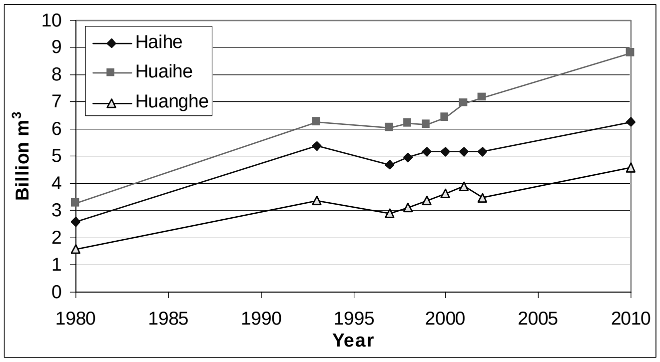

Figure 4. Domestic Water Use in the HHH Region, 1980-2010. Data for 1980 are from UN (1997); data for 1993 are from Zhang (1999); data for 1997-2002 are from MWR (2003a); and the projections for 2010 are from Pan and Zhang (2001)

for 2010 and 200 L/person/day for 2030. This represents respectively a 5 percent and a 10 percent increase in per capita domestic water use by 2010 and 2030 over the base year (1997). In the other two river basins, larger percentage increases of water quota are assigned due to consideration of relatively low basis at present. Because of the lack of reference, it is difficult to judge the appropriateness of the quotas assigned. Nevertheless, experience has shown that the actual quantity demanded responds to changes in water prices. As will be addressed in the next section, water price is one of the key issues concerned in the project management.

Agricultural Water Demand

Compared with the data for industrial and domestic water uses, the accuracy of agricultural water use data is generally low partly because of poor monitoring systems for water withdrawal in rural areas where agriculture is operated by hundreds of millions of small farms. For this reason, the data for agricultural water use from different sources for the same year can vary to some extent. This has caused inconsistency between the base year agricultural water use in the projection by Pan and Zhang (2001) and the statistics from other sources. To avoid confusion, Figure 5 depicts only the actual changes in agricultural water use for the period 1980-2002.

Over the period observed, total agricultural water use did not change significantly, though yearly fluctuations were manifest. In the Haihe and Huanghe basins, agricultural water use appears to decline in later years. The fluctuations are closely related to variations in weather conditions. In dry years, more water is used for irrigation and vice versa.

The projection of agricultural water use is based on the quota assigned per unit irrigated area taking into consideration the efficiency improvement and technology progress. In the baseline projection, agricultural water use in the three river basins is kept unchanged while irrigated areas all increase in the next 10 to 30 years. There are, however, two questions concerning this projection. The first considers the economic efficiency of further expanding irrigated areas. In the projection, irrigated areas in the Haihe basin will increase by about 8 percent by 2010 and an additional 8 percent in the following 20 years. However, with water becoming increasingly scarce, the opportunity cost of expanding irrigation is high. During the past decade, irrigated areas in Beijing and Tianjin have declined in response to the aggravation of water stress and the rise in irrigation cost (Yang and Zehnder, 2001). With China's accession to the WTO, grain import is expected to increase due to the high cost of China's domestic production and its obligation to reduce grain subsidies (Huang, 2000; Rosegrant et al., 2002). A continuous expansion of irrigated areas, thus, would be economically inefficient and practically difficult. There are, of course, other concerns that have made the government favor expanding irrigation. These typically include rural income and employment, food security and social stability. The tradeoffs between economic efficiency and social welfare and equity surrounding irrigation create uncertainties in future agricultural water demand.

The second question concerning the projection is the potential for improving the efficiency in irrigation water use. Low irrigation efficiency is widespread in China. Flood irrigation is dominant. The application of more water-use efficient methods, such as drip irrigation and sprinklers, is very limited. On the North China Plain, the average irrigation efficiency is approximately 50 to 60 percent. This portends a large potential for improving the efficiency (Liu and He, 1996; MWR, 1998; Nickum, 1998; Yang and Zehnder, 2003). An efficiency improvement of 10 percent would spare 10 to 15 billion m^3 of water from irrigation on the North China Plain. This is more than the amount of water to be transferred through the Central Route after completion of the first phase. From a technical point of view, there is almost no doubt that this percentage improvement is attainable. Allocation of this saved water to different users, e.g., transferred out of the agricultural sector or used for expanding irrigated areas, will have significant impacts on future total water demand and consequently the magnitude of water deficit in the region.

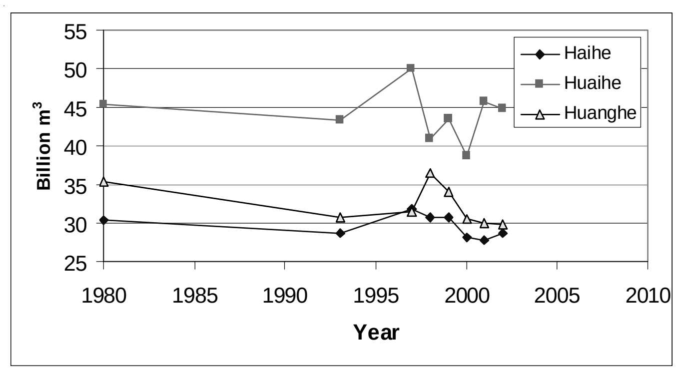

Figure 5. Changes in Agricultural Water Use in the HHH Region, 1980-2002. Data for 1980 are from UN (1997); data for 1993 are from Zhang (1999); data for 1997-2002 are from MWR (2003a); and the projections for 2010 are from Pan and Zhang (2001)

Ecosystem Water Demand

Studies of ecosystem water demand in China only have received high attention since the late 1990s in association with the severe environmental deterioration on the one hand and increasing public concerns about environmental problems on the other (Duan et al., 2001; Liu and Yang, 2002; Wang, 2002; Yang et al., 2003). In the international sphere, the domain is also relatively new (Rockstrom et al., 1999; Postel, 2002; Zehnder et al., 2003). The understanding of ecosystem water demand is rather limited, and the definition and criteria for estimating ecosystem water demand remain contentious.

In the baseline projection, ecosystem water demand is estimated for each of the seven components specified previously. The largest component is the minimum in-stream water use, which is about 15 to 20 percent of the average annual surface runoff. This percentage is set with reference to the Montana-Tennant method (Tennant, 1976) which recommends a minimum in-stream flow of 20 percent to maintain a "good" aquatic ecosystem condition. The estimation for urban and lake water use is based on quota assigned to each urban resident. Land conservation water use is based on quota assigned to per unit land area. Wetland water use and sediment transport and estuary water use are estimated with reference to the amount of water available in the region for the respective uses in the 1950s. The replenishment of groundwater targets the level of groundwater table of the 1970s. Water use for pollution dilution is considered as the required water quantity to be achieved by pollution control at sources. Total required ecosystem water use is the sum of the individual components, deducting overlaps among them.

It should be pointed out that the criteria used for estimating ecosystem water demand are rather arbitrary and subjective. Also doubtful is the determination of overlaps given complex inter-connections among different components. It is difficult to judge whether or not the projected amount of water for ecosystem recovery is appropriate. The wide range between the minimum and required ecosystem water demand further complicates the issue. This leaves a large buffer for an overstating of water demand in the economic sectors before it can invalidate the needs for the SNWT project.

Evolvement of Project Objectives and Decision on Implementation

Given large uncertainties in future water demand, a further question would be how the SNWT project has been able to receive the final approval of the central government and to be implemented rather hastily before the deadline. This section provides an overview of the evolvement of objectives of the project. It will show that the inclusion of environmental goals in the project objectives has provided a strong argument for the needs of the project, paving the way for the final decision on the implementation.

Emergence of the Idea and Initial Assessment of the Project, the 1950s to the early 1980s

When the idea of transferring water from the south to the north was first conceived in the early 1950s, China was still recovering from decades long civil and external wars. The national economy was both weak and backward. Also, at the time floods were the most frequent disasters in the North China Plain (Qian and Zhang, 2001). Against this general background, the early survey and assessment of the SNWT project were mainly carried out in the upper reaches of the Yangtze River and the Huanghe (MWR, 2002; Liu and Zheng, 2002). The main objective was to link the country's two largest rivers at their upper reaches. This work, however, was interrupted from time to time by political turbulence and economic difficulties in the country.

In the late 1970s, China's political situation was gradually settled and economic development came to the top of the government agenda. The assessment of the SNWT project was resumed (Biswas et al., 1983). In December 1979, the planning office of the SNWT project under the then Ministry of Water Resources and Hydropower was established to coordinate and manage the planning and relevant tasks of the project (MWR, 2002).

Substantive Planning of the SNWT Project, the 1980s to early 1990s

During the 1980s and early 1990s, alongside the unprecedented growth of the national economy, there was a rapid increase in water use in the industrial and domestic sectors. Water shortage emerged in most cities on the North China Plain (MWR, 2002). Agricultural water was deprived to alleviate water stress in cities, raising concerns about food security in China (Brown and Halweil, 1998). With most of the local water resources being fully developed, the SNWT project came to the forefront of consideration. The process of project planning was greatly expedited (MWR, 1998, 2002).

The main objective of the project during this period was to alleviate water shortage on the North China Plain, particularly in cities and to sustain the pace of economic development. With this objective in perspective, most studies and debates on the project at the time focused on how much water the north would need to meet economic development today and in the future. The balance of the pros and cons of the project swung with fluctuations of weather conditions. When drought struck, the urgency heightened. The opposition prevailed when rainfall was above average.

In addition to the debate on the magnitude of water deficit, possible adverse environmental and ecological impacts of the water transfer also drew attention. Major concerns included ecological impacts on the Yangtze River estuary due to reduction of river flows, especially during the low flow season; environmental and social-economic impacts on the Hanjiang and surrounding areas as the result of substantial reduction of water resources in the catchment; possible invasion of water-borne diseases from the south to the north through the water transfer; and potential modification of overall ecosystems in the north due to receiving a substantial amount of external water (Liu et al., 1994; Wang et al., 1995; Zhang et al., 1998; Shen and Liu, 1998; Liu, 1998; Liu and Zheng, 2002). Concerns on these impacts, to some extent, deterred the decision on the project.

Environmental Objective and the Final Decision, since the late 1990s

After two decades of rapid economic growth, by the late 1990s a significant improvement in living standards had been achieved for a majority of the Chinese people. In contrast, water stress has continued to intensify and the environment to deteriorate. In the Haihe basin, the picture has been painted as "wherever there is a river, it is dry; wherever there is water, it is polluted" (Zheng, 1999). There has been a growing public concern on the degradation of the environment and ecosystems.

Against this background, the late 1990s saw a broadening of the objective of the SNWT project to include ecosystem recovery on the North China Plain. Although alleviating water stress in the economic sectors remained the near-term priority of the project, improving the environment by allocating required water for ecosystem recovery became a long-term goal. Advocates pointed out that the project is an indispensable measure for environment improvement and sustainable economy development in the region. The broadened objective renders the project with characteristics of public goods (Liu, 2000; MWR, 2000; Pan and Zhang, 2001). In addition, the project is also considered necessary to enhance the image of the North China Plain in general and Beijing in particular (Wang, 2001).

It is worth noting that with the country's increasing embracement of a market economy, a cost-benefit analysis has been attempted in the project assessment. However, the estimation of costs and benefits is seriously affected by uncertainties involved in the project. Absence of markets for environmental goods has further increased difficulty for a meaningful application of the method. In the study by Pan and Zhang (2001), for example, the benefits of ecosystem recovery were expressed as enormous, yet not specifiable. Consequently, the estimated total benefits of the project were highly speculative. In other studies where costs and benefits are assessed, results differ sharply. For example, a study by the World Bank (2001) suggests that the project is economically attractive, whereas a study from WWF (2001) shows the opposite.

Also noteworthy is that the possible overstating of water demand in the economic sectors and economic gains of the project has been heeded in China. Even many advocates of the project also admit that the project may not be efficient from a pure economic point of view when other alternatives, such as water conservation measures, wastewater treatment and reuse, and sea water desalination, are considered (Liu, 2000; Jia, 2001). With the inclusion of environmental objective, however, overstating of future water demand in the economic sectors is no longer a major problem in validating the needs for the project. This is because the projected amount of ecosystem water requirement, approximately 23 billion m^3, is certainly unachievable by water conservation measures in the economic sectors. With the envisaged huge environmental benefits from ecosystem recovery, the concerns on possible adverse environmental impacts have tended to be sidelined.

As ecosystem recovery became the priority, a sentiment arose in the late 1990s that the longer the delay of implementing the project, the more the degradation of the environment and the higher the construction cost of the project (Liu, 2000; Zhang, 2001). The inference was that further debate on the need for the project would be a waste of time. The concern on Beijing's international image only heightened the impatience. With all these factors acted as catalysts, the hasty implementation of the project became inevitable.

Challenges on the Environmental Objective

With the implementation of the project, old controversies remain while new questions arise. How to satisfy water demand in the economic sectors and at the same time achieve the goal of ecosystem recovery is one of these questions.

It must be noted that the water to be transferred after completion of the first phase by 2010 (around 18 billion m^3/year) is only slightly larger than the projected water deficit in the economic sectors at the time (Table 1). Given the importance of economic sectors, meeting their needs has the priority. Water for ecosystem use is only a residual. The size of the residual depends on how much water the economic sectors can spare. Unless there is a significant improvement in water use efficiency in the economic sectors, the residual will be small. In this case, environmental degradation could continue. According to the project schedule, the second phase will not be completed until after 2020 (Pan and Zhang, 2001). Total water transfer capacity will be expanded to around 30 billion m^3/year. The projected water deficit in the economic sectors will be about 20 billion m^3/year at that time, leaving a residual of about 10 billion m^3/year. Putting aside whether or not this residual can satisfy the ecosystem water requirement, a large increase in water use in the economic sectors will mean a substantial increase in wastewater, which is detrimental to the environment. From the viewpoint of increasing the residual for ecosystem water use and reducing the amount of wastewater, it is crucially important to improve water use efficiency in the economic sectors. To this end, water price (or charge) holds a large stake.

If the water price is set too low, not only will the government bear the financial burden for the water supply, but also the transferred water will be used wastefully. Poor efficiency in water operation and maintenance will be inevitable, as evident in many water projects in China. Little water would be left for ecosystems. The environmental objective of the SNWT project would not be achieved. If the water price is too high, on the other hand, the quantity demanded for transferred water in the economic sectors would be low. The project itself would have little economic need. The biggest water transfer project of the world could become a "decoration vase" (Jia, 2001). Indeed, the issue of water price versus water demand is at the crux of the dilemma in water management of the project.

At the moment, it is far from clear what the appropriate price should be for the transferred water. There are a number of studies on the issue and results vary widely. For example, the estimated cost recovery price at the outlet of the Central Route in Beijing ranges from 1.2 yuan/m^3 to 6 yuan/m^3 (US$1=8.2 yuan in 2002) (Jia, 2001; Pan and Zhang, 2001; Hu, 2003; MWR, 2003b). Adding the cost for supplying water to the users, the price would be higher. It is interesting to note that the estimated price at the lower bound is from the Ministry of Water Resources. Expecting that even this price could be too high for consumers, the ministry has suggested that the actual water charge will be determined according to the need (MWR, 2003b). Under this water pricing arrangement, there is hardly any doubt that the SNWT project will put a chronic financial burden on the government. What remains an uncertainty, however, is the attainment of its environmental objective.

Conclusion

From the emergence of the idea in the early 1950s to the launch of the project in 2002, the objective of the SNWT project has been adjusting with the evolution of Chinese society. If the initial idea was merely a daring imagination of the then national leader, the intensification of water stress since the 1980s on the North China Plain generated economic interests in the project. With the development of national economy and the increased urgency to halt the environmental degradation, both economic and environmental interests for additional water had become manifest by the late 1990s.

The analysis in this study has suggested that the information base for validating the needs for the SNWT project is not sufficient. There are a considerable number of uncertainties in future water demand in different sectors. The inclusion of the environmental objective has provided a strong argument for the final decision to start the project. However, the knowledge regarding the amount of ecosystem water demand and costs and benefits involved is inadequate. In this case, emphasizing the objective of ecosystem recovery constitutes risks of inflating the overall gains of the project. The negative environmental impacts of the project, conversely, have tended to be overlooked.

The rationality of implementing the SNWT project will continuously be debated. One challenge facing the government is how to meet the water demand in the economic sectors to sustain the rapid economic development while ensuring the water transfer to achieve the goal of ecosystem recovery. Challenges are also daunting with regard to water legislations, water rights, displacement of affected people, and pollution control. Conflicts among different stakeholders are expected to be intense. Reconciling these conflicts requires the participation of stakeholders in implementation and management of the project. The effort to confront all these problems is a Herculean task that requires revolutionary policy measures (Boxer, 2001). Failure to deal with these problems can jeopardize the purpose of the water transfer and lead to irreversible adverse impacts.

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