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China: The South–North Water Transfer Project—is it justified?

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Abstract

The South–North Water Transfer Project (SNWTP), if fully developed, could divert 40–50 km^3/yr from the Yangtse basin to the North China plain, alleviating water scarcity for 300–325M people living in what even then will be a highly water-stressed region. Construction of the next stage, diverting up to 20 km^3 at a cost of about $17,000M (including $7000M in ancillary costs), is to start in 2002/3. A recent World Bank study suggests that the project is economically attractive. This conclusion has been disputed by the World Wildlife Fund (now the Worldwide Fund for Nature). This paper concludes that little confidence can be placed in either of these analyses. It therefore seeks to throw light on how the project fits within a broader regional and agricultural development setting. The project is hugely expensive, and would at the margin tend to preserve water in low value agriculture and require the resettlement of upwards of 300,000 people. On the other hand, the pace and scale of socio-economic change in China are without precedent, and adjustment problems on the North China plain are greatly exacerbated by water scarcity. Reallocation of water from irrigation to municipal and industrial uses or to the environment is socially divisive and in some instances physically impracticable. The transfer project would greatly alleviate these difficulties. It is these arguments (which are ultimately political and pragmatic), rather than those based strictly on economic or food security concerns, that make the Government's decision to proceed with the project fully understandable.

Keywords: China water; Economic, social and environmental evaluation; Inter-basin diversion; Water allocation; Water Policy; Water transfer

1. Introduction

1.1. The North China or 3-H Plain

The North China or 3-H plain is home to more than 25% of China's population, and accounts for an even higher share of GDP. It is served by three major rivers (the Hai, Yellow (Huang) and Huai, Fig. 1). The plain was formed over millennia from silt deposited mainly by the Yellow River as its

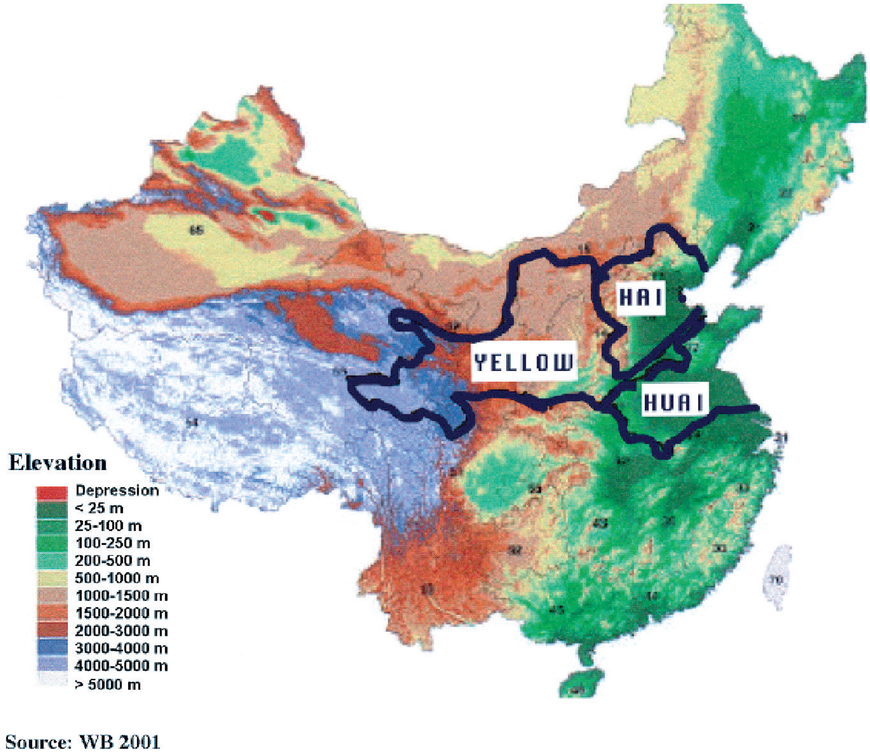


Fig. 1 Relief map of China showing the 3-H basins.

channel shifted, sometimes catastrophically, jostling with the local rivers of the Hai and Huai systems. Since 1949, the lower river has been confined within its current banks and, due to silt deposition, for some 18,000 km is perched up to 10 m above the plain. This creates a dangerous flood risk, but one that has been much reduced over the medium term by the Xiaolangdi Dam which has greatly augmented water and silt management capability in the lower river.

Despite the great rivers and productive aquifers, the 3-H basins face water scarcity as acute as in any major world region. Population verges on 450M (7.25% of the *world* total), of whom 300–325M live on the coastal plain. Renewable water per head is less than 500 m^3/yr and in the Hai basin less than 350 m^3/yr. Some Middle Eastern countries, small islands and populated basins (e.g. in South India) have levels that are lower, but nowhere are so many people faced by so little renewable water. The Middle East and North Africa Region, for instance, has a population of about 300M and renewable water of 900 m^3/hd/yr, twice that of the 3-H basins and almost *three* times that of the Hai basin (population 125M)[1].

The monsoon climate is typified by variable rainfall and by damaging droughts and floods. Flows in the Hai and Huai fall to 70% of average one year in four and to 50% one year in twenty. Those of the Yellow River are less variable given its larger and more diverse catchment. Even so, the lower river dried for up to 180 days per year until Xiaolangdi helped re-establish flows. At the other extreme, a 1975

[1] Rainfall of 400–900 mm makes rainfed crops possible. In this regard, the 3-H plain is better served than much of the Middle East. In Allen's terminology it has more *soil water* (Allen, 2001).

storm in the Huai basin dumped 1005 mm of rain in one day, more than the total annual average rainfall and one of the highest rainfall events recorded anywhere. This was exceptional. But droughts and floods, along with urbanisation and population growth, point to an expensive corollary. Flood protection and pollution control will each, separately, match the huge cost of addressing water scarcity (WB, 2001).

Water supply and demand. Numerous studies have assessed water supply and demand in the 3-H basins. Some have employed informed extrapolation (IWHR, 1998). Others have modelled the water system within a regional economic context (RCNCWR, 1994; WB, 2001). Table 1 is taken from the IWHR study.

- *M&I demands* are forecast to rise from 37 to 94 km^3. Urban use is currently surprisingly high but domestic demand responds to price (Elston, 1999) and use in many industries can be much reduced.
- *Irrigation use* is set to fall from 115 to 108 km^3 but will easily stay the largest single use. Irrigated grains will remain important even as agriculture diversifies.
- *Withdrawals* of local surface water rise and of groundwater decline. But this shift will be small. Moreover, groundwater reductions in the Hai basin reflect re-balancing of the surface/groundwater system rather than a real decline in use.
- *The South–North Water Transfer Project* is presumed fully built, allowing net transfers by 2050 of 43 km^3 from the Yangtse (about 20% of consumptive use).

Table 1. IWHR estimates: withdrawals and use[a]: 1993 and 2050 (projected): km^3.

	1993				2050			
	Hai	Yellow	Huai	Total	Hai	Yellow	Huai	Total
Withdrawals[b]								
Surface water	11	38	37	85	17	31	43	91
Groundwater	25	13	17	54	17	14	21	52
Re-use[c]	...	...	...	...	7	3	6	16
Net basin transfers[d]	6	–10	16	12	13	10	20	43
Total	*43*	*41*	*69*	*151*	*54*	*58*	*91*	*203*
Use[b]								
Urban domestic	2	1	2	5	11	6	12	29
Rural domestic	2	2	4	8	2	3	4	9
Industry	7	5	7	19	12	14	24	50
Irrigation	31	32	53	116	27	34	47	108
FHF[e]	2	1	3	6	2	1	4	7
Total	*43*	*41*	*69*	*153*	*54*	*58*	*91*	*203*

a. The IWHR projections are for the average (50%) year. They are thus comparable to the WB estimates in Table 2.

b. Assumed equivalent to consumptive use, which tends to overstate consumptive use. However, losses (the non-consumed fraction) largely return to the river or recharge groundwater, and in either case can be withdrawn repeatedly. To this extent, withdrawals approach consumptive use.

c. Estimates of re-use in 2050 seem to refer to M&I flows that are treated before returning to the environment. If so, they are only a part of total reuse with the balance accounted for—as in the 1993 estimates—in other sources

d. In 1993, 10 km^3 of surface supplies were transferred from the Yellow to the Hai (6 km^3) and Huai (4 km^3) rivers, and 12 km^3 were transferred from the Yangtse to the Huai. By 2050 transfers from the Yellow River will have ceased and net basin transfers will be entirely from the Yangtse via the South–North Water Transfer Project.

e. FHF: forestry, (animal) husbandry and fisheries

Source: IWHR (1998), quoted in Hydrosult (1999).

World Bank projections (WB, 2001) suggest a more manageable situation (Table 2). Though differing in detail, the Bank Report confirms that water scarcity will be acute and that the first stages of the SNWTP at least are justified. Though supported by both Chinese analysts and the World Bank, the project is nevertheless very costly; it involves the resettlement of up to 300,000 people; deprives the Han sub-basin of water supplies; and has complex environmental implications. Some dissident voices have thus come out against the project, concluding that management and efficiency improvements alone would be adequate (WWF, 2001).

1.2. The South–North Water Transfer Project (SNWTP)[2]

The first canal linking the Yangtse with North China was the Grand Canal, built for the transport of rice and other goods and dating back more than 2000 years. Water transfer studies as such began in the

Table 2. WB estimates: supply and demand for 50% year, 1997 and 2050 (projected): km^3.

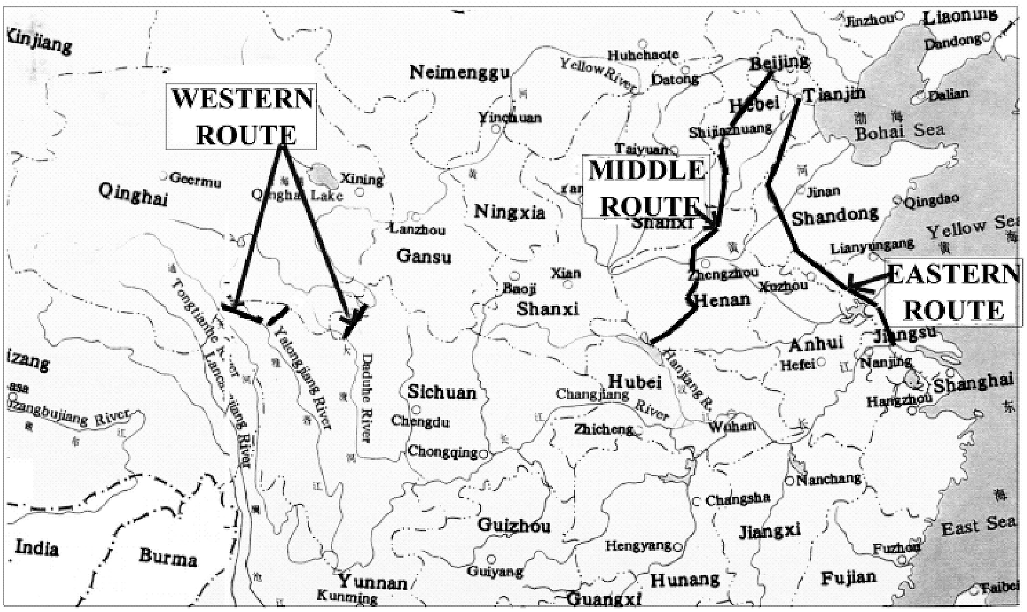
	1997				2050[a]			
	Hai	Yellow	Huai	Total	Hai	Yellow	Huai	Total
Supply[a]								
Surface water[b]	15.1	21.9	34.7	71.7	17.3	24.6	33.2	75.1
Groundwater	15.9	13.0	16.5	45.3	19.4	15.2	25.7	60.3
Transfers[c] from Yellow River	3.7	(–10.0)	6.3	10.0	0.0	0.0	0.0	0.0
Transfers[c] from Yangtse	0.0	0.0	2.9	2.9	6.8	0.0	12.8	19.6
Total	34.7	34.9	60.4	129.9	43.5	39.8	71.7	155.0
Demand[a,d]								
Urban domestic	2.6	1.5	2.4	6.5	6.7	3.7	6.1	16.5
Rural domestic	1.7	1.2	3.0	5.9	1.8	1.4	2.5	5.7
Industry	6.6	5.9	9.4	21.9	9.2	11.8	17.4	38.4
Irrigation	34.7	33.3	44.3	112.3	32.5	30.2	39.2	101.9
Forestry, livestock and fisheries	0.5	1.7	4.6	6.8	0.5	4.0	6.5	11.0
Total	46.2	43.6	63.6	153.4	50.7	51.2	71.8	173.6
Shortage[d]								
Priority (non-irrigation)	2.1	1.6	2.1	5.8	0.3	0.3	. . .	0.6
Irrigation	9.4	7.1	1.1	17.6	7.0	11.1	0.1	18.2
Total	11.5	8.7	3.2	23.4	7.2	11.4	0.1	18.8

a. WB "supply" is comparable to IWHR "withdrawals" and WB "demand" is comparable to IWHR "consumptive use" (Table 1). WB estimates for 2050 assume that the recommended Action Plan is implemented in full (see text).
b. Differentiated by the WB into runoff from external and runoff from local sources.
c. Water is transferred from the Yellow River to both the Hai and Huai basins, and from the Yangtse to the Huai. Once the next stage of the S–N transfer is completed, these transfers will be replaced by water from the Yangtse. Transfers from the Yellow River are derived from IWHR (1998), the residual to the Huai being assumed to be from the Yangtse.
d. "Shortage" and "demand" in this context are ambiguous since irrigation could take almost all available water. See text
Source: World Bank (2001). The estimates are taken from Annex A4.1 of the World Bank Report, which provides details on the individual basins. These differ in a few respects from the summaries by basin given in Annex A4.2.

[2] The project is described in an official English language paper (MWR, 1995). Some aspects can be updated from Liu (1998), US Embassy (2001), WWF (2001), WB (2001) and the *People's Daily* of various dates. A good overall review of the project and its environmental impacts is given in Liu and Tan (1994). Far greater detail is available in Chinese in published form.

1950s when three broad alignments were described (the Western, Middle and Eastern Routes, Fig. 2). These have guided all subsequent studies:

- *The Western Route* diverts water from upper Yangtse tributaries in difficult and remote terrain in the Sichuan and Qinghai mountains. A first stage would take water from a dam on the Yalong River via a 170 km tunnel to the upper Yellow River. Subsequent stages divert water from the Tongtian to the Yalong, and from the Zumuzu to the Tongtian, each stage dependent on completing the earlier works. Preliminary estimates suggest up to 20 km^3 could be diverted.
- *The Middle Route* (Fig. 3) starts at Danjiangkou reservoir on the Han, a major left-bank tributary of the middle Yangtse. The dam was built in 1974 to 162 m but was designed to be raised to 176.6 m. This will increase gross storage from 17.5 km^3 to 29.1 km^3, flood 370 km^2 and displace 225,000 people. The canal crosses the upper Huai and then the Yellow River below Xiaolangdi Dam. It proceeds to Beijing along the foot of the Taihang Mountains. Its total length is 1230 km, with a branch to Tianjin of 142 km. Canal works would displace a further 50,000 people. Natural channels were rejected in favour of a new canal to preserve water quality and command the full area by gravity. More than a thousand structures include a 7.2 km tunnel under the Yellow River. The first stage will divert 9–13 km^3/yr or 25–35% of Han flows at Danjiangkou, though the heightened dam will also have important flood and water control benefits in the lower Han and to the city of Wuhan. The first stage costs some US$7000M, with a further US$3000M in accessory costs, mainly for resettlement but also for Han replacement works (US Embassy, 2001; WWF, 2001). A second stage could increase diversions to 20 km^3 but is only feasible with compensating transfers from the Yangtse to the lower Han.
- *The Eastern Route* (Fig. 4) takes water from the Yangtse about 100 km below Nanjing and 250 km from the sea. A first stage was inaugurated in 1961, based on the Jingdu Pump Station (at 400 m^3/s,



Source: MWR 1995

Fig. 2 Sketch map of the South–North Water Transfer Project.

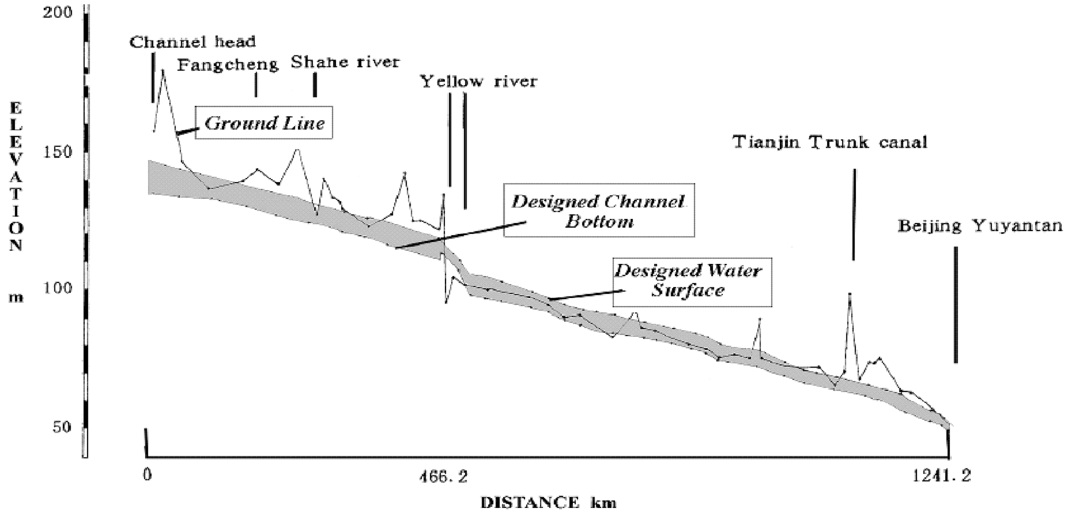


Fig. 3 Profile of Middle Route of the South–North Transfer Project. Source: MWR 1995.

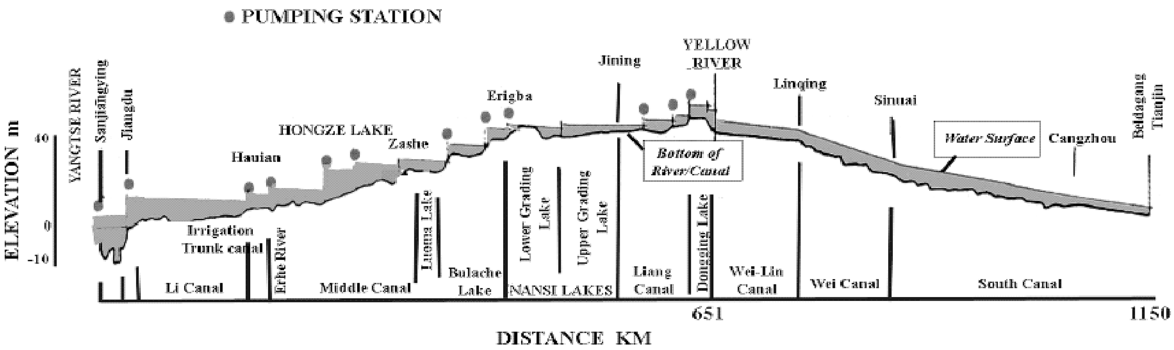


Fig. 4 Profile of Eastern Route of the South–North Transfer Project. Source: MWR 1995.

one of the largest in the world) mainly for irrigation in Jiangsu. Capacity at this and other stations will increase to 600 m^3/s by 2010, 1000 m^3/s by 2020 and ultimately to 1400 m^3/s. Conveyance (1150 km) is via a network of rivers, lakes, reservoirs and canals, including the Grand Canal, most of which exist in some form to the Shandong border. The water will be lifted 65 m by twelve pump stations to the Yellow River, crossed by tunnel. From there, water can flow north by gravity to Tianjin. The next stage will cost US$3000M, including US$600–800M for an emergency Tianjin project (US Embassy, 2001; WWF, 2001). Accessory costs (mainly for pollution control) could cost US$4000M although much of this is desirable in its own right. At full development some 3% of annual Yangtse flows (975 km^3) will be diverted suggesting that the impact on the lower Yangtse will be negligible.

A decision on the Western Route has been postponed until after 2010, but the next stage of the Eastern Route and the first stage of the Middle Route are to go ahead (*People's Daily*, 2002). By any standards, the first stage is a massive undertaking, costing US$17,000M including US$7000M for ancillary works. But large though these costs are, they are of the same order of magnitude as those for the Three Gorges

Dam under construction on the Yangtse, which has proven to be within China's financing capacity. Moreover, they amount to a modest US$40 per head over eight years. In these terms, they are not so forbidding. Even so, is the project justified?

1.3. Scope of the paper

Official reports are not readily available in English. Both they and the WB study conclude that the project is justified and support construction of the next stage (WB, 2001). In contrast, WWF argues that it is "not worth the cost" and "improved water management . . . would deliver more water and considerable environmental benefits" (WWF, 2001). The economic analyses of these two reports are assessed in section 2, which concludes that neither makes a convincing case one way or the other. Section 3 places the project in a broader regional and agricultural development context, focusing on the role of water in the rural economy. Section 4 reviews its rationale within this framework and concludes that, irrespective of the economic case, powerful environmental and socio-political arguments support the project and make the Government's decision to proceed fully understandable.

2. Two recent economic analyses of the SNWTP

2.1. Introduction

The WB and WWF reports not only differ greatly in methodology and assumptions, but their conclusions are also strikingly at odds. The WB employs a constrained optimisation (mathematical) model that requires a massive array of detailed assumptions (some of which are necessarily assertions), solves for differing levels of probability and future years by basin and water region, and meets water demand in an economically optimum way (Annex 3.1 of the WB report gives the details). In contrast, WWF adopts a simple cost–benefit approach and its few assumptions are asserted with little justification. In contrast to the WB, WWF does, however, assess capital costs for differing destinations and users. Moreover, the WB's agricultural assumptions differ greatly from those in another WB report (see below) (WB, 2000).

2.2. Overall economic analysis

WB water values for M&I and industry are derived exogenously but, for irrigation, are endogenous to the model, being estimated for each water region within a consistent hydrological framework. Benefits are based on the project's contribution as a component of an overall Action Plan to reduce water shortages (Table 3). Costs are based on schedules for the next stage of the project (section 1). The WB concludes that the project (notably the Eastern Route) is highly profitable at a 12% discount rate. In contrast, irrigation efficiency investments are said to have strongly negative returns due to their high cost. Even so, they are included in the Action Plan to "contain the shortages for agriculture to tolerable limits" and because the Action Plan as a whole has a positive return.

The WWF benefit estimates are based wholly on exogenous water values, including for irrigation. These are compared with delivered costs at sequential points along the Middle and Eastern Routes at a discount rate of 8% (Table 4). Despite the lower discount rate, the WWF concludes that "the real cost

Table 3. WB economic analysis of shortage reduction investments[a].

Intervention	Shortage reduction[b] % of total	Shortage reduction benefits[c] Present value at 12% ’000 M Yuan	Shortage reduction costs Present value at 12% ’000 M Yuan	Implied cost–benefit ratio
Price increases	17	27	(0)	n.a.
Reuse and pollution control	9	55	39	1.4
Irrigation efficiency improvements	30	27	107	0.3
S–N Transfer: Eastern Route	19	61	20	3.2
S–N Transfer: Middle Route	26	63	46	1.4
Total	*100*	*233*	*217*	*1.1*

a. Table 4.33 in the WB report has been reformulated so as to make the implied cost–benefit ratio explicit.
b. The contribution of the specified intervention to the reduction in physical shortages due to implementation of the Action Plan.
c. Benefits equal the reduction in system-wide economic losses due to the specified intervention. The model accounts for differing economic impacts in differing sectors: for instance, irrigation efficiency improvements account for 30% of the shortage reduction but for only 12% of benefits. The meaning of “shortage” is discussed in the text.
Source: WB (2001), volume 2, based on Table 4.33.

of water from the eastern route would be justified (only) if it were used for urban and industrial purposes . . . the middle route would justify industrial use but not urban use above Hebei”. In other words, the Middle Route cannot be justified for any uses in Beijing or Tianjin and WWF concludes that neither route can be justified for irrigation. In the case of the Middle Route, this remains the case “even if the price of grains were to triple”.

This brief summary perhaps fails to do full justice to the reports, notably to the very detailed mathematics of the WB report. Even so, numerous questions arise. Why, for instance, is the WB discount rate so high? Presumably because this has been the conventional level in China for project analysis, but such massive projects in developed countries seldom use anything like such a high rate. Also why are the estimates in the two reports so very different? This would require detailed study. In the space available here it may be sufficient to discuss four issues: (i) the value of water, (ii) water use efficiency, (iii) water reallocation and (iv) investments in new supplies.

Table 4. WWF estimates of delivered cost at points along the SNWTP.

	Delivered cost (rounded): Yuan/m^3 at 8%
Middle Route	
Hubei	1.4
Henan	5.0
Hebei	9.3
Tianjin	13.6
Beijing	15.8
Eastern Route	
Shandong: Huai Region	1.0
Peninsular	1.5
Hebei	2.3
Tianjin	3.8

Source: WWF (2001).

2.2.1. *The value of water*

Table 5 summarises average WB economic values per m^3. Those for irrigation are derived from "a host of factors within the model, including the cropping patterns, irrigated yields, costs of production, and relative weight of irrigation to total crop water requirement", whereas those for other sectors are derived exogenously from other sources.

The concept of "shortage" in this context is ambiguous (Section 3). This said, the average value of "one cubic metre of water shortage" (2.0–2.4 Yuan/m^3 or 25–30 cents/m^3) (Table 5) seems high. Allowing for inflation, it is about double the figure in an earlier UN-funded study (RCNCWR, 1994). It is far higher than the value in irrigation even though irrigation accounts for 90% of the estimated shortages (Table 6) since priority uses account for more than 50% of the shortage *reductions* attributed to the Action Plan (Table 7). However, this begs the question as to why priority uses cannot be satisfied by reallocation out of agriculture. This is discussed below.

Further doubts arise from the *marginal* values by crop and basin given in Table 8. Even if these correspond to the *averages* in Table 5 (see the footnotes to the tables), why are crop values in the Hai basin no higher (indeed in some cases are lower) than in the other basins given that Hai shortages are so much more acute (Table 6)?

WWF water values are derived exogenously: (i) industry "can exceed 20 Yuan/m^3 (2.5 cents/m^3)" but varies by industry; (ii) urban "of the order of 1–2 Yuan/m^3 (12.5–25 cents/m^3)" and (iii) irrigation "can probably be taken at most at around 0.4 Yuan/m^3 (5 cents/ m^3)" for water consumed or 0.3 Yuan/m^3 (3.75 cents/m^3) for water diverted at 75% irrigation efficiency. If grain prices tripled "the value of irrigation water would be 1–1.5 Yuan/m^3 (12.5–17.5 cents/m^3) at 75% efficiency" (WWF, 2000). No

Table 5. WB estimates of the economic value of water in the 3-H basins.

	Average economic value[a] Yuan/m^3
Uses[a]	
Urban industry	6.0
Rural industry	4.0
Urban domestic	3.0
Rural domestic	3.0
Livestock	2.0
Fisheries/pasture/forestry	1.5
Irrigation	0.8–1.6
(Average)	*(2.0–2.4)*[c]
Water conditions: Year 2000 solution	
95% probability	2.24
75% probability	2.18
50% probability	2.16
25% probability	1.65

a. These *average* values appear to correspond to the value of water for shortage reduction (i.e. water at the margin) rather than strictly to the average value in the sector concerned.
b. Estimates for irrigation are derived endogenously within the constrained optimisation model. Estimates for all the other sectors are derived exogenously from other sources.
c. This average is quoted from the text.
Source: WB (2001), volume 2, Table 3.10 and Table 4.28.

Table 6. WB estimates: supply, demand and shortages by basin for 75% year: 2000.

	Supply	Demand			Shortage		
	Total	Irrigation	Priority[a]	Total	Irrigation	Priority[a]	Total
Hai basin	32.7	37.6	12.4	50.0	15.0	2.3	17.3
Huang basin	35.5	35.5	11.4	46.9	9.5	1.8	11.3
Huai basin	62.2	51.2	11.2	71.9	7.5	2.2	9.7
Total	*130.4*	*124.2*	*35.0*	*168.7*	*32.5*	*6.4*	*38.3*

a. Priority shortages—shortages in M&I (domestic and industrial) and FHF (forestry, husbandry, fisheries).
Source: WB (2001), volume 3, Annex 4.1, Table A.4.1–1.

Table 7. WB estimates: priority and irrigation shortages in 3-H basins: 2000, 2020 and 2050.

	Base case[a]			Action plan case[b]			Reduction[c]	
	2000	2020	2050	2000	2020	2050	2020	2050
				Priority[d] shortages				
95% probability	6.2	13.0	17.5	6.2	5.5	6.5	7.4	10.9
75% probability	6.4	11.7	15.6	6.4	4.7	5.4	7.0	10.2
50% probability	6.0	11.4	15.3	6.0	3.8	4.7	7.6	10.6
25% probability	5.7	11.1	15.0	5.7	3.4	4.1	7.7	11.0
				Irrigation shortages				
95% probability	62.0	71.7	77.3	62.0	62.1	62.5	9.6	14.8
75% probability	32.5	36.7	41.1	32.5	30.5	31.4	6.2	9.7
50% probability	18.6	24.0	26.7	18.6	18.8	19.2	5.2	7.5
25% probability	11.8	16.7	19.5	11.8	13.4	14.0	3.3	5.4

a. Base case—assuming business-as-usual.
b. Action plan case—assuming the action plan is fully implemented (including the SNWTP).
c. Reduction in shortages between the base case and the action plan case.
d. Priority shortages—shortages in priority M&I (domestic, industrial) and FHF (forestry, husbandry, fisheries).
Source: WB (2001), Volume 3, Annex 4.2.

Table 8. WB estimates of marginal values[a] of irrigation water by crop and basin.

Crop	Water deficit[b] %	Hai Yuan/m^3	Yellow (Huang) Yuan/m^3	Huai Yuan/m^3
Rice	0	1.39	1.41	1.49
Winter wheat	20	1.26	1.24	1.23
Summer maize	30	1.79	1.88	1.58
Cotton	20	0.96	0.96	0.96
Soybean	30	0.63	0.80	0.86
Peanut	20	1.01	1.04	1.16

a. These appear to correspond to the *average* values in Table 5, given that the latter are average value of shortage *reduction* (i.e. water at the margin).
b. Marginal values are for optimum (Penman) water applications for rice, but for 20–30% deficits relative to Penman for other crops.
Source: WB (2001), Volume 2, Table 3.22.

basin estimates are made. Other than for industry, these are well below WB estimates and it is not surprising that they reach totally different conclusions. The WWF estimates are *average* values and may not be fully comparable to those of the WB. But the purpose here is not to judge which is correct or to derive new figures, but to draw attention to the great uncertainties associated with *both* reports.

2.2.2. Water use efficiency

An emphasis on water use efficiency has strong *prima facie* appeal. Much has already been achieved but the WWF argues that major potential still remains: "waste reduction and waste water collection and treatment would yield savings of 50–80 km^3 and enormously improve the aquatic environment . . . there is a risk that politically attractive investment in water transfer will divert money, attention and resources from politically difficult measures to improve water management, even though the latter would deliver more water and considerable environmental benefits" (WWF, 2001). No costs are given but it is assumed that any investments required are much more attractive than the SNWTP.

Unfortunately, the savings anticipated by WWF are unrealistic. They equal a *third* of current water use and *three* times WB estimates based on detailed water balances. Since little water reaches the sea (other than flood flows and limited environmental releases), there is no conceivable source for such savings. Neither the IWHR nor WB foresee efficiency gains anything like sufficient to satisfy demand (Tables 1 and 2). The environmental benefits foreseen by WWF are also highly questionable. Farmers fight for what water there is in the dry season. This largely explains why groundwater is over-pumped, flows cease, wetlands and deltas contract and pollution loads cannot be passed to the sea. Indeed, it is hard to envisage any improvement to the environment without additional supplies (section 3).

This said, efficiency improvements should be pursued vigorously to the extent feasible. With respect to M&I, investments need to be justified at long-run marginal cost (LRMC). Since prices are well below LRMC, growth in demand could be greatly curtailed by price and other demand management measures (Elston, 1999; SM Group Inc., 1998). The impact on the water balance would, however, be limited since M&I withdrawals account for only 20–25% of the total and largely return to the water system. Benefits are likely to be in postponed investment and/or improved levels of service and water quality rather than in major water savings.

Irrigation will remain easily the largest user and consumptive use in irrigation accounts for a high proportion of withdrawals. There is thus a strong *prima facie* case for raising irrigation efficiency. But, far from being profitable, WB conclusions suggest such investments have strongly negative returns since "(they) only affect agriculture with low value water" (Table 3). This is, at first sight, surprising and differs radically not only from WWF conclusions but also from other WB reports. For instance, a water conservation project aims to "increase the value of agricultural production per unit of consumed water through increasing yields and reducing non-beneficial water losses" (WB, 2000). Far from being uneconomic, the IRR based on direct agricultural benefits alone is 21%, ranging from 17–25% for individual sub-projects. The project document also claims water savings of 60–95 Mm^3/yr. At an opportunity cost of, say, 2 Yuan/m^3 (Table 4) the present value of these is Yuan 400–640M, with Yuan 190–210M also claimed for lower pumping costs. These benefits are comparable to the agricultural benefits, implying an IRR much *above* 21%.

Why do the two WB reports differ so much? No doubt there are many reasons. But at the heart of the contradiction is the fact that the economic analysis of irrigation modernisation is inherently uncertain and unstable. Benefits comprise the *difference* between two large future streams (net agricultural benefits "with" and "without" the project), neither of which can readily be validated. Small changes in price, yield, intensity, crop mix and other assumptions have a large impact on incremental value-added. The inclusion of fruits and vegetables, for instance, helps explain why the conservation project earns such high returns. But, again, the point here is not to conclude which report is correct but to stress that *all* such analyses are highly speculative given the assumptions needed and the room for unwitting optimism[3].

2.2.3. Reallocation between uses

Water's value in irrigation is well below its value in M&I use (Table 5) and M&I normally receives priority[4]. If reallocation out of irrigation is the least-cost way of meeting M&I demands (allowing for opportunity and externality costs, and for security of supply requirements) then reallocation is economically desirable (Briscoe, 1996). Of course, farmers are not the only ones that lose out if water is reallocated. Others utilise return flows and rural areas may depend on irrigation for much of their prosperity. However, this only provides a convincing *economic* rationale for retaining water in irrigation if linkage and multiplier effects are greater in rural than in urban areas. This cannot usually be proven and may not be true, so linkage and multiplier effects are typically omitted.

Reallocation deprives farmers of accustomed supplies. Ideally, property rights should be recognised[5] and those deprived of these rights, whether directly or indirectly, should be compensated. This occasionally occurs (for instance, Qingdao City in Shandong Province has purchased water from irrigation schemes to avoid paying for expensive Yellow River supplies), and the literature points to the merits of voluntary water markets based on experience in other countries (Dinar & Subramaniam, 1997; Marino & Kemper, 1999). However, in practice farmers are more commonly expropriated by default as cities and upstream users develop supplies, river flows progressively decline and watertables fall. Water released by urban sprawl is also taken up by urban utilities, with farmers compensated, if at all, via the land market.

Irrespective of how it is accomplished, reallocation from irrigation to M&I tends to reduce wealth and jobs in rural areas and to accelerate migration to the cities. The importance of these effects is a matter for debate. Numerous factors are involved in the process of rural transformation, and the evidence of continued rapid agricultural growth even in the Hai basin suggests that water scarcity is not necessarily the most important (section 3). Nevertheless, water conflicts raise contentious issues and can exacerbate adjustment problems. Hence cities in practice often resort to more expensive water—deeper aquifers, more distant rivers—to avoid the need to compensate or confront farmers. This is a pragmatic solution but may involve major costs and becomes increasingly difficult as water scarcity intensifies.

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[3] Moreover, why should Government be involved? "Such measures (i.e. drip, sprinkler etc.) . . . have been increasing rapidly in north China as farmers and other entrepreneurs alter production techniques and technologies in the face of scarce water, and political pressures to adapt. Again, the market can be relied upon, not only to motivate continuing increases in efficiency, but to insure that those increases are economically justified, and go toward producing more of the goods and services society wants" (WB, 2001, Volume 2, p 118). If so, why subsidise on-farm investments? In 1996/67 alone "6 million mu (400,000 ha) (was developed under) sprinklers, drip irrigation, drip under plastic film and micro-sprinkler irrigation" (WB, 2001, Volume 2). There may be a case for funding joint investments (e.g. canal lining) but farmers are the best judge of what is profitable on their own farms. In few other productive sectors would the WB "pick winners" in this way.

[4] The 1988 Water Law (Article 14) states that "In the development and utilization of water resources, the domestic water demands of urban and rural inhabitants shall be satisfied first, while agricultural and industrial water demands as well as navigation requirements shall also be considered and taken care of. In areas deficient of water, urban growth and the development of high water consumption industries and agriculture shall be restricted".

[5] Abstraction licences were first introduced by the 1988 Water Law, though the detailed rules were only issued in 1993. Exchange or sale of permits is not permitted under existing legislation, although it is understood they are to be allowed under a revised law recently passed.

In some cases reallocation is impracticable for physical reasons or because adequate security of supply cannot be assured. Cities at the foot of the Taihang Mountains, for instance, can intercept local rivers and aquifers but cannot access rainfall on the plain. Demand in Beijing and Tianjin by now has also out-grown local sources. This helps explain why continuing “priority shortages” are foreseen by the WB (Table 7) since, although the WB model meets priority demands in preference to those of irrigation, “priority shortages” would continue where this is technically infeasible.

2.2.4. New supplies

Local supplies are almost fully developed, although limited groundwater potential exists in the Yellow and Huai basins and some rivers have yet to be fully controlled by storage. One strategy might be to confine new supplies to meeting “priority shortages” (Table 7). Desalination costs have been falling and recent bids in the USA and Israel have been below US55 cents/m^3 (Cohen, 2001; Stikker, 2001). This is still above the value attributed to domestic demand (Table 5) but desalination may still be attractive if there are few alternatives, given that coastal plants can be located close to demand and supplies can be scheduled in required amounts and quality, independent of climate and other claims. Other countries are actively considering desalination for coastal cities but, as far as is known, desalination has so far been ruled out in China on grounds of cost. Another option would be to confine the SNWTP to meeting “priority demands”. The emergency project for Tianjin is in this category (section 1). The Eastern Route could be phased to meet rising M&I demands without supplying irrigation, although this may not be feasible for the Middle Route given economies of scale. However, bypassing irrigated areas would be difficult. The Eastern Route, for example, passes through the south-east of the Hai basin, an area deprived of water by upstream developments. Neither farmers nor politicians would readily allow water to pass by without agriculture deriving some direct benefit from such a high profile project.

2.2.5. Conclusions

The above suggests that little confidence can be placed in the WB or the WWF reports. But the brief review of alternatives to the SNWTP also suggests that none of these is likely to provide a satisfactory solution: (i) improved efficiency has a role to play but its contribution is likely to be far less than claimed by WWF; (ii) reallocating water from irrigation to M&I is, in principle, attractive but raises formidable socio-political issues and is not always technically feasible; (iii) desalination costs are falling and this remains a possibility for some priority uses in coastal cities but can be ruled out generally; and (iv) scheduling the SNWTP to meet “priority demands” may be feasible for the Eastern Route but is impracticable for the Middle Route and would encounter major socio-political objections.

These conclusions suggest that North China is faced by a stark choice: *either* it will have to live with rising water pressures, *or* the hugely expensive SNWTP project will have to be built, despite resettlement and other adverse effects. In making this choice, much depends on how significant water is in determining the pace and scale of rural and agricultural change on the North China plain. Put another way, what are the prospects for the rural sector “with” and “without” the SNWTP? To throw light on this question, the project needs to be considered within a broader context than is typical of conventional economic analyses.

3. The regional and agricultural development context

3.1. Introduction

Water is one factor among many that determine the pattern of regional and agricultural development. Under some circumstances it is the *critical* resource but it is not obvious that this is so on the North China plain. The economic transformation is well under way and farming is no longer the only (or even always the most important) source of income for the rural community. Moreover rainfed farming is feasible over most of the plain and, if irrigation is deprived of water, land and labour can continue to be engaged in admittedly low productivity agriculture.

Agriculture employs perhaps 40–45% of the labour force and indirectly far more. No doubt, this share will decline rapidly. Nevertheless, rural adjustment in North China has been rapid and unsettling. By easing pressures on the water resource, the SNWTP could help moderate the traumas associated with this process. Moreover, the project is a direct and non-controversial means of meeting priority demands and provides an opportunity for containing environmental degradation. The question remains whether these benefits outweigh the costs of such a large and irreversible project.

3.2. Economic and agricultural growth

GDP and crop data are available by province. About 80% of the area of seven provinces fall in the 3-H plain (Table 9), with the balance mainly in the Yangtse basin. In turn these provinces account for 100% of the Huai, 77% of the Hai and 7.5% of the Yellow basins. The balance of the Hai lies mainly in the mountains of Shanxi. Most of the Yellow basin lies in poor interior provinces that face different issues to those addressed in this paper.

Growth on the 3-H plain has been more rapid than for all of China. Given its acute water constraint, growth in the Hai basin has, in particular, been striking. Hebei, occupying 70% of the Hai plain, has grown more rapidly than all of China in industry and services and equalled it in agriculture. Major factors in respect of the latter have been rising grain yields (Fig. 5) and diversification. Grain yields rose rapidly during the 1978–84 reforms, levelled off in the late 1980s but enjoyed a new spurt in the mid-1990s. In contrast, land use has changed only modestly. Grain output in Hebei may have peaked but crop and livestock diversification has fuelled continued agricultural growth.

One way of placing this performance in context is by international comparison. The water literature often refers to a world water crisis (WWC, 2000) and IWMI foresees that countries including Egypt, Iran, Pakistan and South Africa will by 2025 “face physical water scarcity . . . (with not enough) water to meet their agricultural, industrial and environmental needs” (Seckler *et al.*, 1998; IWMI, 2000). Yet the 3-H basins already have far less water per head than is expected in any of these countries. On IWMI’s criteria, the Hai basin has been in a severe water crisis for decades. Yet this has not reduced the creation of economic wealth, including agricultural wealth, on an unprecedented scale. How can this apparent contradiction be explained?

One explanation is *groundwater mining*. Over much of the plain this is a local phenomenon but in the Hai basin mining is more general. About 50% of ground and surface water potential in the Hai basin overlap. Exploiting groundwater rather than surface water can be a rational response by cities and commercial farmers (MWR, 1992). It costs more at the margin but is under local control. In some places, mining leads to irreversible effects, e.g. when cones of depression lead to land consolidation or where

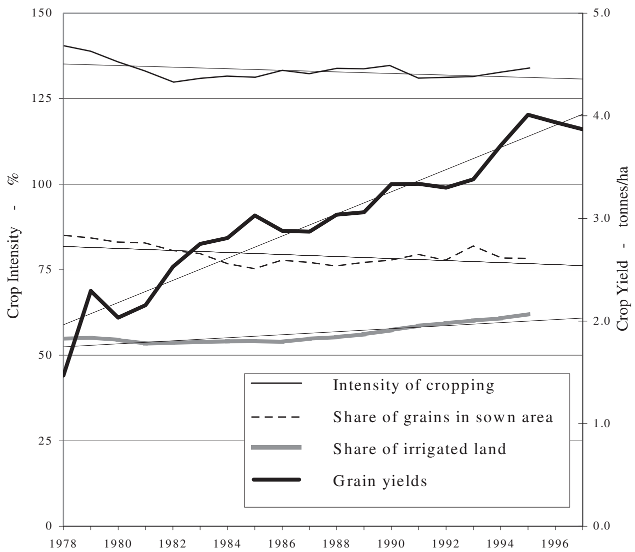
Table 9. GDP and agricultural trends: China and main provinces on 3-H plain.

	China	Beijing	Tianjin	Hebei	Henan	Shandong	Anhui	Jiangsu
GDP: 1978=100								
1978	100	100	100	100	100	100	100	100
1980	116	123	121	110	125	120	113	117
1985	194	191	189	178	218	210	219	218
1990	283	282	244	266	314	312	290	351
1995	489	493	426	525	578	677	560	769
1997	570	590	546	671	727	845	722	966
Primary Industry[a]*: 1978=100*								
1978	100	100	100	100	100	100	100	100
1980	109	101	117	100	106	120	108	109
1985	162	146	187	161	162	191	183	161
1990	204	210	303	194	214	229	210	196
1995	292	274	427	294	314	401	287	311
1997[b]	336	265	468	330	386	441	336	344
Grain[c]*—Sown Area: M ha*								
1978	120.6	0.6	0.6	7.9	9.1	8.8	6.2	6.3
1980	117.2	0.5	0.6	7.5	8.9	8.5	6.0	6.1
1985	108.8	0.5	0.5	6.5	9.0	8.0	5.9	6.4
1990	113.5	0.5	0.5	6.8	9.3	8.2	6.3	6.4
1995	110.1	0.4	0.4	6.8	8.8	8.1	5.9	5.8
1997	112.9	0.4	0.4	7.1	8.9	8.1	6.0	6.0
Grain[c]*—Production: M tonnes*								
1978	304.8	1.6	1.2	16.9	21.0	22.9	14.8	24.0
1980	320.6	1.9	1.4	15.2	21.5	23.8	14.5	24.2
1985	379.1	2.2	1.4	19.7	27.1	31.4	21.7	31.3
1990	446.2	2.6	1.9	22.8	33.0	35.7	25.2	32.6
1995	466.6	2.6	2.1	27.4	34.7	42.5	26.5	32.9
1997	494.2	2.4	2.1	27.5	38.9	38.5	28.0	35.6

a. Including agriculture, livestock, forestry and fisheries.
b. Assuming provincial agricultural price indices for the period 1995–7 equivalent to the national index.
c. Including soybeans and tubers.
Sources: SSB (1996, 1999).

salinity intrusion occurs. But over much of the plain watertables fall but remain accessible and are partially recharged in high rainfall years; water quality deteriorates but not everywhere all at once; and wells can be deepened. If pumping becomes too expensive, or groundwater too polluted, or well yields too low, then land at the margin reverts to rainfed farming, is abandoned or is lost to urban use. But this is a gradual process that is masked in the short term by stochastic rainfall patterns. Agricultural growth can persist over a surprisingly long time despite groundwater use that is ultimately unsustainable. The real issue is whether the country/region in question makes good use of the time provided to develop in other ways and the likelihood is that this is what is happening in North China.

Economic growth has also led to *degradation of the surface system*. However, this should be placed in context. No doubt the drying up of rivers, contraction of deltas and other wetlands, and water pollution all have costs that some consider very large (WB, 1997b). But developed countries only began to address such problems once they became rich. Life expectancy (71 years) is higher than for most



Source: SSB (1995, 1999)

Fig. 5 Crop intensities and yields: Hebei Province: 1978–97.

countries with a similar GDP per head and, although this is an inexact measure of environmental damage, it may indicate what is important to China's population at this stage of its development. And, while environmental costs must be accounted for (section 4), they do not preclude continued rapid economic and agricultural growth.

A somewhat different explanation lies in the view that China's statistics *over-state growth* (Rawski, 2001). Perhaps the growth in Table 9 is illusory. But, despite repeated warnings to the contrary (WB, 1997a; Brown 1998), China continues to be broadly self-sufficient in grains[6]. If output is over-stated, then calorie consumption per head is lower than commonly supposed based on food balances. Even so, food consumption is high for a country at China's income level (FAO, 2001). And though grain output in the Hai basin may have peaked and Beijing and Tianjin are in part dependant on grains from Manchuria, this pattern merely reflects comparative advantage, including the water endowment. All the signs are that water has yet to preclude agricultural growth, irrespective of whether this is exaggerated in Table 9.

3.3. Agricultural prospects

The WB report is remarkably pessimistic about the future (Table 10). For the period 2000–10, the WB report anticipates a decline in crop output of about 5% and stagnation in the value of agricultural output.

Table 10 implies a sharp break with recent trends. But how likely is this? Water scarcity is nothing new. Moreover, there is surprisingly little variation among the basins despite major differences in water

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[6] In 2001, after two years of drought, China still had a positive balance in its agricultural trade and remained a net exporter of all the major grains (Ministry of Agriculture, 2002).

endowments (Table 2). According to the WB report: ". . . agriculture will have to cope with decreasing or at best static water supply in the coming decades. This trend has already started . . . (even so) crop production has managed to increase or at least be maintained for most years . . . The reasons . . . are not entirely certain . . . because many variables . . . can influence productivity including (a) water, (b) fertilizers, (c) energy, (d) labor, (e) land, etc. . . . The present study has reviewed . . . (previous) studies on this issue . . . using a combined economic/hydrologic model to determine the impact of changes in water availability . . . it is evident that in the 3-H basins, *water is the single most important input factor to maintain productivity*" (emphasis added) (WB, 2001, Volume 2).

The critical importance attributed to water is consistent with views expressed, for example, by IWMI and IFPRI in other contexts: "In a growing number of countries and regions, water has become the single most important constraint to increased food production" (IWMI, 2000); and "Water will be the major constraint to achieve food security in many developing countries" (Rosegrant & Ringler, 2000). Yet water has yet to constrain agricultural growth in North China, despite acute water scarcity, so why should it suddenly become so decisive?

A more measured conclusion might be that, at worst, agricultural growth will slow, and at best will continue much as before. A lot depends on general performance since opportunities for high return diversification arise within the wider economy. So long as China develops rapidly, agricultural value-added on the 3-H plain will continue to rise. No doubt the structure of the rural economy, and the farmers who prosper, would differ greatly under a scenario where there was more water. But market economies are remarkably responsive institutions and can adjust to a wide range of conditions. Water stress is one factor amongst many to which adjustments must be made. Producer prices may, for instance, be significantly more important.

3.4. Grain prices

As in many other developing countries (Timmer, 1988), agriculture in China in the past was taxed via the procurement system with the essential aim of funding industrial and urban development. During the early reform period, producer prices were raised, reducing the extent of this tax. Subsequently, producer

Table 10. WB projections of crop production and agricultural values, 3-H basins.

	2000	2010	2020	2050
Crop Production[a]		Mtonnes		
Hai	39.2	36.8	35.8	34.9
Huang (Yellow)	26.7	24.7	24.2	23.7
Huai	56.5	55.3	54.7	34.9
Total	122.4	116.7	114.8	112.1
Value of agricultural production		'000 M Yuan		
95% probability	111.1	112.9	110.5	107.8
75% probability	120.1	123.0	121.3	119.2
50% probability	125.9	127.6	126.6	125.4
25% probability	129.3	131.2	130.5	129.7

a. After allowing for WTO effects. The impact of WTO accession is not thought to be great, being estimated as being equivalent to 2% of crop production in 2010 declining to 1.5% in 2050.

Source: WB (2001), Volume 2. Tables 6.4 and 6.7.

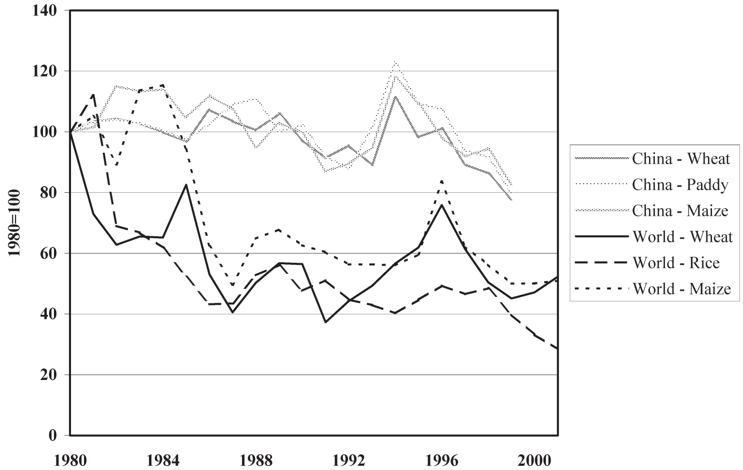

Fig. 6 World grain prices and China producer prices: 1980=100.
World grain prices have been converted to constant prices by the MUV index.
China producer prices have been converted to constant prices by the retail index.
Sources: WB (various commodity price series), FAO (2001), SSB (1999)

prices drifted down until they were again sharply raised in 1995/6 (retail prices rose even more to curtail fiscal costs (WB, 1997a)) (Fig. 6). This increase also proved temporary and by 1999 producer prices had again fallen to 20% *below* 1980 levels.

Producer prices in 1999 may have been 20% below their 1980 levels but over the same period (1980–99) world prices fell by 40–60%. So, while Chinese farmers received prices that were below the import equivalent level for most of this period (i.e. were taxed), for the first time in modern history domestic grain prices appear now to be *above* world prices (WB, 1997a; USDA, 2001). This cannot be maintained in the long term since WTO entry will open grain markets to foreign imports. Will world prices continue to fall? This is hotly debated (Mitchell *et al.*, 1997; Rosegrant & Ringlet, 2000). Falling prices have characterised world grain markets for decades, if not centuries. It is conceivable that Malthusian pressures will lead to a sharp break with the past (Brown, 1998), but most observers expect these pressures to be offset by technical change and farm subsidies in developed (and developing?) countries. Grain prices are therefore likely, at most, to rise modestly and will probably continue to fall.

With WTO entry foreclosing tariff and trade restriction options, China may thus have to live with low grain prices. This will lead to formidable political and financial problems if farm incomes are to be safeguarded[7]. Official policy aims to contain grain imports to less than 5% of domestic demand. This will be assisted by the fact that grains (and meat?) in urban areas have become inferior goods. Indeed, this may be emerging in rural areas (Table 11). According to USDA "following China's WTO accession, imports of wheat, soy beans, vegetable oils, and cotton are likely to rise. China's rice exports may rise while corn exports will likely fall . . . China's livestock sector is internationally competitive . . . but sanitary issues limit export opportunities" (USDA, 2001). This suggests that grain imports will remain small relative to

[7] China is not alone in facing these problems. India, for instance, is in a very similar situation. Indeed, comparable problems are faced in developed countries, which is why farm subsidies were introduced in the first place. What is new is that world prices may have fallen below the levels needed to safeguard farmers even in *low*-income countries.

output, presumably in line with China's underlying comparative advantage. It further suggests that grain imports are unlikely to be a serious economic issue unless economic growth itself stalls[8].

3.5. Rural income trends

Rural incomes in China rose between 1978–97 by more than urban incomes (Table 12). Many factors offset declining grain prices, including sequential market reforms, technical progress, input subsidies (e.g. for irrigation), agricultural diversification, village and township enterprises, and urban remittances. Even so, the ratio of urban to rural incomes remains high by world standards (WB, 1997b). Rural incomes in Henan and Anhui have fallen behind but in Shandong and Jiangsu they have risen relatively fast. Hebei may be atypical among 3-H provinces in its lack of water and northern location but, in terms of rural incomes, it is about average and the ratio of rural to urban incomes is relatively favourable (Table 12).

Table 11. Grain and meat consumption per head: All-China.

	Grain consumption: kg per head		Meat consumption: kg per head	
	Urban	Rural	Urban	Rural
1985	135	257	22	8
1990	131	257	25	13
1995	97	259	24	13
1997	89	251	24	15

Source: SSB (1999).

Table 12. Urban and rural incomes and expenditures: China and Hebei Province.

	Urban: Yuan at current prices			Rural: Yuan at current prices			Income: constant prices[a]: 1978 =100	
	Income	*Living expenditures*		*Income*	*Living Expenditures*			
	Average	Total	Food	Net	Total	Food	Urban	Rural
China								
1978	343	311	179	134	116	79	100	100
1980	478	412	235	191	162	100	129	132
1985	739	673	352	398	317	183	168	232
1990	1510	1279	694	686	585	344	212	246
1995	4283	3538	1766	1578	1310	768	351	331
1997	5160	4186	1943	2090	1617	890	395	410
Hebei as % of China average								
1978	87	88	89	85	82	80	n.a.	n.a.
1980	90	89	87	92	88	79	n.a.	n.a.
1985	93	90	86	97	94	81	n.a.	n.a.
1990	101	100	94	91	83	72	n.a.	n.a.
1995	94	92	85	106	84	81	n.a.	n.a.
1997	96	96	86	109	86	79	n.a.	n.a.

a. Deflated based on the national retail price index (the consumer price index is available only since 1985).
Sources: SSB (1996, 1999).

[8] In Allen's terminology, China might have to import some "virtual water" (Allen, 2001). But China is a huge country and even if agricultural growth slows on the 3-H plain due to water constraints, output should rise elsewhere where water is far less of an issue.

Not all farmers have benefited equally. Income growth has been rapid in irrigated areas and in the proximity of towns. A dichotomy has arisen not only between urban and rural incomes but also between a prosperous and expanding minority of commercial farmers and the majority who depend on grains. This dichotomy may become more pronounced as the commercial sector expands in response to market opportunities, and as traditional grain farmers are faced by low prices. Remittances and other non-farming activities are already more important than farming to many rural families and the World Bank anticipates that farm income will account for no more than 25% of rural incomes in Hebei by 2020 (WB, 2001). Even so, the fear that rising inequalities will lead to rural discontent helps explain much in public policy, notably continued economic reforms along with socio-political conservatism.

3.6. The impact of water scarcity

Cropping patterns, farm practices, holding and operating sizes, and work and migration patterns all shift and adapt as each farmer responds to his or her opportunities. This is why markets are so often successful in directing economic activity. Factor endowments, including water, set the scene but change is driven by prices, markets and relative incomes determined as much by what happens in the cities as in the countryside. If growth was stagnant with farmers locked into subsistence, water scarcity might prove as painful to the overall economy as to those directly affected. But with rapid urbanisation, diversification and growth, water scarcity is just one more factor to which the system must adapt.

Even so, the more acute the water constraint, the greater is its role in the rural adjustment process. Other things being equal, commercial farmers will commandeer scarce water if for no other reason than that they can afford to deepen wells and pay higher pumping costs. M&I demands are also likely to be satisfied at the expense of irrigation in locations where a choice can be made (section 2). Water scarcity will thus tend to fall on those least able to afford it—on smaller farmers growing grains in more isolated locations. This is inequitable but this is how markets work. Those that add least value per unit of water are the first to part with it, moving to other jobs (e.g. in cities), leaving water to those who can make more productive use of it.

Farmers do not, of course, explain their predicament in this way. For them, water is an ever-present preoccupation and for some it is decisive in driving them off their land. Moreover, they are aware of rising inequities both within the rural community and between cities and countryside. Along with low crop prices, this strengthens farmer grievances. The issue is not whether the rural transition can be avoided but the pace at which it occurs and the stresses to which rapid change gives rise. In this context, can the SNWTP help ensure that the rural transition is more manageable and more acceptable to the bulk of the population?

3.7. Irrigation: user of last resort

The most cost-effective use of SNWTP water will be the direct supply of M&I. But the above suggests that the *real* impact at the margin will be to preserve water for the farmer growing irrigated grains since, if the project is not built, cities and commercial farmers will secure their needs at his expense.

The irrigated area in the 3-H basins is some 30 Mha. This is shared about equally between surface and groundwater systems. The WB estimates that 71% can be fully irrigated in the mean year but only 51% in the 75% year (WB, 2001). In other words, large areas with irrigation infrastructure cannot secure requirements and large areas are effectively rainfed, especially in dry years. For the 75% year, shortage of irrigation water relative to demand is put at 24% (38% in the Hai basin) (Table 13).

"Demand" and "shortage" in this context are, however, ambiguous concepts since "shortage" is relative to a "demand" that is itself based on current cropping and water use efficiencies (WB, 2001). Since cropping and efficiency are themselves functions of water availability, the estimates of demand are in effect dependent on what farmers must accept under current conditions. In other words, the demand estimates are based on a circular argument. There is no reason to doubt that farmers would "demand" far more than is estimated by the WB if it could be made available. And, relative to this demand, the "shortage" would also be much greater.

A more conventional definition of demand is implied later: "usage of water is well below the demand curve and the use of water is dictated more by shortage management than price" (WB, 2001). On this definition, demand is what farmers *demand* at the prevailing marginal cost (price) of water. Since surface water is cheap (irrigation charges seldom cover much more than O&M costs), demand on this definition is far higher than in Table 13. If demand is limited to availability at a particular time, then prices would have to be far higher and also variable in response to rainfall, crop condition and other factors[9]. Yet, at any lower price, demand is essentially arbitrary and if "demand" is arbitrary then so is the resulting "shortage".

This dilemma can be clarified by adopting Elston's suggestion that irrigation on the 3-H plain is best regarded as "water user of last resort" (Elston, 1999). By this he means that irrigation can absorb all the residual water available after other needs are met. Exceptions occur when rainfall reduces demand or flood flows exceed storage and/or diversion capacity. But for most of the time irrigation capacity (greatly) exceeds the water available. There is thus no point in estimating irrigation demand since irrigation simply absorbs the balance of what is available after other needs are met. These needs include environmental demands since, unless action is taken to reserve water for the environment, irrigation can be expected to absorb any water going. Another way of putting it is that, if water is scarce and there is excess diversion capacity, irrigation replaces the environment as "user of last resort".

Table 13. WB estimates of irrigation water demand and supply and the status of the irrigated area: by basin for the 75% year and 2000 conditions.

	Hai	Huang	Huai	3-H basins
Irrigation water demand and supply	km^3			
Demands	36.5	43.3	54.4	134.2
Supplies	22.6	34.7	44.9	102.2
Shortage	13.9	8.6	9.5	32.0
% Shortage	*38%*	*20%*	*17%*	*24%*
% of effective irrigation area[a]	%			
Fully irrigated	15	60	73	51
Partially irrigated	70	26	20	38
Rainfed	15	14	7	11
Total	*100*	*100*	*100*	*100*

a. The land area with irrigation facilities (surface and/or groundwater) that can be irrigated if water is available.
Source: WB (2001), Volume 2, Table 3.6.

[9] Even where water is fully controlled and piped (e.g. in Israel) and volumetric pricing is feasible, irrigation is in practice subsidised and even in theory prices can only approximate to true marginal cost. Nowhere in the world does a water price balance supply and demand in the irrigation sector (Perry 2003).

If irrigation is “user of last resort”, irrigation is under stress most of the time[10] and scarcity (“shortage management”) rations irrigation use. Farmers respond to scarcity in real time. If water is scarce, they compete. If it is abundant, they relax. Recharge and return flows are re-used and non-beneficial losses are typically low. Farmers respond to pumping costs and other price signals but these reinforce rather than substitute for scarcity. Farmers also irrigate extensively (Table 13) rather than intensively since this tends to increase their returns. Each farmer has different resources, needs, capacities, constraints and opportunities. No doubt stress favours the powerful and can lead to head/tail inequity, over-abstraction and system damage. But in economic terms, water is used efficiently when in short supply (that is *when it has value*) and “shortage management” leads to solutions as good as can reasonably be expected. This is above all true at the basin level so that a preoccupation with on-farm rather than basin-wide losses can be very misleading.

Rational farmer responses to water stress help explain sustained agricultural growth. Not only is irrigation efficiency higher than generally thought *when it matters* but, as scarcity grows, water is focused on higher value crops and activities and the average return to water increases as low return crops are abandoned. But the farmer can only respond to *the water he receives*. Interventions in system management (whether in reservoir management, system-wide distribution, groundwater regulation, or pricing of water, pumps and/or energy) may therefore well have much greater potential than investment subsidies on-farm. This also has important implications for the evaluation of the SNWTP to which the discussion now returns.

4. Implications for the SNWTP

4.1. Introduction

The economic analyses reviewed in section 2 focus on costs and benefits of the project and neither presents a detailed vision of the “without” case. It is nonetheless clear that the WB’s view is that the “without” case would involve unacceptable water shortages, while the WWF’s view is that it would provide a context for successfully addressing water management and environmental issues without the distraction and huge costs of the SNWTP.

Neither of these views is fully convincing, not merely because of the doubts thrown on the analytical content of the two reports but also, more importantly, because a project with the strategic characteristics of the SNWTP cannot be considered in isolation from the broader regional and national context. Section 3 reviewed this context, concluding that, though economic and agricultural growth could be maintained without additional water from the SNWTP, they would be associated with aggravated socio-political and

[10] Stress is due not just to scarcity and excess infrastructure but is inherent in surface system design. M&I systems typically meet limited high value and fairly constant daily demands but surface irrigation must respond to very variable demands and supplies. Intermittent stress is therefore in-built since otherwise costs would be prohibitive and/or irrigated areas would be unnecessarily restricted. Irrigation infrastructure, for instance, may be sized for a design cropping pattern three years in four with dry season intensity well below 100%. But *ex ante* design mean little *ex post* to the farmer who would like to expand his cropped area even in a dry year and even in the dry season. Groundwater can approach irrigation on-demand since the marginal costs of sizing infrastructure are low. But, even for groundwater, full irrigation is not always possible (e.g. for large tubewells or if aquifer yields decline or if demand rises in a drought). On the 3-H plain, design stress is accentuated by regional water scarcity and over-development of the irrigation infrastructure.

environmental problems. These could be greatly ameliorated by the project. This final section considers more directly the trade-offs between the different objectives (economic, environmental, social) in the hope this can throw some light on whether or not the project should be implemented.

4.2. Economic issues

Available supplies easily exceed M&I demands (Tables 1 and 2) and reallocation from irrigation could, in theory, cover all future M&I needs at the required degree of security. If so, it is irrigation values at the margin that should determine SNWTP benefits. Only if reallocation is physically difficult or too expensive (e.g. for cities below the Taihang Mountains) should economic returns be weighted to reflect the value of water in M&I uses. Meeting M&I demands from the SNWTP (if it is built) will still of course often be cheaper and easier than reallocation, in which case any marginal cost savings should be fully accounted for.

Figures 7 and 8 show in general terms how SNWTP costs and benefits vary with unit water value and discount rate. Capital costs are based on recent reports (WWF, 2001; US Embassy, 2001) and are arbitrarily phased over seven years for the Middle Route and six years for the Eastern Route (see notes to the figures). For the Middle Route, accessory costs are fully attributable to the project. For the Eastern Route two cases are shown that include 100% and 50% of accessory costs, respectively. O&M costs for the Middle Route are 0.06 Yuan/m^3. They are higher for the Eastern Route because of pumping, and are put at 0.18 Yuan/m^3 to the Shandong border, rising to 0.38 Yuan/m^3 to Tianjin (WWF, 2001). Benefits are net of O&M costs.

On this basis, the value of SNWTP water before allowing for O&M costs would need to be perhaps 0.9 Yuan/m^3 for the Middle Route to be economically justified at a discount rate of 12%, and about 0.7 Yuan/m^3 to the Shandong Border for the Eastern Route (allowing for 50% accessory costs) or 0.9 Yuan/m^3 in Tianjin. If the marginal value of water for the mean (50%) year is 2.16 Yuan/m^3 (Table 5),

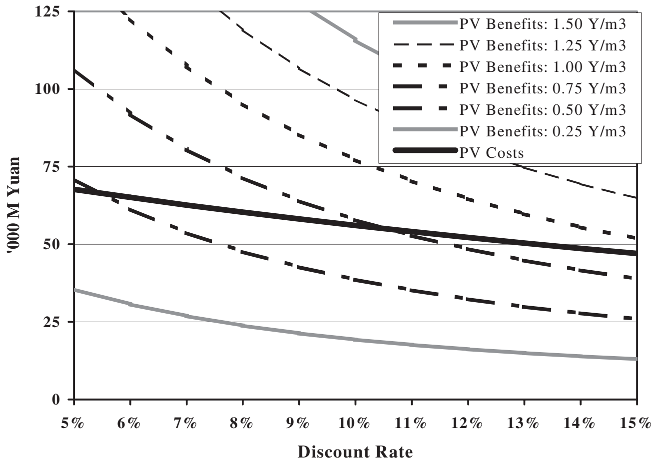

Fig. 7 SNWTP Middle Route: Present value (PV) of costs and benefits.
Costs for the Middle Route are capital costs, phased over seven years according in the following assumed ratios:
Year 1: 5% Year 2: 10% Year 3: 20% Year 4: 20% Year 5: 20% Year 6: 15% Year 7: 10%
Net benefits are less O&M costs.
Sources: Based loosely on estimates in WB (2001), WWF (2001) and US Embassy (2001).

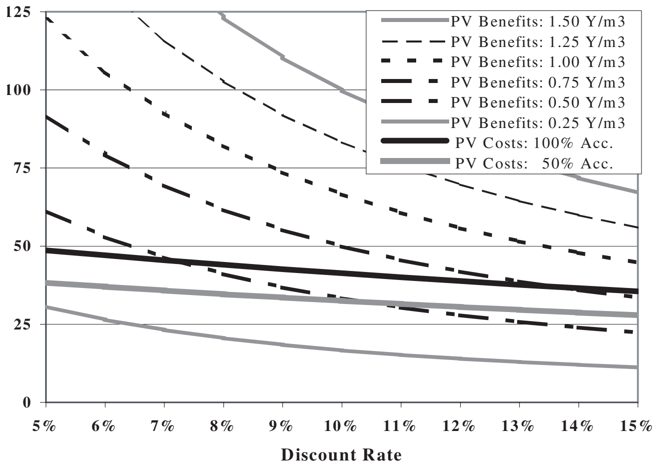

Fig. 8 SNWTP Eastern Route: Present value (PV) of costs and benefits.
Costs for the Eastern Route are capital costs. Two estimates are illustrated respectively including 100% of accessory costs and 50% of accessory costs. They are phased over six years according in the following assumed ratios:
Year 1: 10% Year 2: 15% Year 3: 20% Year 4: 20% Year 5: 20% Year 6: 15%
Net benefits are less O&M costs.
Sources: Based loosely on estimates in WB (2001), WWF (2001) and US Embassy (2001).

then both routes are economically attractive, even at a 15% discount rate (the WB's conclusion). If the marginal value is 1.25 Yuan/m^3 (the estimate for wheat, Table 6), then both routes still appear justified at 12%. But if the value is 0.3–0.4 Yuan/m^3 (the average value for irrigation water from the WWF) then both routes fall short of what is needed to justify the project even at a 5% discount rate (WWF's conclusion).

Section 3 suggested that the project's main impact would be to preserve low return agriculture. If so, additional water would presumably have a value below 0.8 Yuan/ m^3 in the case of the WB's estimates (Table 5) and below 0.3–0.4 Yuan/m^3 in the case of the WWF's estimates. Since there is also a downside risk to grain prices and cost overruns and implementation delays are typical of large construction projects (as pointed out by WWF), it might be concluded that the project falls short in economic terms. On the other hand, marginal values exceed average values and unit benefits may be higher than estimated by WWF if water use is more efficient than supposed.

The truth is that it is impossible to reach firm conclusions on the basis of the information and analyses reviewed in this paper. The uncertainties are just too great. All that can be said is that, even if the marginal value of water were no higher than, say, 0.4–0.5 Yuan/m^3, the economic benefits would still be very large, even if they failed to fully cover costs. Moreover, despite the risk of delays and cost overruns, China has demonstrated the capacity to construct massive projects (e.g. Three Gorges) whereas river basin and environmental management have proven to be far more intractable. Moreover, at least in the Government's view, social unrest is potentially the most serious threat of all.

4.3. Environmental issues

If irrigation tends to replace the environment as "user of last resort", action must be taken if the environment is to be safeguarded. Failure to do so leads to the drying up of rivers, rising pollution, the contraction of wetlands and non-sustainable groundwater use. These effects are inter-connected; for instance falling watertables establish a hydraulic gradient that drains rivers and wetlands[11].

Reserving water for the environment is, however, fraught with difficulty. Farmers and irrigation staff are very reluctant to let water pass by when water has value. Moreover, as scarcity intensifies, groundwater becomes ever more attractive as it is under local control and additional to, and more valuable than, cheap but increasingly scarce and unreliable surface water. Over time "the tragedy of the commons" leads to falling extractions due to well interference, falling watertables, dwindling yields and rising pumping costs. But regulating extractions is extraordinarily difficult given well numbers, measurement difficulties and the strength of farmer interests. Pumping costs offer a mechanism for self-regulation but cannot account for full externality costs. Irrespective of how serious they are, however, the SNWTP *must* have substantial environmental benefits[12].

In principle, water managers could maintain minimum flows and environmental allocations by adopting appropriate reservoir, diversion and groundwater regulation policies and practices. Releases for aesthetic and pollution management purposes are sometimes made, for instance to the capital city. Silt is another critical issue for the Yellow River and some Hai tributaries. Xiaolangdi Dam, for instance, had silt management as a main objective both with a view to silt retention to limit deposition in the lower river, and in terms of the management of water and silt flows in the lower river itself (incidentally with mixed impacts on the delta).

Nevertheless, environmental releases are the exception and this is understandable. It takes a great act of will to control diversions, and regulatory and management capacity is inevitably limited given the vast areas involved. In contrast, official control over the water transfer system would make choices in favour of the environment much easier. Impacts in the Han basin—both positive and negative—also need to be weighed in the balance (section 2) and ecologists also raise the issue of species migration and other risks when water is transferred between watersheds. Nevertheless, given the scale of environmental degradation in the Hai and Huai basins, and the vast resources of the Yangtse, it is hard to believe that the overall environmental case in favour of the SNWTP is not strongly positive.

4.4. Socio-political issues

Under its WTO commitments, China will increasingly forego the option of adjusting producer prices to protect the farmer. If domestic prices are above world prices, then—subject to transitional arrangements—producer prices will need to be adjusted downwards at the expense of farm incomes. And if world prices continue to fall then, other things being equal, incomes of grain farmers will also continue to fall. Income differentials within rural communities and between urban and rural areas would increase further. Numerous other factors may offset or balance these effects, not least the impact of urban remittances and structural change. Nevertheless, low grain prices will tend to impact on the most vulnerable farmers, and could put substantial pressure on the social fabric.

There are, of course, numerous ways other than formal trade protection for managing rural adjustment. A targeted social security system is one approach. But creating such a system would be a

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[11] Baiyangdian Lake in Hebei is an important and representative example. According to a press release: "Northern China's largest lake doomed to dry out early next year due to drought and reckless water use by factories and farmers" (Reuters, 2000).

[12] It is very hard to understand why WWF suggest the contrary (section 3) though it is true that the SNWTP may divert funds from pollution control and to this extent WWF has a weak case.

formidable administrative and financial task, one that much richer countries have found challenging. No doubt other subsidy solutions could be considered but why should the 3-H plain have priority in the use of public social funds? Poverty in the interior is a far more serious and compelling issue.

In itself, the SNWTP would not resolve the problems associated with depressed farm incomes and structural change. But it would help buy time and make these issues more manageable—fewer farmers would be driven off the land, rural communities could be more readily preserved, conflicts would be moderated and rural adjustment would be generally eased and slowed. The project would also contribute to national food security and, given the difficulties of compensating those who lose quasi-property rights in water, it could have equity benefits. Finally, though massive in scale, the SNWTP is a fairly straightforward construction project and easier to implement than more intractable management and regulatory measures. This alone may be a powerful argument that supports the project.

Social benefits in the 3-H basins need to be set against any adverse impacts in the Han basin, notably the large resettlement programme. Resettlement is a massive and controversial task that has denied international funding for many dams worldwide. Nevertheless, China's record is reputedly fairly good[13]. Provided oustees are as well—or better—off as a result of resettlement, this at least partially offsets the trauma of losing their homes. And countries in the developed as much as the developing world have required comparable sacrifices in the interests of the public good.

5. Conclusion

The SNWTP is a costly and ambitious project. This paper argues that a convincing case has yet to be made in English that its direct economic benefits—though undoubtedly substantial—would in themselves justify the direct costs. The paper has, however, developed environmental, social and pragmatic arguments that greatly strengthen the case for the project. The "without" situation would inevitably be associated with the further deterioration of an already degraded environment and lead to the further acceleration of an already rapid rural transition. Few countries are equipped with the regulatory authority, management ability and political will needed to address such issues satisfactorily. And, though China has shown considerable economic management capability, the environmental and social pressures building in North China are in many ways unprecedented. A decision on trade-offs between these various arguments must, of course, ultimately be left to those who are accountable. While no firm conclusions can be reached on whether or not the project is justified based on the information and analyses reviewed in this paper, the Government's decision to proceed is fully understandable.

Acronyms and abbreviations

3-H basins - Hai, Huang (Yellow) and Huai basins of North China
GDP - Gross Domestic Product
GOC - Government of China

[13] Experience in the early years of modern China was poor, for instance at San Men Xia Dam built in the 1960s with USSR assistance. Recognising these problems, the Government sought a separate WB Resettlement Loan for Xiaolangdi Dam, which was implemented satisfactorily. On the other hand, reports on Three Gorges have been mixed.

FAO - Food and Agriculture Organisation
FHF - Forestry, Husbandry and Fisheries
ICID - International Commission for Irrigation and Drainage
IFPRI - International Food Policy Research Institute
IWHR - Institute of Water and Hydroelectric Research
IWMI - International Water Management Institute
IRR - Internal Rate of Return
m - metre
M - Million
M&I - Municipal and Industrial
mu - Chinese measurement of area (15 mu = 1 ha)
MWR - Ministry of Water Resources
O&M - Operation and Maintenance
PRC - People's Republic of China
RCNCWR - Research Center of North China Water Resources
SNWTP - South-North Water Transfer Project
SSB - State Statistical Bureau
UNDP - United Nations Development Programme
USDA - United States Department of Agriculture
WB - World Bank
WWC - World Water Council
WWF - World Wildlife Fund (now Worldwide Fund For Nature)
WRI - World Resources Institute
WTO - World Trade Organisation
Yuan - Chinese currency (8.3 Yuan = US$1 in 2001)

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