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Water

This is a companion volume to our previous issue – Water-I. The two together highlight the many interconnected facets of water – a vital element for the sustenance and development of human resources and for economic growth.

Coleridge's Ancient Mariner was prophetic when he bemoaned, "Water, water, everywhere, nor any drop to drink". Three-quarters of the globe is constituted of water. Yet, the human being, himself more than three-quarters water, is dependent on nature's cycle of precipitation available only by way of surface and ground water. This cycle, though within finite bounds, is theoretically, renewable. But nature itself is unpredictable and random in the distribution of this bounty. Much of it flows back to the sea. Added to this, our propensity to take this resource for granted and pollute and waste it is leading us to the brink of serious water scarcity in the face of a burgeoning population. The two issues of The Asian Journal have been brought out in the background of a water scarcity looming large over the most populous developing countries of this region in the Asian continent.

D. K. Chadha, Chairman of the Central Groundwater Board cautions that unless effective steps are taken to augment the supply of ground water through artificial recharging by harnessing the monsoon surpluses, water scarcity has to be faced sooner than later. Anil Agarwal and Dr. Kelkar dwelt on this theme in the previous issue. Prof. Hashim, who was the Chairman of the National Commission for Integrated Water Resources Development Plan, points out that the fragile balance between the availability and requirement of water and the critical bond between water and food security, in the coming decades, can only be maintained with efficient water usage. He also suggests the possibility of investing abroad in agriculture. Surinder Sud also underlines the need for a shift to non-food crops, particularly in the post-WTO regime, but emphasizes that sustainable exploitation of water for agriculture requires a judicious blend of technological upgradation with our vast traditional wisdom in this field.

R. Jhamtani deals extensively with the problem of water pollution and feels that use of market-based economic instruments and fiscal policies might be more effective than mere legislation. Chetan Vaidya also stresses the need for a shift from emphasis on improving bulk supply of water in the urban sector, to that of private sector participation in water and sanitation services – a shift which, he feels, will lead to more effective curbs on inefficient and wasteful usage of water in the urban sector.

But both of them, like T.C.A. Srinivasa-Raghavan who in the previous issue dwelt at length on the potential for development of a formal market for water in India, mention the precondition of a regulatory framework and institutional support for such a shift to be really effective. Perhaps for all utilities which have a 'public good' character, it is not enough to get the price right and leave the rest to the market, specially for a country with vast numbers of poor people. Hence comes the role of the State. Dr. Rita Sharma sees this role as that of an enabler and facilitator which could set in motion a negotiating process between environmental and equity problems leading to an ultimate solution. She feels the answer lies in turning the water-users themselves into water managers by bringing together all groups at the level of watersheds concerned with land and water use, to discuss the mutually sort out their conflicting demands.

If sharing of a common resource is achievable at the local level through an interactive process, it ought to be feasible at higher levels of regional and national boundaries as well. Dr. Rajiv Gupta analyses the regional water transfer issue in the case of Sardar Sarovar Project and sees it as a model of participative development, continuously improving with inputs from the anti and pro-project forces, harmonizing the human rights of those affected by the project with the human rights of those benefited by the project. We are also familiar with the long-standing triangular dispute on water-sharing in southern India. In the previous issue of this Journal, Ramaswamy Iyer had dealt with this problem in some detail and also disabused us of over-reliance on large technology-driven, supply side projects. For example, the harnessing of the water resources of the Ganga-Brahmaputra-Meghna basin entails a number of big projects, the consequences of which are not fully predictable. He also pointed out that measures of the kind called for investments of a magnitude which was indeed hard to come by in the public sector. On the other hand, private sector investment, if forthcoming, was likely to be marginal at best. He, like Dr. Rita Sharma, had put more faith in local initiative and solutions arrived at by local communities.

Nevertheless, considering the fact that international river basins account for a major share of water resources on earth, management of these resources has to be on the agenda of the nations of the region. In the previous issue William Cosgrove discussed this in the context of the World Water Vision exercise and pleaded for making 'water everybody's business' while R. Rangachari analysed this aspect in the Indian context. In the current issue, Dr. Le Huu Ti discusses the Mekong River Commission's study as an example of regional integration of water resource management.

In the previous issue, Dr. Dov Sitton spoke of the Israeli experience in the development of water resources. This issue contains two articles on the Chinese experience. Dr. A Vaidyanathan notices in the Chinese experience a commonality with India by way of over-exploitation of both surface and ground water and its consequences. There is also a heightened interest in the construction of large reservoirs as a source of hydroelectric power and also for flood control. He, therefore, advocates continuing interchange of knowledge and experience between the two countries. Like many other writers, he also feels that our problems cannot be solved by engineering along; they call for specific policies and institutions. Rusong Wang and Zhiyuan Ouyang analyse the water scenario in China in detail and conclude : "The word 'Crisis' (Wei Ji) has both the meaning of risk (Wei) and opportunity (Ji)". Having a long tradition of sustainable water management and human ecological philosophy, in China the water vision has both optimistic and pessimistic perspectives… the key is technological innovation, institutional reform, lifestyle change, water diversion, ecological engineering and intelligent governance. Facing this challenge, China is standing on the crossroads towards either a miserable or a prosperous future with the water-related fortune in its own hands".

A common concern runs through all these expert writings, for public awareness, and for policies and institutions underpinning the reforms needed for optimal development and use of water resources. Surinder Sud points out that the National Water Policy of 1987, drafted with the aim of ensuring sustainable use of water, failed to serve the desired purpose as it was not backed by suitable regulatory and other measures. Our purpose in bringing out these special issues, as mentioned by K. L. Thapar in his Introduction to the previous issue, is to trigger an informed debate on the subject and to see some action initiated soon. The urgency for action is all the more pronounced as a severe drought is predicted in some districts of Rajasthan, Gujarat, Madhya Pradesh, Chattisgarh and Orissa for the third consecutive year.

We would once again like to reiterate that water as a crucial element for the development of human resources and for economic development deserves to be treated as an infrastructure like transport, communications and energy.

Hiten Bhaya

FROM FOOD SECURITY TO WATER SECURITY

Dr. S. R. Hashim*

FOOD SECURITY FOR A GROWING POPULATION

One of the most serious concerns of India over the last fifty years after Independence, has been to ensure food security for a growing population. It has also been one of the most significant successes of development planning in India that a reasonable degree of food security has been achieved. The seriousness of the concerns about food security as well as the significance of achievements in this sphere should be judged in the backdrop of conditions prevailing over almost a century prior to Independence in 1947. Food production had been constantly declining over this period due to the British policy of extraction from the agricultural sector through forced cultivation of indigo and opium. Shortage of food led to enhanced impact of epidemics and frequent famines in which millions perished. During 1911 and 1921, even the absolute population declined. Per capita availability of food was constantly declining over the first half of the 20th century. After Independence, there was a sudden spurt in the growth of population due to effective control of epidemics, improved health measures and a more serious effort at meeting food requirements. However, famines could be eliminated only after the sixties. The last severe famine occurred during the years 1965 and 1966. There have been years of deficient food production and shortages even after sixties – the last such year being 1987-88. But the situation could be managed with the help of buffer stocks and some imports, and the presence of a wide network of public distribution system which has played a crucial role in alleviating the situation in years of shortages.

Production of foodgrains increased from 53 million tonnes in 1951 to over 205 million tonnes at the end of the century. The basic element of the Indian food security system has been the achievement of self-sufficiency in production of food grains. Production increases have been achieved by technological breakthroughs in seed varieties and cultural practices, expansion of irrigated agriculture, intensive use of chemical inputs and a support price system to ensure to the farmers a stable income with steady growth. This strategy has produced desirable results.

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Other elements of the food security system are buffer-stocking, public distribution system combined with open market operations from time to time, and special programmes for poverty alleviation to enable the poor to buy food. Though poverty, as it is understood today in India, has not yet been reduced to levels with which one could feel comfortable, the strategy has succeeded in eradicating acute hunger in most of the country.

The strategy of self-sufficiency in foodgrain production was a well-thought out one. Food production has been the predominant means of livelihood for a large section of peasant cultivators and agricultural labourers. Agricultural growth in general and growth in foodgrain production in particular has been an important factor in eradicating poverty and ensuring food security. On the supply side, the world foodgrain market is narrow in comparison with India's domestic production and demand. The size of international rice market was about 12-13 million tonnes and that of the international wheat market was about 110-120 million tonnes in 1997 when India's total foodgrain production was 195 million tonnes. In this situation, India's entry in the world market with a demand even of 10-15 per cent of its requirements could heat up the market to intolerable limits. There was also a strategic consideration : given the political environment of cold war days, 'food' had all the potentials of being used as a strategic weapon.

However, the system of food security has consumed large amounts of budgetary resources as subsidies. Food subsidy was Rs.662 crore in 1980-81, and it increased to Rs.6,000 crore by 1996-87 (0.5% of GDP). A significant proportion of food subsidy represents the cost of carrying buffer stocks, which, in recent years, has been about 25% of the food subsidy.

TURNAROUND IN DEVELOPMENT PARADIGMS

The turn of the last century truly marks the end of an epoch in the history of Indian economic development. Having lurched around a path of growth of around 3.5 per cent per annum for more than three decades, the country is now on a steadier path of growth of around 6.5 per cent per annum. The agricultural sector which used to experience the most volatile fluctuations in production, has stabilised to a considerable extent, thanks to irrigation development, activity diversifications and regional spread. Increased production in agriculture is largely due to productivity gains. The industrial and services sectors have become more vibrant. Foreign direct investments have started flowing in. But what is more important and also to a large extent responsible for a better growth environment is that there has been a radical change in the philosophy of development itself.

The country has taken up economic reforms, privatisation and market liberalisation with steadiness and determination. There is a change in the world economic environment towards more openness and integration, and India has shown determination to take advantage of the global opportunities which this process of globalisation has thrown up. Information technology has linked up nations, business corporations and even individuals with each other all over the world, and India has shown its prowess to be in the forefront of this new information revolution.

In the wake of these developments, it is natural to have a re-think about each element of the past development paradigms. The system of food security has also been extensively debated in recent years. While the need for food security has not been questioned, the method of managing our food security system has come under scrutiny. There has been a plea for liberalising trade not only in foodgrains, but also in all other agricultural commodities. A view is held that the virtually closed nature of Indian agricultural trade on both export and import sides, has led to high protection for oilseeds and sugar subsectors, and taxation of foodgrains and cotton. On the import side, it is said that opening up of India's agriculture to more competition would result in important efficiency gains for all crops and improve incentives to producers of foodgrains and cotton. In order to insulate the food security system from the vagaries of the market, the open trade system has, however, to be backed up by futures trading and a strong and efficient bufferstocking system.

We do not intend, here, to go into the merits of the debate on the open trading system in terms of implicit 'protection and taxation'. Rather we intend to examine one particular aspect of the implications of the present food security system based on 'self-sufficiency' in foodgrain production, that is, its implications for water requirements. This we do in the perspective of the next fifty years. We believe that with growing population, even after taking into account all the possible deceleration in the rate of its growth, water will be the most scarce resource over the next fifty years, and even after. Energy is already a scarce resource, but energy is still tradable at affordable prices, and one could intensify efforts to find alternative economic sources of energy. Situations might arise in which water scarcity could pose more intractable problems for human and eco-environmental health.

Energy has been traded in open markets for a long time, and hence energy pricing already reflects to a considerable extent its scarcity value. To the extent distortions still exist in the pricing of some forms of energy or for some uses due to excessive subsidisation, the governments have become acutely conscious of such distortions in the wake of rising prices of energy and are hastening to correct these. As such, there is hope that price will make efficient allocation of this scarce resource in different uses, while at the same time inducing researches to find cost-effective alternatives. Water has not been generally traded in open markets. Water markets, where they have existed, have dealt with only a small part of the total use of water. Government systems have been largely responsible for supplying water for domestic and agricultural uses at prices, which far from reflecting the scarcity value, do not even reflect the operational costs of water supply, leave alone the huge investments which are made in creating systems for harnessing water. Rationalisation of water prices can only go upto an extent, and not beyond. However rational a pricing system is evolved, it will never reflect the scarcity value of water. Therefore, price of water could never become an effective tool for regulating water use and allocating water rationally (from economic/scarcity point of view) among alternative uses. Therefore, there is the need to evolve a detailed perspective on water availability, water needs, and allocations of water among different uses.

NATIONAL COMMISSION ON WATER RESOURCE DEVELOPMENT

The National Commission for Integrated Water Resources Development Plan was constituted by the Government of India in September, 1996 to take an overall view of the nation's water resources vis-a-vis the nation's requirements for water, and to prepare a comprehensive and integrated plan for conservation, development and augmentation of these resources to meet the needs for drinking water, water for agricultural and industrial uses, water for protection of environment, etc., taking into account the possibilities of inter-basin transfers and keeping in view all the related issues, like floods, water institutions, water laws, water economics and related international issues. While there have been commissions on agriculture, irrigation and floods earlier, this was the first national commission on water resources. The Commission submitted its report under the title 'Integrated Water Resource Development - a Plan for Action' in September, 1999.

The main task before the Commission was to assess the growing needs of water over time, as also its availability, with the possibilities of augmenting it through a variety of measures, while at the same time taking care of environmental concerns. While doing this the Commission kept a perspective of fifty years in view. Fifty years is also the period over which the Indian population is expected to be growing even with all the possible measures of population control. India will have its largest population around the year 2050, after which the population is expected to stabilise. Needless to say, that all the requirements for water arise from direct or indirect needs of human beings, and therefore, population is the most important factor in assessing the water requirements.

POPULATION PERSPECTIVE OVER THE NEXT FIFTY YEARS

After considering various population projections available (i.e., those of United Nations, Registrar General of India, Visaria & Visaria, etc., in particular), the Commission adopted the projections given by Visaria and Visaria to represent the higher variant of growth and the lower variant of UN projections to represent the lower variant of growth. The low variant of UN projections starts with estimates of population for the base year 2000 higher than Visaria & Visaria's projection. Visarias projected a population of 995 million for the year 2000, while the UN lower variant projected it to be 1013 million. Today, the generally accepted estimate for the year 2000 is about 1000 million. Other variants of UN start with even higher base level estimates for the year 2000, like 1022 million for the middle variant and 1030 million for the high variant. Instead of dealing with too many variants of population estimates, for the limited purposes of this article, we would rather deal with a single variant, which also appears to be a more plausible variant and that is Visaria's variant. The population projections are presented in Table 1.

Table 1 : Population Projections

(million)

	2010	2025	2050
Rural	759	730	610
Urban	387	603	971
Total	1146	1333	1581

WATER REQUIREMENTS FOR FOOD AND AGRICULTURE

It is estimated that the total withdrawal/use of water in the country, for all purposes, in the year 1990, was 552 km^3, which comes to about 655 m^3 per person. Irrigation accounted for nearly 83% of the total use. Drinking water and municipal uses accounted for 4.5 per cent, and industrial development including energy development accounted for 6.5 per cent of the total. The remaining six per cent was used for other purposes. Agriculture has been the largest consumer of water, and within agriculture, food production, particularly foodgrain production claims the largest share in water use. Even though, the share of agriculture in GDP has been declining over the years, and will decline further in future, the intensity of agricultural activity has grown and is likely to continue to grow. Agriculture has been the source of employment and income for nearly two-third of the Indian population, and will continue to support a large section of the Indian population even with increasing pace of urbanisation and diversification of employment opportunities. Food security based on self-sufficiency in food production has been the national policy.

An assessment, therefore, of the future requirements has primarily to take into account the future needs of agriculture and food production. It is also important to examine the 'water requirement' implications of the self-sufficiency paradigm in this context.

Various available models of food demand projections have been considered. These models generally take into account income and environmental (urban-rural)responses to food demand, given the basic tendencies and habits of population in the matter of food consumption, and also checking the minimum requirements against well-considered nutritional norms. Needless to say, that the absolute population and its growth is the most important factor in projecting the total food requirement. Though projections are generally in terms of the requirements of foodgrains, to the extent there is a possibility of foodgrains being substituted by other foods in the distant future, the foodgrains can be treated as a surrogate for that diversified food basket. The essential purpose of this exercise, after all, is the projection of water requirements.

The estimates of the required foodgrain production in the country are set out in Table 2, which also gives the estimates of the break-up of the foodgrain production from irrigated and unirrigated land.

Table 2 : Projections of Foodgrain Production

	Years			
	1993-94	**2010**	**2025**	**2050**
Foodgrain productivity from irrigated land (tonne/ha)	2.30	3.00	3.40	4.00
Foodgrain productivity from unirrigated land (tonne/ha)	1.00	1.10	1.25	1.50
Total Production from irrigated land (mn tonnes)	118	166	234	409
Total production from unirrigated land (mn tonnes)	80	83	88	85
Total foodgrain production (mn tonnes)	198	249	322	494

It would be seen that from the base of 198 million tonnes in 1993-94 (or about 205 million tonnes now) foodgrain production will have to increase to 494 million tonnes in the year 2050, i.e., nearly two-and-a-half times of the existing production levels. This increase will have to come from productivity gains both in irrigated and unirrigated agriculture, but the reliance will be more on irrigated agriculture. Almost the entire additional production will have to come from irrigated agriculture alone.

The net cultivated area in India has remained constant at around 143 million hectares for a long time. It could at the most be stretched to 145 mha given the growing non-agricultural demand for land. However, the intensity of cultivation (through multiple cropping), which was 131 in 1993-94, is projected to increase to 160 in the year 2050. Cropping intensity, in a way, is an indication of the real pressure on land, and an intensity of 160 is very high. Cropping intensity of this magnitude would require very high doses of chemical and other inputs, besides water. Traditionally about 70% of irrigated and 66% of unirrigated cultivated area has been devoted to foodgrain production. These proportions are projected to remain the same. The percentage of irrigated to gross cropped area would increase from 36 in 1993-94 to 63 in 2050. These projections are summarised in Table 3.

Table 3 : Projections of Land Use Parameters

	1993-94	2010	2025	2050
Net cultivable area (mha)	142	143	144	145
Cropping intensity (%)	131	135	142	160
Gross cropped area (mha)	186	193	204	232
Ratio of irrigated to gross cropped area(%)	36	41	48	63

For the purpose of estimating water requirements for irrigation, separate estimates have to be made for surface and ground water irrigation, as the extent of each of these would depend on the nature of sources of water and their development in different areas/regions. Also, the parameters (depth or delta and efficiency of irrigation) are different for the two sources. The depth of irrigation requirement, or delta is the water required (per ha) at canal source head, and it depends on requirements of different crops, climatic conditions, soil quality and the efficiency of water conveyance. More the conveyance losses, lower is the efficiency. Needless to say, that at national level, only a broad average in respect of these parameters could be considered, while in reality the parameters are very much location-specific. These parameters, along with the water requirement for irrigation, are shown in Table 4.

Table 4 : Water Requirements for Agriculture

	2010	2025	2050
Irrigated area from surface water (mha)	37.2	50.1	75.9
Irrigated area from ground water (mha)	41.9	48.1	70.3
Assumed delta for surface water*	0.91	0.73	0.61
Assumed delta for ground water*	0.52	0.51	0.49
Surface water required for irrigation (km^3)	339	366	463
Ground water required for irrigation (km^3)	218	245	344
Total water required for irrigation (km^3)	557	611	807

* Delta decreases as the irrigation efficiency improves.

What is to be particularly noted is that our estimates are based on the assumption of a very high level of efficiency in future, i.e., from about 36% efficiency in 1993-94 to 60% efficiency in the year 2050. Achieving such a high level of efficiency would demand strict volumetric control on water released for irrigation; acceptance of an assumed cropping pattern and cropping intensity; high level of water management skills at the field level; and investments in canals, field channels and various other irrigation devices like pipes, drips and sprinklers.

In the year 1990, about 458 km^3 water was used for irrigation, which increased to about 524 km^3 in 1997-98. The requirement will grow by more than 50% by the year 2050, i.e., to 807 km^3, subject to the realisation of all the assumed efficiencies.

OTHER REQUIREMENTS OF WATER

Given the uneven distribution of water sources, the per capita water availability for domestic uses varies between 50 lpcd (litre per capita per day) to 800 lpcd in different areas/regions. After considering the various norms and recommendations in this respect, the Commission adopted the goal of supplying 220 lpcd in urban areas and 150 lpcd in rural areas for domestic uses by the year 2050, in a phased manner. The total water requirements for domestic and municipal uses are estimated to be 43 km^3 in 2010, 62 km^3 in 2025 and 111 km^3 in 2050. As per projections, 70 per cent of urban water supply and 30 per cent of rural water supply would be met from surface water sources, and the balance from ground water sources. In addition, 4.8 km^3, 5.2 km^3 and 5.9 km^3 of water for the years 2010, 2025 and 2050, respectively, would be needed for the bovine population.

Water requirements for industrial uses are estimated to be 37 km^3, 67 km^3 and 81 km^3 in the years 2010, 2025 and 2050, respectively. The requirement of 81 km^3 in the year 2050 has been worked out on the assumption of significant breakthrough in the adoption of water-saving technologies for industrial production. 70% of this is expected to come from surface water sources. Water requirements for power sector are estimated at 19 km^3, 33 km^3 and 70 km^3, respectively, for the years 2010, 2025 and 2050, and 80% of these requirements are expected to be met from surface water sources.

For the purposes of navigation in the navigable stretches of the rivers, and for environmental purposes, i.e., for maintaining the quality of water in a river flow, a certain minimum amount of flow has to be maintained in the river. Due lack of such flows, to some of the rivers in certain stretches have at present become extremely polluted. In addition to taking other measures for keeping a rivers clean, a minimum flow of good quality water is also to be maintained. It is estimated 12 km^3, 20 km^3 and 35 km^3 water in the years 2010, 2025 and 2050, respectively, will be required for this purpose.

The total future water requirements are presented in Table 5. These figures show that irrigation is and will remain a dominant use of water even in a 50-year perspective. Therefore, it is in the fitness of things to focus attention mainly on irrigation in respect of water use efficiency within the sector and optimum water allocation between irrigation and the rest of the sector. Between 63 to 65 per cent of the total needs of water will have to be met from surface water sources, and the rest from ground water sources.

Table 5 : Total Water Requirements of India

Major Uses	1997-98		2010		2025		2050	
	km^3	%	Km^3	%	Km^3	%	Km^3	%
Irrigation	524	83	557	78	611	72	807	68
Domestic	30	5	43	6	62	7	111	9
Other uses	39	6	78	10	120	15	186	16
Evaporation losses	36	6	42	6	50	6	76	7
Total use	629	100	710	100	843	100	1180	100

In 1997-98, about 399 km^3 of water was drawn from surface water sources, and there is the possibility of such withdrawal going up to about 752 Km^3 by the year 2050, that is, an 88% increase. This implies construction of a large number of reservoirs and canals, and also in many cases, resolution of inter-state issues before water development projects could be implemented.

WATER AVAILABILITY

Water resource is a flow concept. The water which annually flows through the natural water cycle in a country is regarded as the water resource. This includes both the surface and the underground flows. Since there is variation in such flows from year to year, the mean flow is considered as the resource. The underground aquifers and reservoirs moderate the variations in use to a large extent by depleting or adding to the stock, i.e., the base level of reservoirs or aquifers. As per the latest estimates made by the National Commission, the total water resources of the country are 1952 km^3. This water resource is most unevenly distributed over different river basins or sub-basins. For example, Brahmaputra sub-basin alone accounts for 32 per cent of the total water resources. Ganga sub-basin accounts for another 27% of the resource. The remaining 41% of the water resource is distributed over 23 other river basins all over the country, and, among these, Godavari contributes the largest – its share being 5.7 per cent of the total.

'Water availability', however, is a narrower concept than water resource. By availability is meant 'availability' for use, or utilisable water resource. While the concept of 'water resource' is based on natural conditions alone, 'water availability' depends both on natural conditions (i.e. the basic resource) and on efforts and ingenuity in using the given resource. The entire resource is certainly not utilisable. Some water must flow down the river to the sea. A large part of flood water flows down to the sea. Withdrawability of water largely depends on storage and diversion structures and on absorbing capacity (i.e., the demand side). There are limits to the creation of such structures due to physiographic conditions, environmental considerations, state of technology, rehabilitation and resettlement problems, economic feasibility and availability of investible resources. Inter-basin transfers can enhance the quantum of utilisable water resources, but the constraints mentioned above get magnified in the case of inter-basin long-distance transfers. Inter-state disputes on water sharing and on the concept of water development, are, of late, becoming a greater hindrance to the optimal development of water resources. Problem becomes even more critical when two countries are involved.

The utilisable water resource from surface water sources is estimated at 690 km^3. This estimate is based on : (a) the completed storage of 174 km^3; (b) storages of 76 km^3 from projects under construction; (c) small tanks providing storage of 3 km^3; and (d) 132 km^3 of storages from identified projects yet to be taken up for construction. All these add up to a total of 385 km^3 of storages, which would be necessary to make the utilisation of 690 km^3 possible.

Ground water resources are more widely distributed over land than surface water resources and, hence, are also used more widely, sometimes depleting the basic stock. As per the National Water Policy, development of ground water resources is to be limited to the utilisation of replenishable component of ground water. The total utilisable ground water resource is estimated at 396 km^3.

The total availability of water resources (both surface water flows and ground water), thus, adds up to 1086 km^3. To this could be added the additional return flows (recycling) of water as a result of additional utilisation. Such additional return flows in the final year of the perspective period, i.e., 2050, are estimated to be 169 km^3, thus enhancing the total availability to 1255 km^3.

THE CRITICAL BALANCE

Requirements of water have been estimated at 1180 km^3 in the year 2050. The availability of water in 2050 is estimated at 1255 km^3, and this includes the additional return flows of 169 km^3. Given the normal range of errors in such long-distance projections, the availability and the requirements can be said to be very critically balanced. There are assumptions of higher performance on both the sides, on the side of estimating the availability as well as on the side of estimating the requirements. The Commission has brought into focus the criticality of the situation in the following words:

"First, the balance between the requirement and availability can be struck only if utmost efficiency is introduced in water use. Second, average availability at the national level does not imply that all basins are capable of meeting their full requirement from internal resources. Third, the issue of equity in the access to water, between regions and between sections of population, assumes greater importance in what is foreseen as a fragile balance between the aggregate availability and aggregate requirement of water" (Report of the National Water Commission, p.73).

On the side of estimating the water requirements, perhaps the most critical assumption is enhancing the irrigation efficiency from the present level of about 36% to the ultimate level of 60%. The efficiency level of 60% is the ideal, the ultimate goal. The steps and measures that are required for achieving this level of efficiency are many and some of them not so easy. Yet, if such critical assumptions have been made, it is only with a view to emphasising the need for taking steps for meeting the ultimate requirements of water. Steps like modernisation of canal systems, lining of canals, construction of field channels, installation of volumetric control devices on the heads of field distribution systems, promotion of better practices of irrigation which conserve and save water, like sprinkler systems, drip irrigation (where applicable), prevention of high rate of evaporation from water storage systems, etc., are the measures which require heavy investments both on the part of the states and on the part of the farmers. While commercial farmers could afford such devices, given incentives for saving water, small and marginal farmers who comprise more than 80% of the farm holders, would not be able to afford the required investments in water saving devices. In spite of heavy subsidies, some of the modern devices of irrigation have made little progress in popular acceptance. State governments suffer heavy losses in their irrigation sectors, and more recently in the wake of financial crunch investments in irrigation have been severely curtailed. Hence, only those projects, assisted by the World Bank or some such agencies could be taken up for modernisation. There are other measures also which have been found to be even more difficult to implement. Most important of these is the proper pricing of irrigation water. Irrigation revenues do not even cover the cost of physical maintenance of the system. Costs of the overall operation of the system are much higher and the total cost of the irrigation system is still higher. Water rates charged are incredibly low. This affects the system's efficiency much too adversely. Irrigation organisations are unable to do needed repairs and maintenance, causing losses of water. On the other hand, low price of water induces inefficiencies in use, like over-irrigation, flood irrigation or choice of water guzzling crops.

Sometimes, short-sighted policies also cause long-run inefficiencies. It has been invariably observed that in the initial stages of the development of a large irrigation system, when the reservoir becomes ready, but only a part of the canal system is in place (since the canal system takes much longer time to construct), there is more water than could be used by the limited area of irrigation command which has been developed. This situation may sometimes prevail over 5 to 10 years or even more. In such a situation, there is always a temptation to give excessive amount of water to the farmers. The farmers then get used to a cropping system which uses excessive quantities of water and they also get into the habit of using water wastefully. A certain practice develops, a certain cropping system gets established, like rice or sugarcane in otherwise a water-short region, and industries and infrastructure develop around that cropping pattern. Later, when the entire irrigation system is completed, it becomes difficult to withdraw the excessive quantities of water given to the head-reach farmers, and the tail-enders are left literally high and dry. This is the story of any number of irrigation projects. Reaching 60% irrigation efficiency implies not only doing the correct thing in the future, but correcting the past mistakes as well which involves difficult social and political decisions. The question of low-price-induced inefficiencies in water use is, more or less, the same in other sectors as well, but irrigation being the largest user of water has been particularly mentioned here.

The critical balance between availability and need for water also implies very intensive use of water and its multiple recycling. Overuse of water in some regions, particularly the over extraction of water from underground aquifers has already started creating adverse impact on environment, like enhanced salinity and ingress of sea water. It is a matter of serious concern, particularly in the coastal regions where even drinking water is becoming a problem. Overuse of water from surface sources dries up the rivers almost completely during off-monsoon seasons, thus turning the rivers almost into open drains.

A good part of the available water comes from recycling of used water, either as return flows from domestic uses and irrigation or as planned recycling, like use of treated sewage water for irrigation purposes. But, with every cycle of use, the quality of water deteriorates. More intensive the water use, more is the deterioration in quality. Return flows from irrigation bring chemical residues from fertilisers and pesticides. Return flows from domestic uses could bring harmful bacteria. Return flows from industrial uses have been by far the most polluted, as these contain harmful toxic wastes. Problem can be alleviated through strict regulation and control, but some restraint on overuse of water has also to be exercised.

It is important to note that the critical balance between supply and demand is achieved only at the national level. National water resources, however, do not form a single pool from which water could be easily transported to all the points of need. Water is very unevenly distributed over the country. This year, while large parts of the country, namely, Bihar, Bengal and Assam, have suffered devastations from floods, in terms of loss of human life and property, there are severe drought conditions in western Madhya Pradesh where even drinking water has become a problem. Situations like this arise almost every year. While inter-basin transfers of water could be considered on a limited scale after meeting the full needs of the surplus basins, there are many difficulties, technical, social and political, in the way of such transfers.

Local water resource development and management could be an important element of the strategy of meeting the water needs of the future, particularly in water-scarce regions. This type of development requires full involvement of the local people. The Five Year Plans have laid great emphasis on local watershed development, water harvesting and water conservation, but the progress so far has been slow. Good results have been obtained only where dedicated voluntary organisations have taken a lead in organising the people and coordinating various government programmes at the ground level. This has happened only in some regions.

TOWARDS WATER SECURITY

It is clear from the foregoing that even though the book accounting of water in the perspective of next 50 years appears to be balanced, water is going to be an extremely scarce resource. This scarcity could not be mitigated by trade. Water cannot be imported at affordable costs. Therefore, while it is important to undertake all the measures required for improving efficiency in the use of water, conserving water, preserving its quality and investing in further development of water resources including possible inter-basin transfers, at the same time, it is imperative to think about ways of reducing the need for water. We have already noted that irrigation is the dominant use of water. Irrigation is also an activity which can use less water or more water depending upon the nature and composition of crops and other agricultural activities. This, in turn, depends on development strategy and policies. The water needs in the foregoing pages have been calculated on the assumption of self-sufficiency in food production even for a population of nearly 1.6 billion in the year 2050. While food security for a large population is certainly important, one could think of alternative ways of meeting the food security objective.

Self-sufficiency in foodgrain production has been adopted as a strategy for reducing dependence on imports in view of the uncertainties of the international markets in handling large quantities of foodgrains. But, similar objectives could be achieved by collaborating/investing in the production of foodgrains and other water-intensive agricultural products like sugar in other countries which have abundant land and adequate water, but are short of labour and capital, and do not have enough demand for increasing domestic agricultural production. Such possibilities have not been explored in the past, particularly in the field of agriculture. In the field of energy and energy-based products like fertilisers and petrochemicals such arrangements have already started working. There is a possibility of working out similar arrangements in the field of agriculture also with friendly countries.

As a specific example, one could take the case of Republic of Kazakhstan. Kazakhstan has a total geographical area of 2.7 million sq km (86% of the Indian land mass) and a population of 15.9 million, only 40% of which resides in rural areas. The country comprises mainly of steppe land, plains and low plateaus. The northern region of Kazakhstan (mostly plains) has very good agricultural land. The climate is continental with long cold winters and short hot summers. The average length of crop-growing season ranges from 125 days in the North to 175 days in the South. Rainfall in the northern plains ranges between 300 mm to 500 mm, mainly as snow from October to April. It raises the field soil moisture content as well as recharges the underground aquifers.

Consequent upon a fall in the demand for agricultural products after 1991(i.e., after separation from the former Soviet Union) and due also to decline in availability of inputs and labour, a large part (almost half) of formerly cultivated lands have been abandoned, and are lying as fallow now. Foodgrain production has come down from 25-30 mn tonnes in pre-1991 period to 12-15 mn tonnes now. Wheat is the main product. The country still remains a net exporter of agricultural products because of much lower domestic demand. Kazakhstan's wheat is of a very high quality with high protein content and is also valued for negligible use of chemical fertilisers. South and Central Kazakhstan (mainly steppe land and plateau) have vast grasslands ideal for animal husbandry.

The country has the potential of increasing productivity and production substantially given the right combination of organisational and technological inputs and, of course, the market for the products. The Government of the Republic of Kazakhstan has undertaken the programme of privatisation of agricultural land, and has allowed participation of foreign companies in the development of agriculture. They permit leasing of land to foreign companies.

A Singapore based NRI company (employing Indian managers) took 150,000 hectares of land on long lease in 1996-97 for commercial farming in the northern region of Kazakhstan. The company started with direct farming, but has now changed to farming through local farmers while the inputs are supplied by the company and marketing is handled entirely by the company. Other foreign companies have also started showing interest.

It would be in the interest of India to explore the possibilities of large scale long-term investments in agriculture in Kazakhstan and also in other friendly countries similarly situated. This would give us relief from the strains of the self-sufficiency syndrome, and will at the same time enable us to take care of our food security. We would be taking care of even a bigger objective, that is, 'water security' for the nation.

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MANAGEMENT OF INTERNATIONAL RIVER BASINS

Le Huu Ti*

Since the international rivers account for a major share of freshwater resources available on earth, improvement in the management of these rivers will have an important role in the sustainable utilization of the world's fresh water resources and in the realization of the World Water Vision. An insight to the evolution of the institutional foundation for cooperation in the development and management of international river basins is made in this paper, based on the analysis of the Mekong cooperation process and that of selected international river basins. Such analysis aims to identify strategic elements of such an institutional evolution. The Mekong experience points out the importance of the core value of Mekong cooperation: the Mekong Spirit and also the key accomplishment: to become "a major development region of Asia". The evolution of the Mekong Spirit, over the decades, has crystallized the four strategic elements of the institutional foundation: (1) shared vision, (2) mutual understanding, (3) mutual trust, and (4) common goal. Progress in the Mekong cooperation process has also resulted in the development of new institutional approaches to international river basin management towards the shared vision. The new institutional approaches reflect not only the requirement to develop suitable strategic planning approaches but also the need to adopt key conceptual elements that need to be incorporated into the basin development process.

INTRODUCTION

General Perception

In a study[1] carried out by the Mekong River Commission Secretariat (MRCS) in 1993 on "Comparative Analysis of the Legal and Institutional Aspects of Selected International River Basin Commissions[2]", enormous differences were found in the overall conditions of cooperation among international river basin commissions. These differences reflect the complexity caused by the differences

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in social, cultural, political, economic and natural or environmental conditions among the riparian states. With such a complex situation, the MRCS study recommended to identify common denominators to describe the overall framework of water resources management in international river basins. According to the analysis of the MRCS study, the most fundamental common denominator would be the willingness of cooperation, based on which some derivations could be made to suit differences in the economic development stages of the riparian states. The willingness of cooperation at the initial stage of development forms the foundation of cooperation. As the development of the common water resources progresses, willingness of cooperation would improve. In principle, this change would entail further consolidation of the foundation of cooperation and, as a consequence, the willingness of cooperation would continue to enhance with the increase in the level and scale of joint efforts to form the main thrusts of cooperation and major trends of joint development activities among the riparians. Therefore, the institutional framework at the international level needs to be firmly rooted in such willingness of cooperation to act as the leading mechanism to guide joint efforts and to nurture the main thrusts of cooperation towards sustainable basin development.

Furthermore, it was found from a survey conducted by ESCAP[3] in 1998 on "Regional Experiences in the Integration of Water Resources Management into National Economic and Social Development in Asia and the Pacific" that perception of community participation was widely accepted at the local level and given lower priority at the national level. In recognition of the importance of public participation, the ad hoc expert group meeting subsequently held in June 1998 recommended the governments to design programmes aimed at enhancing public awareness and increasing public participation in water resources management. The analysis of the ESCAP survey results also showed a common perception that in order to ensure an effective integration of water resources management into the economic and social development process, integrated water resources management needs to be carried out as a process within an overall framework of national economic and social development. On the basis of such a perception, the overall framework of national economic and social development and the process of integrated water resources management can be seen as essential elements for the establishment of a sound foundation for water resources management in an international river basin. Although these elements may be common across the international boundaries of the riparian states, they need to reflect and respond to the cultural, political, social, economic and environmental concerns of the respective countries. In other words, they need to be conceived and adopted within the national context. At the international river basin level, these national elements are expected to be harmonised and implemented within an international framework, commonly accepted and adopted by the riparian states. Discussion on public awareness in this context will, therefore, be limited, as this paper aims to provide inputs to the sector consultation from the viewpoint of implementation of "Water Vision" of international rivers and at the level of an international framework.

Linking the Institutional Framework and the Vision Process

In this paper, the Vision process is conceived as a new process being developed to ensure the sustainable management of our limited water resources. Such a process is guided by strategic approaches towards *shared vision* at different levels of the world community: local, national, regional and global. The institutional framework at each level constitutes the mechanism for such a process and its evolution needs to be seen as a part of the development process. Within the context of building and realisation of *shared vision* in international river basins, the institutional framework is analysed in this paper from the following two aspects of the vision process:

- Strategic elements of the institutional foundation; and
- Institutional approaches to basin development.

Discussion of these two aspects is aimed at identifying key elements of the Vision process for international river basins towards establishing or strengthening the international framework for the development and management of international river basins to support the economic and social development processes, based on selected Asian experiences, particularly those at the Lower Mekong River Basin.

INSTITUTIONAL FOUNDATION FOR INTERNATIONAL RIVER BASIN MANAGEMENT – MEKONG EXPERIENCE

Brief Description of the Mekong Cooperation Process

The Mekong is the longest river in Southeast Asia and the eighth largest in the world in terms of runoff (4,75,000 million m^3). The Mekong cooperation has existed for a long time. Prior to 1950s, several international agreements were reached among the riparian states of the lower Mekong basin. These agreements were mainly aimed at: maintenance of peace, exploitation of mineral resources, and trade promotion. Since the early part of 1950s, the Bureau of Flood Control of the United Nations Economic and Social Commission for Asia and the Pacific (then ECAFE) adopted the Lower Mekong Basin as one of its major studies with the approval and assistance of the governments of the riparian countries in the lower Mekong basin. The Bureau then carried out preliminary field investigations to focus the opportunities that existed for developing the river's irrigation and power potential. That was the first time when a systematic study of water resource potential of the lower Mekong was made. In 1956, ECAFE carried out a field reconnaissance on the basin's potentialities with respect to hydropower, irrigation and flood control in close cooperation with the four riparian countries and this resulted in a report titled "Development of Water Resources in the Lower Mekong Basin". The report provided a conceptual framework for planning the development of the river basin as "an integrated system". It advocated an international approach to Mekong river development by calling for the close cooperation of the four riparian countries in data collection, planning and development.

These initial efforts formed the cornerstone to strengthen cooperation among the riparian countries, and to open up an established channel of communication between developed countries and the riparian countries themselves for the flow of resources and technology into the region for development. On the basis of these efforts and in response to the decision taken by the ECAFE at its thirteenth session, the Committee for Coordination of Investigation of the Lower Mekong Basin (the Mekong Committee) was established by the governments of Cambodia, Lao People's Democratic Republic (Lao PDR), Thailand and Vietnam as an intergovernmental agency under the aegis of the UN-ESCAP on the basis of equality of rights. As indicated in the name of the Committee, coordination of investigations has formed the starting point of long-term and sustainable cooperation for the development of the Lower Mekong Basin. This pragmatic approach of international cooperation was based on a perception that the Mekong River is a *River of Promise*.

The Committee became one of the most significant institutional mechanisms for the development of the Mekong's water and land resources on behalf of its members who then, either individually or collectively, did not possess the resources and technological expertise to conduct detailed investigations for basin development. In order to encourage follow-up action to the investigations, the establishment of the Mekong Committee in 1957 also laid down one of the most important foundations for cooperation among the riparian countries. This foundation was based on the principle of mutual accommodation for the betterment of the Mekong people in building up confidence and trust. This foundation continued to be manifested in the many resolutions on principles and criteria for use, allocation, conservation, and development of the Mekong water resources. This foundation also reflects the common goal of the countries in creating opportunities for each other to develop the Mekong resources. Cooperation among the Mekong riparian countries has, therefore, been built on the foundation of mutual benefits among the riparian countries; creating opportunities for development; mobilising international assistance; and promoting stability of peace in the subregion.

Over the past four decades of cooperation, the Mekong joint efforts have resulted in important achievements with more than four-fold increase in the average GDP per capita, although the key mainstream projects have not been implemented to date. During this period, national and bilateral as well as multilateral efforts have contributed to the development of the Mekong water and related resources to meet the development needs of the subregion. Among the sub-basins in the Mekong Basin, Northeast of Thailand was the region having the highest development rate during the 1960s and 1970s. This highest development rate was attributed to the opportunity created by the Mekong cooperation as acknowledged by Dr. Boonrod Binson, a former long-serving Member for Thailand in the Mekong Committee, when commenting on the role of the Committee in development of Thailand:

> "In the 1950s, development of the Northeast was considered to be of lower priority than the other regions, especially the Central Plain, due to its remoteness and underdeveloped status. The establishment of Mekong Committee attracted many donors to this region of Thailand. As consequence, the Northeast has obtained good financial support from both outside and inside to attain what it is today." (Lecture by Dr. B. Binson on the occasion of the first anniversary of the Integrated Energy Development Institute of Thailand, 17 April 1992).

The common efforts of the riparian countries in the lower Mekong basin have been recognised by 26 donor countries and 19 international organisations[4]. The recognition of the Mekong Spirit of cooperation resulted in an important flow of assistance and investment to the subregion (to the tune of US$1,600-2,000 million up to 1987)[5] and was manifested in the award of Magsaysay in 1968.

Since the beginning of 1990s with the return of peace in Cambodia, the Mekong subregion has become a major focus of cooperative development efforts. The potential benefits of such regional efforts and the conducive environment for an integrated development are well recognised by many as reflected in the view expressed by the Asian Development Bank (ADB): "Within the subregion there has been a natural process of economic integration. Intraregional trade has begun to blossom, notably in the important area of energy; there has been cooperation on the shared resources of the Mekong River system, especially in the field of water management; and there has been some cooperation in the area of human resource development. The challenge is to build on existing efforts, developing multilateral initiatives where appropriate. This can take place without any formal association, and within the framework of existing relationships[6]".

The establishment of a Greater Mekong Subregion (GMS) Cooperation Programme by ADB since 1992 has thus magnified the importance of the cooperation infrastructure that has been built up over the decades through the Mekong participatory process. Since then, the GMS Programme has been able to further enhance active participation of all the Mekong Basin member countries and increase collaboration of various important donors and international organisations. Other forms of subregional cooperation have also begun to emerge. Among the new major subregional initiatives[7] are the Forum for the Comprehensive Development of Indochina (an initiative of Japan aimed to focus private sector and aid donor interest on the development priorities of the three former Indochina countries – Cambodia, Lao PDR and Viet Nam), ASEAN-Mekong Basin Development Cooperation (established by the ASEAN leaders in December 1995) and the Golden Quadrangle (an initiative of Thailand to focus on economic cooperation between Thailand and its upstream neighbours – Lao PDR, Myanmar and Yunnan Province of China). All the above international initiatives and efforts have thus turned the Mekong River Basin into a new subregional development focus of Asia.

Strategic Elements of the Institutional Foundation for Mekong Cooperation

Since 1957, the Mekong Spirit continues to develop and evolve in joint development efforts and cooperation. The evolution of the Mekong Spirit is necessary to keep pace with the increasing complexity of the development process, to effectively support and coordinate development activities and to guide common efforts in overcoming short-term issues. Such evolution continues to solidify the foundation of cooperation. The strategic elements that led to important achievements of the Mekong cooperation have crystallised over the years due to the evolution process and can be grouped into the following four components: shared vision, mutual understanding, mutual trust and common goal.

Shared Vision of Cooperation

The introduction of integrated development and detailed investigation programmes initiated by ESCAP (then ECAFE) at the early stage of the Mekong cooperation programme had provided necessary inputs to firmly establish a shared vision of cooperation among the riparian countries. The milestone was reached when the first Indicative Basin Plan was published in 1970 (widely known as the 1970-IBP) to provide details of possible schemes to develop the Mekong potentials. Since the publication of 1970-IBP, the Mekong River has been known internationally as a *River of Promise* of Southeast Asia[8].

Mutual Understanding

The first regional project sponsored by the Mekong Committee in 1957 was the establishment of a basin-wide network of hydro-meteorological stations for regular collection of data. The network started with only a few stations in 1957 and continued to grow to some 400 stations in 1975. Efforts were also made to reconstitute the record at the beginning of the century. Collection of data continued and gained momentum in the early 1960s, with major field investigations on hydrography (for navigation and water resource development of the mainstream); socio-economic surveys for planning to establish benchmarks for development and to determine the most important areas of improvement; and investigations of other resources. This programme continued to be carried out almost continuously throughout the history of cooperation, even during various difficult periods and the information continued to be disseminated to all the member countries in the Lower Mekong Basin. The dissemination of information was further strengthened with the implementation of the annual flood forecasting operations since 1970. The *free flow of information* has thus ensured *equality in access to information* and contributed to strengthening mutual understanding among the riparian countries. In a way, this concept was partially reflected in an observation made by A.T. Wolf (1999): "the best example of this internationally is on the Mekong where the Mekong Committee's first 5-year plan consisted almost entirely of data-gathering projects, effectively both precluding data disputes in the future, and allowing the riparians to get used to cooperation and trust"[9].

Mutual Trust

In order to lay foundation for mobilisation of technical and financial support for Mekong development, the Committee identified four important tributary projects in the four countries: Prek Thnot in Cambodia, Nam Ngum in Lao PDR, Nam Pong in Thailand, and Yali Falls in Viet Nam. Among these first projects was the Nam Ngum hydropower project in Lao PDR, of which the construction and completion marked an important step in the direction of cooperation: a dam built with contribution of the riparian countries and donors in one country to supply nearly 80 per cent of its energy to its neighbour. Since its completion in 1971, the Lao Nam Ngum project has supplied electricity to the Thai power market without interruption, even during several critical periods in the relationship between these two riparian countries. The experiences of this joint undertaking provided an important foundation and vivid lesson on how various important and difficult steps could be taken in the area of water resources development for international cooperation. This exemplary achievement has thus solidified mutual trust among the countries concerned and provided the Committee with a good show-piece for further mobilisation of financial support and investment. There are also other joint studies and undertakings of the Mekong Committee which have been instrumental in strengthening mutual trust among the riparian countries, such as the Friendship Bridge, Mekong Irrigation Programme, Mekong Ferry Crossing and Inland Navigation Programme.

Common Goal : the River of Prosperity

In the words of the Chairman of the MRC Council for 1995-96, the Mekong cooperation process has reached a stage of maturity for integrated development to turn the Mekong River Basin into an area of prosperity. "Looking back to the past 38 years of Mekong cooperation, the assistance and support provided by the donor community has contributed not only to improvement of social and economic conditions of many millions of the Mekong inhabitants, but also to strengthening of the Mekong cooperation and mutual understanding and trust among the riparian countries. The foundation of a river of cooperation has now been firmly established, let us look forward to turning the river of promise into a river of prosperity: an important goal of the Mekong River Commission[10]". For this purpose, a new concept of basin development planning (BDP) was adopted in the new Mekong Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin (signed in 1995) to lead to Subregional Interdependent Economic Growth and Sustainable Development. It was expected that with a new Basin Development Plan, the MRC could play a leading role in ensuring sustainable development of the Mekong River Basin and contribute to prosperity of the Mekong peoples.

Over the past four decades, the Mekong cooperation process has been able to make use of the complementarity of the disparity in the resources potentials among the riparian countries to contribute to the economic and social development of the subregion. However, the different economic growth rates which were caused by various reasons, including political and security problems, have resulted in the current relatively large discrepancy in the economic development levels among the riparian countries. Nevertheless, the Mekong Spirit remains firm and the Mekong cooperation process is strong. The fundamental characteristic embedded in the Mekong cooperation process can be described as the common attitude of *mutual respect* as adopted by all the riparian countries. Over the years, adoption of the concept of *mutual respect* has helped the riparian countries to maintain the Mekong cooperation process firmly on the basis of national sovereignty.

INSTITUTIONAL APPROACHES TO INTERNATIONAL RIVER BASIN DEVELOPMENT

General Principles

The General Assembly of the United Nations adopted in May 1997 the Convention on the Law of the Non-navigational Uses of International Watercourses (hereafter referred to as the Convention)**.** In adopting the Convention, it expressed "the conviction that a framework convention will ensure the utilisation, development, conservation, management and protection of international watercourses and the promotion of the optimal and sustainable utilisation thereof for present and future generations". The Convention stipulated various general principles required for the management of the international watercourses. The general obligations included in the Convention stipulate that:

- "Watercourse states shall cooperate on the basis of *sovereign equality*, *territorial integrity*, *mutual benefit and good faith* in order to attain optimal utilisation and adequate protection of an international watercourse; and
- In determining the manner of such cooperation, watercourse states may consider the establishment of joint mechanisms or commissions, as deemed necessary by them, to facilitate cooperation on relevant measures and procedures in the light of experience gained through cooperation in existing joint mechanisms and commissions in various regions."

Water resources management of river basins is recognised as a process, as denoted in the Convention. Management has been defined therein as "(a) Planning the sustainable development of an international watercourse and providing for the implementation of any plans adopted; and (b) Otherwise promoting the rational and optimal utilisation, protection and control of the watercourse." Towards the sustainable development of international river basins, not only cooperation among the riparian states is a prerequisite, but adoption of an integrated water resources management is also necessary. It is increasingly recognised that the benefits of use of shared waters can be maximised only through international cooperation and in many cases the potential to increase benefits to all riparian countries can be realised only by integrated development. It is also increasingly recognised that individual water projects cannot be undertaken with optimum benefits before a plan for the entire drainage area has been conceived for integrated basin management. This calls for the development of strategic institutional approaches to basin development.

Strategic Approaches : A New Basin Development Planning Process in the Mekong River Basin

The Mekong experience[11] pointed out that the formulation of a Mekong Basin Development Plan (BDP) would have to link to the national targets of socio-economic development of all the riparian countries in order to ensure practicability of the basin planning process. By so doing, the basin planning process would be able to incorporate related national development strategies in the BDP and priority development activities of the Mekong basin in the national development priorities. The implementation of the BDP would require coordination of national development policies and corresponding sectoral development strategies to ensure stability of basin development as a whole. Furthermore, the complexity of the development process would require further strengthening of the legal and institutional framework in order to ensure effectiveness of cooperation in the implementation of the BDP and for Mekong basin development. It was also pointed out that adoption of the participatory approach for the planning process is essential for the acceptability and thus practicability of the BDP.

A New Context of Basin Development Planning

The signing of the Agreement on Cooperation for the Sustainable Development of the Mekong River Basin (hereafter referred to as the Agreement) in April 1995 by the four riparian countries of the Lower Mekong Basin marked a new phase of cooperation among the Mekong riparian countries for joint development of the Mekong waters and related resources. The Agreement establishes the Mekong River Commission with a new mandate and a new vision. The new mandate aims to direct efforts towards a new focus of cooperation vision: *an interdependent subregional growth*. In order to realise the vision, the countries agree to establish a Basin Development Plan (BDP) with a new concept for strategic institutional approaches to basin development: as "the general planning *tool and process* that the Joint Committee would use as a blueprint to identify, categorise and prioritise the projects and programmes to seek assistance for and to implement the plan at the basin level" (Definition of Terms of the 1995 Agreement).

Perception of Principal Issues in Lower Mekong Basin Development

The principal issues for effective, active and sustainable cooperation in the Lower Mekong Basin were identified in the previously mentioned study[12] to form strategic elements of a three-pronged approach of basin cooperation as given below:

Urgent needs of economic development: Three major sectors with development activities having high economic efficiency were identified to be the Mekong transport system, the Mekong tourism programme, and industrial development programme, including hydropower development. Development of these sectors is considered necessary to sustain the high economic growth rates prevailing in the Mekong basin.

Stabilisation of the basin development process: Four major complementarity programmes to ensure stability of the Mekong basin development are: (i) provision of good-quality water for domestic consumption to the majority of the population; (ii) expansion of irrigated agriculture; (iii) improvement in water resources management; and (iv) protection of the environment. Improvement of the social conditions would lead to better participation of all the communities in economic development programmes, better income distribution and more effective protection of the environment.

Framework of long-term basin development: An effective framework needs to include the following components: (i) formulation of a comprehensive physical development plan; (ii) strengthening the effectiveness of the existing legal and institutional framework; (iii) development of a human resources core group; and (iv) development of the financial resources.

Approach to Preparation of the Mekong Basin Development Plan

On the basis of the past experiences of Mekong basin development planning, it was recommended that the new planning approach should address the following five key issues of development planning:

Active participation of the riparian countries is required throughout the BDP formulation study. Such participation is expected to increase mutual understanding and trust among the riparians;

Continuity and consistency of the basin planning work is necessary to ensure priority of the planning work for the Mekong core functions and those stipulated in the Agreement;

Advanced technology and latest achievements in basin/national planning will be required, including involvement of international experts, so as to obtain latest information technology and related planning techniques;

A solid foundation of the basin development knowledge based on baseline surveys of past basin development planning work and current situation with related national policies is important; and

Core human resources elements for the basin development planning process are expected to be established by the project to ensure sustainability of basin planning and effectiveness of cooperation.

Conceptual Elements of the Mekong Basin Development Plan

Apart from the above key issues required to be addressed in the basin planning process, the Mekong Basin Development Plan needs to include the following six conceptual elements:

Establishment of a comprehensive framework of water resources development: The BDP would need to provide a comprehensive framework within which major projects and programmes could be presented for development not at their maximum potentials but at realistic level and related national needs of social and economic development could be included for more effective interaction and cooperation among the riparian countries;

Established common goals for socio-economic achievements in basin development: From a global point of view, these goals would aim to sustain economic growth rates, ensure good income distribution and reduction of unemployment, minimise harmful effects of development and conserve the environment, and promote cultural enrichment;

Common strategies for basin development : Common strategies are aimed at creating suitable conditions to facilitate national socio-economic development programmes;

Short and long-term priority programmes of action (including study and development) and mechanisms to implement and update them : Priority programmes are action plans for sectoral development (such as water resources, hydropower, navigation, agriculture, fisheries, forestry and tourism) as well as cross-sectoral development (human resources and environment). The combination or integration of these plans reflects two dimensions: spatial dimension to form a basin plan and time dimension to represent sectoral strategies and a coordinated basinwide programme approach;

A dynamic cooperation framework conducive to basin development depending on the levels of development : The basic framework of cooperation is stipulated in the Agreement. The Agreement also envisages further development of the cooperation framework to create conditions conducive to joint development as well as national development; and

Facilities and information systems to support basin planning work : Information systems together with necessary hardware and software are instrumental to cooperation and joint development. Development of the facilities and information systems constitutes an important aspect of cooperation.

Recent Developments at the Mekong River Commission (MRC)

In parallel to the national efforts at improvement of water resources management, a Strategic Plan was recently developed by the MRC to guide joint national efforts. The Strategic Plan had a deep root from the national contexts mentioned above and responded to the regional and international call for a concerted programme of action. In this concerted effort, a planning team was established and a coordinated approach was adopted. These joint efforts have established a basin planning process which reflects an important achievement in strategic planning approach towards ensuring equitable benefits of close collaboration among the riparian countries. The strategic plan was conceived as an ongoing process of setting goals and policies and plans to achieve those goals within a specified time-frame, and measuring the results through systematic feedback. Goals are specifically aimed at helping the MRC work toward its common visions both of the Mekong Basin and the kind of organisation the countries would like the MRC to be.

It may be pointed out that the draft Strategic Plan for the Mekong River Commission (1999-2003) was approved by the MRC Council in October 1998. The approval of the Strategic Plan by the Council laid down the most important foundation for the adoption of strategic planning approach for the management of the Mekong Basin water resources. This indicates a major shift in the basin planning approach adopted within the framework of Mekong cooperation and in line with the 1995 Agreement.

However, as a general observation, it can be noted from the above Mekong experience and also experiences of the selected river basin commissions mentioned earlier, that strategic planning towards integrated basin development constitutes one of the most important tools in the institutional approaches towards sustainable management of water resources of international river basins. Such strategic approaches aim to create an equitable opportunity for all riparian countries to develop and also to guarantee conservation of the basin's natural resources for the present and future generations. The effectiveness of cooperation would greatly depend on how much the riparian countries would commit themselves to the planning process and water resources development. Furthermore, equitable participation in the process is necessary to provide a better system accountability for construction, operation, and maintenance of common works. Equitable participation would consist of:

- Equitable participation in planning, decision-making, management and financing; and
- Establishment of appropriate mechanisms for the sharing of costs and benefits derived from the development of common projects.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The above analysis of the Mekong cooperation process provides an insight into the evolution of the institutional foundation for cooperation in the development and management of international river basins and particularly the identification of strategic elements of such an institutional evolution. The Mekong experience points out the importance of the core value of cooperation: the Mekong Spirit and key accomplishment: to become "a major development region of Asia". The evolution of the Mekong Spirit, over the decades, has crystallised the following four strategic elements of the institutional foundation:

- shared vision;
- mutual understanding;
- mutual trust; and
- common goal.

The Mekong experience also identified the need to adopt the common concept of mutual respect to ensure advancement of the process on the basis of national sovereignty.

Progress in the Mekong cooperation process has also resulted in the development of new institutional approaches to international river basin management towards the shared vision. These approaches reflect not only the requirement for the development of suitable strategic planning approaches but also the adoption of key conceptual elements that need to be incorporated into the basin development process.

It may be noted that these main features of the evolution of the Mekong cooperation process are closely related to the general principles for equitable use of international watercourses stipulated in the Convention on the Law of the Non-navigational Uses of International Watercourses, adopted by the UN General Assembly in May 1997.

In comparison with the cooperation experiences in other international river basins, the Mekong experience showed that differences in the political, cultural, social and economic environment of the riparian states can be integrated into the overall cooperation framework to form the institutional foundation of cooperation and to create better opportunities to realise the shared vision. In line with this, a general approach for the application of the general principles of the Convention should include the following elements:

- A prerequisite for successful cooperation is the goodwill of all riparian states. Under this premise, mutual understanding and trust for a fair cooperation and equitable participation should be promoted;
- Differences in the status of economic development or richness in resources should be turned into potentials for more active cooperation and participation in the joint development process; and
- Mutual accommodation should be translated into action plans to help promote the development process, as emphasis on the difference in development priorities could impede the development process.

Recommendations

Since the international rivers account for a major share of freshwater resources available on earth, improvement in the management of these rivers will have an important role in the sustainable utilisation of the world's freshwater resources and in the realisation of the World Water Vision. In this context, the following recommendations are made:

- The continuing World Water Vision process (including its action framework) should give sufficient attention to the promotion of development of "shared vision" in international river basins and encourage the development of confidence-building processes among the riparian countries in the follow-up action programme. Participation of external support agencies will be important in the development of such confidence-building processes.

- Sharing of information needs to be further promoted among the riparian countries and all stakeholders so as to enhance mutual understanding necessary for building mutual trust and creation of development opportunities. Sharing of information will need to be further expanded to various sectors, particularly for integrated basin development and strategic planning and for creating a network of cooperation among international river basin organisations.
- Integration of environmental, cultural and political dimensions into the economic and social development process of international river basins forms an increasingly complex task for which research needs to be supported and undertaken by various interested parties. These research activities should be promoted and coordinated in a network so as to ensure important contribution to the Vision process.

NOTES

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IRRIGATION IN CHINA[1]

Dr. A. Vaidyanathan*

INTRODUCTION

Irrigation plays an important role in augmenting agricultural production over most of Asia. Irrigation works essentially harness water flowing in streams and rivers, and tap water from underground to supplement water available from local rainfall, increase the duration of such supplies during the year, and achieve greater reliability. By doing so, irrigation stabilises crop yields, enables more water-intensive and higher-yielding crops to be grown, extends the cropping season and facilitates more intensive use of manures and fertilisers, leading to higher yields per unit of land.

Asia has a long history of irrigated agriculture; Mesopotamian and Indus-Valley civilisations were based on irrigated agriculture. Many countries have a long tradition of irrigation. The tanks of South India and Sri Lanka, the Ahirs and Pyres of Bihar, the Balinese subaks, local irrigation works in the Philippines and Japan being among the striking examples of this tradition. The scale of irrigation development in these countries, however, was much more limited in terms of spatial distribution and in relation to total cultivated area than in China.

Irrigated agriculture was practised in northern parts of China since at least the 8th century BC. Some of the systems, constructed during the pre-Christian era, were quite large even by modern standards. And records show, more or less, continuous activity since then in the spreading of irrigation works in different parts of the country. Over 8000 works are reported to have been constructed till the beginning of the 20th century.

Irrigation development acquired a much greater prominence during the 20th century for a variety of reasons: the liberation of the countries in the region from colonial rule and the importance attached by the newly independent countries to accelerated economic development; the rapid growth of population and food requirements in the context of a progressive decline in availability of land; the crucial role of irrigation for augmenting yield and exploiting the potential of new varieties of crops and fertilisers; advances in design and

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construction techniques enabling construction of large reservoirs; and the advent of mechanical and electrical pumps for lifting ground water.

The second half of the 20th century witnessed an unprecedented growth in irrigation. There has also been a major change in its characteristics: the importance of large reservoirs and of ground water has greatly increased. These trends, noticed everywhere, are particularly striking in India and China. Irrigated agriculture in both the countries has increased manifold. Currently, the area under irrigation in both these countries is nearly 50 mha, the largest and perhaps the most diverse in the world. Though the evolution and characteristics of Chinese irrigation systems differ significantly from those of India, there are also strong similarities in the kind of problems being faced and the concerns regarding the future. It should, therefore, be interesting to look at the Chinese experience.

CHARACTERISTICS OF IRRIGATION IN CHINA

It is estimated that at the beginning of the 20th century, China had some 200,000 miles of canals, several thousand miles of dykes and embankments (mostly for protection against floods), and a large number of reservoirs of different varieties and sizes, covering an area of 13,000 sq miles. It would seem that most of the areas currently being irrigated and the facilities serving them were already in place by that time. There was little new construction during the first half of the century. Besides, being a period of wars and internal military strife, the existing systems were not maintained properly with the result that they suffered extensive damage. When the People's Republic of China was established in 1950, total irrigated area was officially estimated at no more than 12 mha!

One of the first tasks of the new government was to launch a programme to rehabilitate existing facilities, and also to augment/upgrade them. According to one estimate, total irrigated area increased to 34 mha[2] by 1956, 40 mha by 1970 and nearly 50 mha in 1995. The post-Revolution decades have also witnessed construction of new reservoirs (including construction of big and medium storages)[3], reinforcement and construction of 130,000 km of dykes and some 100 large canals for diverting floods and draining waterlogged areas; sinking of a large number of new wells and phenomenally increasing the number of electrical and mechanical pumps.

The Chinese irrigation system is dominated by relatively small scale, surface water based works. Currently, there are about 85,000 reservoirs in the country with an aggregate capacity of 457bcm. Of these, nearly 82,000 have a capacity of between 0.1 and 10 mm^3 with a total storage capacity of around 56 bcm. About 2100 medium-scale reservoirs (defined as those with capacity between 10 and 100 mm^3) have an estimated 72 bcm capacity. Large reservoirs (with capacities exceeding 100 mm^3 and a total capacity of 357 bcm) account for over 70 per cent of the country's storage capacity. There are, in addition, 6 mn small ponds, but they account for a miniscule fraction of the total capacity.

Another indication of the predominance of small systems is that of the 5800 irrigation districts in which government was involved and served more than 20,000 ha were only 144 in number and they served 7.9 mha out of a total of 48 mha (each being a unit of management); as many as 5200 districts commanding between 617 ha and 20,000 ha irrigated 13.3 mha. Systems with command of less than 667 ha irrigating 13 mha were managed by local communities; area irrigated by works (mainly wells, tubewells and very small works) managed by individual farmers was nearly 14 mha.

A number of significant contrasts between China and India are worth noting. Flood control and drainage works figure much more prominently in China. It is worth recalling that massive works to control the floods of the Yellow river basin were among the earliest recorded efforts in water management. Waterlogging and salinity – estimated to affect 27 mha and 7 mha, respectively, compared to a total irrigated area of 50 mha – are much more prominent.

The storage capacity of reservoirs in China is estimated at 457 bcm compared to 190 bcm in India. A noteworthy difference is that in India storages of less than 10 mcm capacity account for barely 2 per cent while those with more than 500 mcm capacity account for nearly three-fourth of the total[4].

No estimates of ground water extraction or area irrigated by ground water in China are available. In India, they are estimated to account for a fifth of water utilised for irrigation and nearly half the irrigated area. Well irrigation is largely confined to northern parts of China and its extent is not known. There is hardly any well irrigation in the southern parts of the country where surface water is abundant and has been extensively harnessed. The reported number of wells and tubewells (3.7 mn) and pumping stations (0.5 mn) is large; so is the extent of area reported as "powered irrigation" (65 per cent of the total in 1995). However, these pumps are not all used for lifting ground water; a great many are used to lift surface water from storages and channels, and for drainage purposes. The Chinese statistics do not differentiate between pumping for different purposes; they report only the extent of "drainage and irrigated area by pumps" (currently, 21 mha)[5].

Compared to India, rainfall in the southern and eastern parts of China (where much of the country's agriculture and irrigation is concentrated) is relatively abundant, the rainy season has a longer spell, and temperatures in the growing seasons are lower. These factors cumulatively reduce moisture deficits to be met by irrigation. Also, rivers in this region flow for a larger part of the year, thus enabling diversion of stream flow to be used more effectively and widely for irrigation. This perhaps explains why grannaries of China – the Sezchuan region, the Yangtze and the Pearl river basins – could sustain intensive agriculture by developing relatively small, local surface irrigation sources.

These very circumstances also make flood control and drainage major problems of these regions. Apart from large dykes and embankments for flood control, farmers use a variety of devices to ensure proper drainage. Previously, waterwheels were widely used both for applying water and keeping the fields drained. In recent times, large reservoirs and energised pumping have come to play an increasing role for these purposes.

Conditions in North China are, however, markedly different: rainfall is lower and concentrated in a fewer months. But during the rainy season, the rivers – especially the Yellow river – are prone to heavy floods. Effective flood control is a prerequisite for sustaining agriculture. This calls for massive works and complex engineering. The construction of such works nearly 2500 years ago ranks among the most striking technological achievements during the early phases of Chinese history. The technology for flood control developed here was subsequently used and adapted as agriculture spread and grew in the southern regions. In recent times, the growing pressures of population and food requirements have led to an increased demand for irrigation and construction of large reservoirs which serve both for flood control and as a source of irrigation. It has also led to a rapid expansion of ground water exploitation.

Hydro capacity has increased at a phenomenal rate since 1980. Currently, China's installed capacity for hydropower (71 GW) is about a fifth of the estimated exploitable potential (378 GW). Nearly three-fourth of it calls for large sized (250 MW or more) projects mostly on the Yangtze and south and southwest river basins. At present, reservoirs with a total storage capacity of 60 bcm (including the mammoth Sanmen Gorge project across the Yangtze); additional projects with a storage capacity of 97 bcm and generating capacity of 45 mkw are planned. These developments have raised concerns on grounds of environmental impact and their desirability has become the subject of controversy.

ROLE OF COMMUNITY MANAGEMENT

Another distinctive feature of Chinese irrigation, which is also related to the predominance of relatively small systems, is a long and effective tradition of community management. The large flood control and irrigation systems which were prominent in the early phases of Chinese history were clearly not the product of local community effort. Only a strong centralised state, exercising dominion over extensive territory and large populations, could mobilise and organise men and materials on the required scale. The ability to construct such works was also a means to enlarge territories and enhance the political power of the state. The emergence and growth of early Chinese empires is, thus, linked to the importance of large-scale water control works in North China – giving rise to familiar theses of 'Hydraulic Society' and 'Oriental Despotism'.

But, as already mentioned, such large-scale works account for only a small part of the Chinese irrigation system, which is made up of relatively small systems. There is ample historical evidence to show that these were mostly constructed and managed by the local leaders – the large landowners and the gentry. Since irrigation significantly increased productivity, the landowners stood to gain from such increase and, therefore, had a strong incentive to construct these works and manage them. They also had the power to make rules and enforce them to ensure the smooth functioning of these works. The gentry-landlord control over power at the local level and their management of local irrigation systems continued to be important throughout the centuries.

The state neither contributed to, nor interfered with the functioning of these local systems. There were occasions when the higher echelons of the government were involved in expanding and integrating these systems or constructing some new systems. Their main function was to repair and maintain the large (mainly flood control) works by mobilising corvee labour.

The traditional irrigation systems of India, like those of China, were also the product of local effort born out of the landownership of landlords, temples and local chieftains. The advent of colonial rule, and the significant change in the village-level land control and power structures that followed, weakened community institutions, including those established for managing water. This led to the state taking over direct responsibility for rehabilitation of facilities which had suffered damage; in some cases, for undertaking works to improve and extend them; and, increasingly, for repair and maintenance. The state, which depended largely on land revenue, had a direct interest in ensuring that irrigation facilities were in good repair. Not only did the state intrude into the domain of traditional systems, it also constructed, financed and managed several new works. The criterion was the prospect of enhanced land revenue to cover costs and to yield a reasonable net return on investment. Attempts were made to get beneficiaries to contribute to the costs (capital and recurring), but these were eventually given up. Since Independence, large-scale canal irrigation has come to occupy a prominent place. As such, practically all new investments (including investment in the modernisation of existing small-scale works and construction of new ones) in the sector are funded by the government. Investment in privately owned groundwater irrigation also benefits from a sizeable government support in a variety of ways.

As a contrast, in China, the tradition of community responsibility for the management of such works has been maintained even after the Revolution. The dispossession of the gentry and the landlords of their land destroyed the traditional institutional arrangements of rural China and also the power structure which went with it. With the collectivisation of land ownership and cultivation (under the commune system), a new structure, in which the communist party cadres were given a central and strong role, was put in place. Under this new arrangement, communes were made responsible for developing and managing local resources; providing basic education and health services to all; and ensuring social security to the aged and the infirm. The resources for all these activities were required to be mobilised by the communes and that too after paying taxes (mainly in the form of compulsory grain deliveries) to the government. The higher levels of government also got involved and gave some financial support only for activities (including land and water development) covering several communes.

In the case of systems which served a single commune or team, the entire cost had to be borne by it. Only limited amounts (in the form of technical assistance and construction material) was given by the government. In the case of multi-commune systems, the state agencies at the prefectural/provincial levels were directly involved in planning, construction and management. They also provided part of the funding. But even in these cases, user communities had to contribute labour for construction (According to a recent estimate, nearly 30 per cent of the investment in water conservancy works was contributed by collectives). Having invested a substantial amount of their own resources, beneficiaries of even state-owned systems in China have a strong sense of stake in them. The rapid rehabilitation of irrigation facilities during the 1950s and 1960s was accomplished under this regime. The excesses and mistakes of mass campaigns (especially, during the Great Leap Phase) notwithstanding, the achievements of this decentralised, but highly organised, community-level effort are truly remarkable and unique.

As for management, the states' hydraulic bureaucracy, though large, has been concerned mostly with relatively large state projects. In the case of multi-commune systems, the maintenance of storages, main and branch canals and associated structures, the determination and enforcement of allocation rules and resolution of disputes is the responsibility of the system managers. Professional managers appointed by the government do play an important role. But they function under management committees comprising user community representatives and professionals. The management of the tertiary levels of even large systems is left to the communes and teams. They control the appointment, remuneration, etc. of the local personnel; set the rules for water distribution; and resolve disputes. Till the decollectivisation of the 1980s, the party cadres played an important role in all these activities at all levels.

Deficiencies of the irrigation systems and their management came into prominence during the 1970s when the poor quality of works done during the Great Leap, the methods of labour mobilisation (especially for large projects), shortages and maldistribution of water and its inefficient use, and poor cost recovery, figured prominently in discussions on water. How widespread these were, and what their impact was, cannot be assessed. However, detailed accounts of the problems and the attempts to solve them in a number of information specific systems are available. They reveal highly innovative and insightful approaches and sensitivity to both technical and institutional aspects.

IMPACT OF RECENT REFORMS

The abolition in the early 1980s of the communes and the introduction of contract farming on an individual basis brought about a profound change: downgrading of the role of party cadres in the communes and in the management of irrigation systems eliminated, or at least greatly weakened, the existing centres of local power which could ensure orderly management of water and mediate in conflicts. It also meant that system managers had to deal with a vastly greater number of claimants which increased the potential for disputes and conflicts over water allocation and scheduling, contribution to maintenance, and payment of water fees. Consequently, the task of management became more difficult. The net effect, predictably, was considerable deterioration in the working of the systems. More than half of the key construction projects deteriorated in varying degrees due to natural ageing, poor design and construction, illegal encroachments, and damage or destruction of system facilities. Deterioration in management resulted in a decrease in the irrigated area and this trend could be stalled only after 10 years of effort.

Reform efforts since the eighties have focussed on rationalising valuation of "water conservancy assets" and of contributions made by different levels of government and by the collectives; laying down clearer guidelines for financing investment and delineating responsibilities for management; enacting laws to define the territorial jurisdiction of irrigation systems; and laying down principles for the levy of water charges and for encouraging sideline activities to supplement them.

By all accounts, there is no significant change in the categorisation of schemes into those falling under the purview of the central government, those in the domain of the provinces and those managed by the local communities. Nor is there any change in the roles and functions of different tiers of management. The notable new development lies in formally recognising the territorial jurisdiction of various systems and empowering their managements to take preventive and corrective action against damage or destruction of their facilities.

The mechanism for periodic verification and valuation of the assets of water conservancy systems – which seems to have been in vogue since the 1950s – is being recast with a view to improving the scope and basis for evaluating contributions by different levels of government and the collectives. The idea is apparently to convert systems into corporations/cooperatives and vesting notional ownership rights in different entities (the state, the irrigation organisations and the irrigators) on the basis of their contributions to creating the facilities. These rights are to be the basis for sharing the profits arising from the operation of these corporations/cooperatives.

Changes in the internal management structures of these systems are also being made. The role of party cadres has been drastically curtailed in favour of participatory co-management. All systems, at all levels, are expected to have management committees made up of elected representatives of users and officials of government. The production teams, which used to be the basic unit of the management, have been replaced by village irrigation management groups whose members are elected by the irrigators. The management committee at each level is required to prepare and implement plans for maintenance, regulate water delivery and use, and collect water fees.

The basis of water rates is sought to be rationalised in accordance with the principles applicable to all parts of the country. The basic aim is stated to be the recovery of costs of maintenance and operational repairs as well as the costs of rehabilitation and improvement. Whether any part of capital charges are to be recovered – as the commitment to the general principle of economic pricing implies – is left unsettled. Differential pricing for different uses is recognised. The basis for irrigation charges is sought to be changed from one of a flat area-based rate into a two-tier system consisting of a flat rate per unit area and variable rates based on the volume of water used. The managements of irrigation systems are also encouraged to find ways of reducing costs and augmenting their incomes by setting up the so-called "sideline enterprises".

Innovations in management have also been reported. The most important of these is the institution of "contract management" whereby the responsibility for carrying out specific tasks (especially maintenance, repair and sideline enterprises) is entrusted to individuals or organisations on a fixed fee determined through a process of competitive bidding. The tasks to be performed, their volume and quality are specified in the contract. Contractors who do better than agreed norms are given an extra payment or allowed to keep the savings in costs. The expectation is that this will provide a strong incentive to reduce costs and improve efficiency.

Overall assessments of the progress of the reform or its impact are not available. However, several case studies of the reform experiments have been reported. Reading between the lines, one can get some idea of the problems encountered in implementing reforms. Poor management, overstaffing, excessive bureaucratisation, inadequate cost recovery and resistance to increased water rates continue. So do the problems in ensuring effective collection of dues. Solutions to overstaffing – which involve laying off people already on the rolls of the irrigation organisations – remain elusive. Contract management seems to raise new problems, such as reconciling it with the concept of co-management and profit-sharing among stakeholders, as well as the subjectivity of performance norms and the difficulty of monitoring their compliance. Issues concerning redefinition of rules of water allocation between and within systems, measures to reduce waste and increase the productivity per unit of water, and the mechanisms for securing acceptance and effective compliance with stricter rules in the context of individual farming and the manner in which they are being addressed under the new institutional structure, do not figure prominently in the discussions on reforms; nor do the problems of pollution of water bodies and depletion of ground water. The impact on overall performance of the systems also seems to be unclear. Chinese discussions on the subject underscore the experimental nature of the reforms, China's awareness of the problems and its willingness to learn from experience.

Some Western observers paint an alarming picture of growing water scarcity and water pollution and raise doubts about China's capacity to meet its growing food requirement from its own production. There is reason to believe that some of these fears are exaggerated (especially on shortage of water because of vast scope for reducing waste and improving control over timing and volume of irrigation). But concerns about pollution and ground water depletion are better grounded.

There is growing evidence of over-exploitation of both surface and ground water in the region – reflected in the diminishing of downstream flows in the rivers and progressive lowering of the ground water table. Shortage of surface water and the depletion of ground water in the northern regions has, of late, stimulated considerable interest in the possibility of diverting water from the more abundantly endowed southern river basins. There is also a heightened interest in the construction of large reservoirs as a source of hydro-electric power, and also for flood control.

Many of these problems have also become serious concerns in India. But these cannot be solved by engineering; they call for policies and institutions which will provide strong incentives for judicious and efficient use of water and arrest the alarming spread of pollution. The two countries have much to learn from each other, but this would require much closer, more frequent and continuing interchange of knowledge and experience between water professionals (not just engineers) in the two countries.

NOTES

1. This article is based on the author's review of the available literature on Chinese irrigation (summarised in Vaidyanathan, 1999), a series of papers on the experience of the past reform period presented at an International Conference on Irrigation Management Transfer held in 1994, (Johnson, *et al* 1995) and recent debate of the prospects of water scarcity and food production in China (Brown and Hazell, 1998; and Helig, *et al* 2000).
2. The near trebling of irrigated area in such a short period probably reflects the fact that much of the infrastructure already existed in 1950, but was in a serious state of disrepair. It is noteworthy that at that time, less than 40 per cent of irrigated area was served by gravity canals, and nearly an equal area by farm ponds and ditches.
3. According to Chinese definition 'big' reservoirs are those storing more than 100 mm^3 of water; and medium are those storing 10 to 100 mm^3.
4. Note that gross utilisation from surface source is about twice the reservoir capacity. Some storages are replenished more than once partly or fully during the rainy season as the volume of water used is likely to be much higher than the storage capacity.

5. Historically, Chinese farmers used manually operated waterwheels (estimated at 1.5 mn at the turn of the century) for lifting water from surface ponds/channels. Most of these have since been replaced by energised pumps.

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GROUND WATER RECHARGE : OPTION FOR GROUND WATER MANAGEMENT

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In the past five decades since independence, India has witnessed phenomenal development of ground water resources and has successfully met the demand for water for diverse uses. As a result, the country has achieved self-sufficiency in foodgrains besides providing assured drinking water throughout the country except for a few problem areas. Because of distinct advantages like ubiquitous presence, wide distribution, assured, timely and dependable supply, and because of the ground water abstraction structure being under the direct control of the user, it has come to stay as a preferred source for various uses. Dependence on ground water for irrigation has increased due to introduction of high-yielding crops and adoption of multi-cropping pattern of agriculture. Rapid development of ground water resource from about 5% in 1951 to 37% in 1998, has led to the problem of declining ground water levels in certain high demand areas. In the third millennium, demand for water will further rise to 784 to 850 BCM in 2025 and 973 to 1180 BCM in 2050. Ground water management options would need to be oriented towards maximising the availability of ground water. Artificial recharge techniques by harvesting the surplus monsoon runoff have proved to be effective in augmenting ground water storage.

Uncontrolled exploitation of the ground water resources for meeting the increased demand for water coupled with increased urbanisation has resulted in declining ground water levels. Besides, haphazard disposal of untreated urban and industrial wastes and excessive application of fertilisers and pesticides/insecticides in agricultural fields has resulted in the deterioration of ground water quality thereby further reducing the availability of fresh ground water resources. Urgent measures are, therefore, required for conservation and augmentation of ground water resources.

GROUND WATER RESOURCE AVAILABILITY

Ground water resource has two components viz. static and dynamic. The static fresh ground water resources (aquifer below the zone of water level

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fluctuation), which have accumulated after a long period of time, have been estimated as 10812 billion cubic metres (bcm). As per the National Water Policy, development of ground water resources is to be limited to utilisation of the dynamic component of ground water which is replenished annually consequent to rainfall. The present development policy, therefore, forbids utilisation of static reserves to prevent ground water mining. The dynamic resource has been assessed as 432 bcm. After making a provision of 71 bcm for domestic, industrial and other uses, the available ground water resources for irrigation have been assessed as 64.05 million hectares (mha). State-wise availability of in-storage and replenishable ground water resources is given in Table1.

Table 1 : State-wise Ground Water Resources Availability

State	Replenishable Ground Water Resources (bcm)	In-storage ground water resources (bcm)		
		Alluvium/ Unconsoli-dated Rocks	Hard Rocks	Total
Andhra Pradesh	35.3	76	26	102
Arunachal Pradesh	1.4	—	—	—
Assam	24.7	92	—	92
Bihar	33.5	2557	11	2568
Goa	0.2	—	—	—
Gujarat	20.4	92	12	104
Haryana	8.5	42	1	421
Himachal Pradesh	0.4	13	—	13
Jammu & Kashmir	4.4	35	—	35
Karnataka	16.2	—	17	17
Kerala	7.9	5	6	11
Madhya Pradesh	50.9	14	27	41
Maharashtra	37.9	16	22	38
Orissa	3.2	162	13	175
Punjab	18.7	91	—	91
Rajasthan	12.7	115	13	128
Tamil Nadu	26.4	98	—	98
Tripura	0.7	101	—	101
Uttar Pradesh	83.8	3470	30	350
West Bengal	23.1	1625	1	1626
Total UTs	0.4	4	—	4
Total	431.9	10633	179	10812

STATUS OF GROUND WATER DEVELOPMENT

Ground water development programme in the country is generally restricted to shallow zones within 50 metres depth and is primarily sustained by investment by farmers themselves or through finance obtained as loan from the institutional sources. The public sector outlay is limited to only such items as ground water surveys, construction of deep tubewells for community irrigation, services provided and grants extended to small and marginal farmers. The programme of ground water development, therefore, poses less burden on the public exchequer.

The past five decades have witnessed phenomenal increase in the growth of ground water abstraction structures due to technically viable schemes for development of the resource backed by liberal funding and availability of power and diesel, good quality seeds, fertilisers, Government subsidies, etc. The green revolution in the post-Independence era has also led to excessive development of ground water particularly in northern parts of the country. Further, during periods of drought, there is additional dependence on ground water since the storage dwindles in surface reservoirs and the impact of vagaries of weather on ground water is not pronounced and is normally delayed.

Ground water development has occupied an important place because of its role in stabilising Indian agriculture and its usefulness as a means for drought management. The stage of ground water development in the country, as estimated in 1991 was 32%. Upto March, 1998, the stage of development reached approximately 40% of the available ground water resource for irrigation. This is evident from growth of ground water abstraction structures from the pre-Plan period till date. The number of ground water abstraction structures has increased from merely 4 million in 1951 to nearly 17 million in 1997. This rapid pace is likely to continue, since the surface water resources are fully committed. With the growth of ground water abstraction structures, there has been considerable increase in irrigation potential from ground water, which has increased from 6.5 mha in 1951 to 45.73 mha in 1997. The growth of abstraction structures and irrigation potential since 1951 is given in Table 2.

Table 2 : Growth of Ground Water Abstraction Structures ('000) and Irrigation Potential (mha)

Year ending (March)	Dugwells	Private tube-wells	Public tube-wells	Total	Cumulative irrigation potential created from ground water
1951	3860	3	2.4	3865.4	6.50
1980	7786	2132	33.3	9951.3	22.00
1985	8742	3359	46.2	12147.2	27.82
1990	9407	4754	63.6	14224.6	35.62
1992	10120	5379	67.6	15566.6	38.89
1997	10501	6743	90.0	17334.0	45.73

IMPACT OF DEVELOPMENT ON GROUND WATER RESOURCES

The rapid pace of water resources development during the past five decades has led to many problems. In many arid and hard rock areas, overdraft and associated quality problems are increasingly emerging. In 231 blocks (out of total of 4272) in various states in the country, besides 6 mandals in Andhra Pradesh and 12 talukas in Gujarat, situation of overdraft exists, i.e. the stage of ground water development has exceeded the annual replenishable resource. In addition, 107 blocks all over the country besides 24 mandals in Andhra Pradesh, 14 talukas in Gujarat and 34 watersheds in Maharashtra are 'dark', i.e.

the stage of ground water development is more than 85% of the annual replenishable resource. State-wise details of over-exploited and dark areas are given in Table 3. The overdraft has resulted in failure of wells, shortage of water supplies necessitating increased pumping lifts and pumping costs and even salinity ingress in coastal areas.

On the other hand, large areas particularly in the command areas of major and medium irrigation projects suffer from waterlogging and soil salinity or alkalinity problems. Further, high intensity of irrigation without adequate drainage also results in upward movement of water table and increases chances of waterlogging conditions to develop. As per the assessment made by the Working Group on Problem Identification in Irrigated Area with Suggested Remedial Measures (1991), about 2.46 mha of the area under surface water irrigation projects is waterlogged or threatened

Table 3 : Categorisation of Blocks/Mandals/ Talukas/Watersheds as Over-Exploited and Dark on All India Basis

State/UT	No. of Districts	No. of Blocks/Mandals/ Talukas/Watersheds				
		Total	Over Exploited		Dark	
			No.	%	No.	%
Andhra Pradesh	23	1104	6	0.54	24	2.17
Arunachal Pradesh	8	48				
Assam	23	134				
Bihar	42	585			1	
Goa	3	12				
Gujarat	19	184	12	6.52	14	7.61
Haryana	16	108	45	41.67	6	5.56
Himmachal Pradesh	12	69				
Jammu & Kashmir	14	123				
Karnataka	19	175	6	3.43	12	6.86
Kerala	14	154			1	0.65
Madhya Pradesh	45	459			3	0.65
Maharashtra	30	1053			34	3.23
Manipur	6	26				
Meghalaya	5	29				
Mizoram	3	30				
Nagaland	7	21				
Orissa	27	314				
Punjab	12	118	62	52.54	8	6.78
Rajasthan	30	236	85	36.02	11	4.66
Sikkim	4	4				
Tamil Nadu	21	384	54	14.06	43	11.20
Tripura	3	17				
Uttar Pradesh	63	895	19	2.12	22	2.46
West Bengal	16	341				
No. of Blocks (Except Andhra Pradesh, Gujarat & Maharashtra		4272	231		107	
No. of Mandals (Andhra Pradesh)		1104	6		24	
No. of Taluks (Gujarat)		184	12		14	
No. of Watersheds (Maharashtra)		1503			34	

Andhra Pradesh	1104 Mandals/309 Blocks
Gujarat	184 Talukas/218 Blocks
Maharashtra	1503 Watersheds/231 Talukas/366 Blocks

Note : Over-exploited blocks are blocks in which level of ground water development is more than 100% of annual ground water recharge.

Dark blocks are blocks in which level of ground water development is more than 85% and within 100% of annual ground water recharge.

by waterlogging. The area affected by soil salinity is estimated as 3.06 mha and that by soil alkalinity as 0.24 mha.

The unscientific development of ground water in some coastal areas in the country has led to landward movement of sea water – fresh water interface resulting in contamination of fresh water aquifers. Problem of salinity ingress has been noticed in Minjur area of Tamil Nadu and Mangrol – Chorwad – Porbandar belt along Saurashtra coast. Over-pumpage from freshwater aquifers has caused flow of water from the underlying saline aquifers. This has rendered a number of tubewells out of use. Further, shallow wells, which used to yield freshwater in Pondicherry region east of Neyveli Lignite Mines, have started yielding saline water due to salinity ingress. It has been established that the interface has moved 6 km landwards.

Changes in ground water quality have been observed in major agricultural and industrial belts and urban complexes. This has been due to over-use of fertilisers, pesticides/ insecticides in agriculture and haphazard disposal of untreated urban and industrial wastes. Pollution due to human and animal wastes and fertiliser application has resulted in high levels of nitrate, potassium and phosphates in ground water in parts of Bihar, Haryana, Gujarat, Orissa, Uttar Pradesh and National Capital Territory of Delhi. Fluoride concentrations above permissible limit for drinking purposes have been reported in parts of Andhra Pradesh, Haryana, Madhya Pradesh, Orissa, Punjab, Rajasthan and Uttar Pradesh. Pollution of ground water with toxic chemicals in the vicinity of industrial zone of Faridabad with higher concentrations of chromium, copper, nickel and zinc have been reported. In Ludhiana, ground water is polluted with chromium. In Rajasthan, pollution of ground water occurs in Udaipur, Pali, Khetri and Jodhpur. From Kanpur city in Uttar Pradesh, higher concentrations of chromium and iron have been reported. In Warangal city in Andhra Pradesh, effluents from textile industries have affected the ground water quality in a localised area. In Tamil Nadu, discharges from tanneries have affected ground water quality in the area.

In addition to the above problems caused by human interference, natural factors have also affected the ground water quality. It has been estimated that over 1.93 lakh sq km area in parts of Haryana, Punjab, Delhi, Rajasthan, Gujarat, Uttar Pradesh, Karnataka and Tamil Nadu is affected by inland salinity in ground water (EC>4000 micromhos). Saline/ brackish ground water resources upto the depth of 300 metres below ground level in alluvial areas and 100 metres below ground level in hard rock areas have been estimated to be of the order of 1164 bcm. Further, occurrence of high content of iron in North-eastern states and arsenic in eight districts of West Bengal is also a critical problem.

PROJECTED WATER DEMANDS

While the availability of fresh water is decreasing, the demand for water of various use sectors is increasing with the growth of population. India's population has already crossed one billion, putting additional pressure on natural resources and hampering the development task. Depending upon the country's capacity to contain population growth, adoption of water saving techniques, rate of growth of gross domestic production, rate of growth of expenditure and a host of other factors, the total water requirement for various uses by the year 2050 as estimated by the National Commission for Integrated Water Resources Development Plan is expected to vary between 973 and 1180 bcm. Water requirements for various use sectors in the years 2010, 2025 and 2050 are given in Table 4.

Table 4 : Estimated Sectoral Water Requirements

(in bcm)

Uses	Year 2010		Year 2025		Year 2050	
	Low	High	Low	High	Low	High
Irrigation	543	557	561	618	628	807
Domestic	42	43	55	62	90	111
Industries	37	37	67	67	81	81
Energy	18	19	31	33	63	70
Inland Navigation in addition to Ecological Need	7	7	10	10	15	15
Flood Control	–	–	–	–	–	–
Environment						
i) Afforestation	–	–	–	–	–	–
ii) Ecology	5	5	10	10	20	20
Evaporation	42	42	50	50	76	76
Total	694	710	784	850	973	1180

The annual average water availability in terms of replenishable utilisable water resources of the country has been estimated at 1086 bcm (690 bcm from surface water considering that the available surface water resource shall be completely tapped +396 bcm from ground water). The per capita availability of utilisable water, which was 3000 cubic metres in the year 1951 is now about 1100 cubic metres and would reduce to 660 cubic metres by the year 2050. The water availability at national average, in the year 2010 shall be below 1000 cubic metres and shall start hampering health, economic development and human well-being.

ARTIFICIAL RECHARGE – AN INESCAPABLE MANAGEMENT OPTION

Keeping in view the increased demands of water for various uses and decreased availability of fresh water resources, it would be a difficult task at the national level to increase availability of water. By the middle of the third millennium, surface water resources shall be fully committed. Consequently, there would be additional stress on ground water. Concerted efforts are, therefore, required at the national as well as regional levels to transform all types of water into utilisable category.

Artificial recharge of ground water is one of the management options, which is being practiced in many countries. It contributes to effective quantitative water resources management, safety and continuity in water supply. It is, therefore, going to be one of the important planning necessities for the country in the times to come. The ground water reservoir offers technically feasible alternative to store additional quantity of water available in the country during monsoon. The storage of water underground minimises evaporation losses and requires no storage space on surface. The artificial recharge besides conserving the surplus run-off arrests and even reverses declining ground water levels. In coastal areas, artificial recharge measures are effective in pushing back the sea water-fresh water interface. In areas affected by ground water pollution, artificial recharge helps in improving ground water quality through dilution.

Rainfall which is the main source of recharge to ground water is not uniform in time and space throughout the country. In some areas, there occurs excessive rainfall causing high run-off and even floods. Even in low rainfall areas, showers of high intensity occur a couple of times in the monsoon period every year, which produce flash floods. Out of 4000 bcm of average annual precipitation in the country, about 1150 bcm is annually lost as surface run-off. By harvesting this surplus monsoon run-off, the problem of water scarcity can be solved to a great extent. Based on the preliminary studies, a National Perspective Plan has been prepared for recharge to ground water by utilising surplus monsoon run-off. The ground water storage potential in the country is summarised in Table 5.

Table 5 : Ground Water Storage Potential

(in bcm)

Water available for recharge	872
Water required to create sub-surface storage upto 3 m below ground level	591
Feasible ground water storage	214
Utilisable ground water storage potential	160

Most of the peninsular river basins are occupied by hard rock terrain where run-off is very high due to low infiltration rate. Special attention needs to be paid in such areas to augmenting ground water storage. Technique of hydrofracturing can be employed in hard rocks to increase the secondary porosity to augment recharge to ground water.

Recharge Worthy Areas

A number of hydrogeological situations located in various parts of the country provide ample scope for artificial recharge of ground water. The

Himalayan foothills and intermontane valleys comprising of piedmont deposits are extremely suitable for the recharge to ground water reservoir by adopting various spreading techniques. The Bhabar-Terai belt in Uttar Pradesh, Kandi-Sirowal tract in Jammu and Bist-Doab tract in Punjab having steep slopes are occupied by fan deposits. The water levels in these tracts are deep due to high run-off. The infiltrated water that is being subsequently generated as base flow to various rivers can be harvested by constructing suitable water retention structures which, in turn, will augment ground water thereby resulting in rise in ground water levels in the higher reaches.. The desert areas of Rajasthan are characterised by scanty rainfall and high evapo-transpiration rates requiring use of recharge techniques that employ quick transport of run-off water so as to minimise evapo-transpiration losses. Alluvial aquifers of Gujarat are suitable for recharge through construction of spreading basins and check dams in the recharge zone. The karstic terrain in parts of Madhya Pradesh, Maharashtra and Andhra Pradesh is favourable for construction of recharge structures like spreading basins, check dams and small capacity percolation ponds. The talus and scree deposits occurring in Satpura mountain front in parts of Maharashtra are favourable locales for artificial recharge. In peninsular India which is mostly underlain by rocks of Archaean basement complex and Deccan Traps, recharge structures, such as check weirs, gully plugs, check dams, percolation tanks, etc. are feasible depending upon the topography, thickness of the weathered/fractured zones, continuity of fractures and climate.

Various Techniques of Artificial Recharge

A wide spectrum of artificial recharge techniques are in use. They vary from place to place depending upon the hydrogeological framework of the area. Figure 1 gives broad categorisation of recharge techniques. Table 6 indicates different recharge measures being practised in various parts of the world.

Aquifer Storage Recovery

The aquifer storage recovery (ASR) being followed in many parts of the world is a technique for storing water underground through wells during times when it is available and recovering this water from the same wells when needed to meet peak, long term and emergency water needs. ASR technique is being applied throughout the United States, and also in Canada, England, Australia, Israel and other countries This technique has proved to be a viable, cost-effective option for storing large volumes of fresh water in fresh, brackish and other non-potable aquifers at depths upto 900 metres. This technique, however, still remains to be tried in India. Looking at the success achieved through ASR in

Figure 1 : Artificial Recharge Techniques

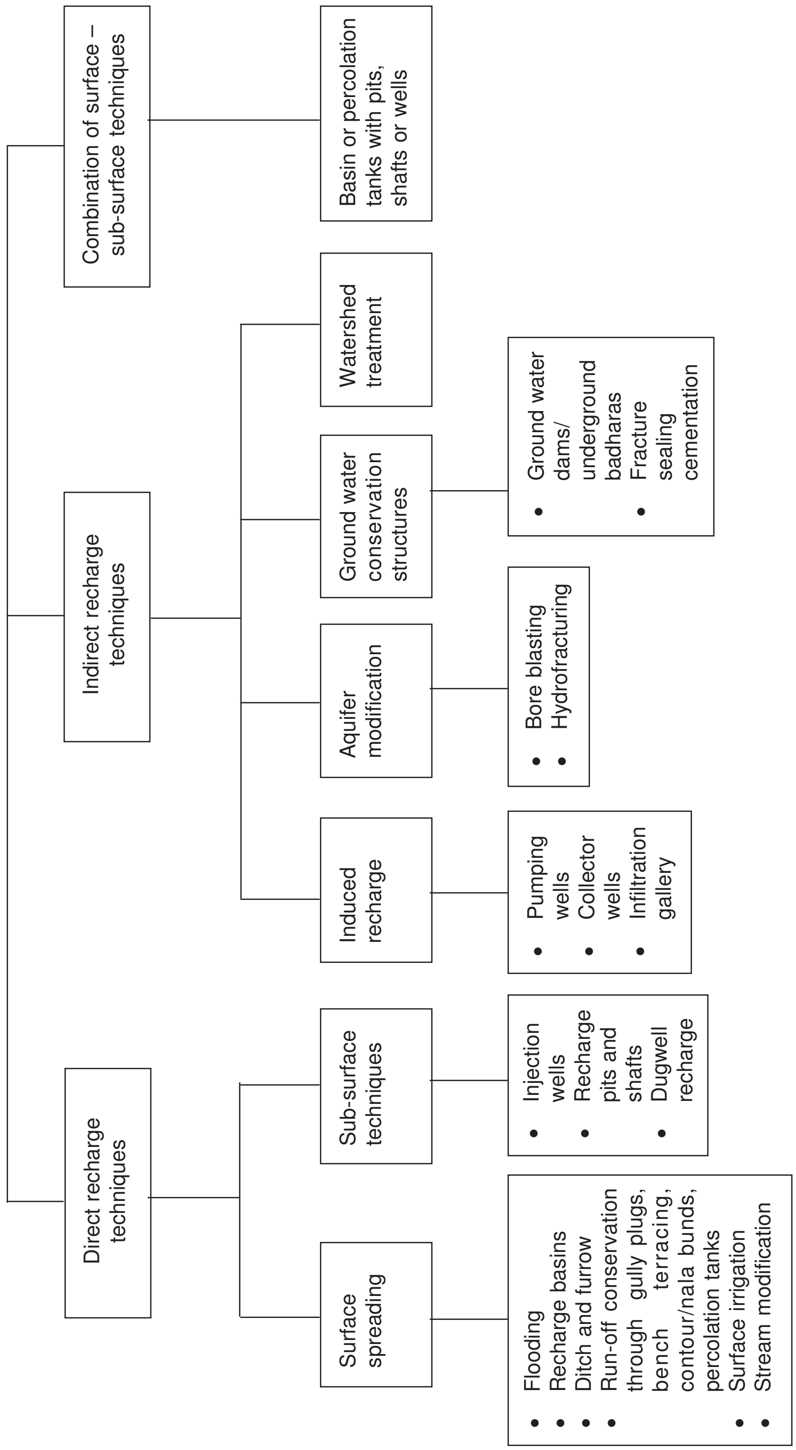

Table 6 : Recharge Practices in Various Parts of the World

	Type of artificial recharge structure	Purpose
California	Spreading basins, injection of treated waste water	To eliminate the overdraft and reverse sea water intrusion thereby improving water quality.
Paris	Spreading basins	To ensure sustainable water quality in over-drawn alluvial aquifers, where tank filtered water is limited in quantity and quality.
Kuwait	Waste water recharge through infiltration ponds	To tackle problem of depletion of brackish ground water.
Amsterdam Dune area	Injection Wells	To maintain water supply to the area.
South Australia	Aquifer storage and recovery – injection of treated waste water	To sustain ground water systems, to reduce reliance of urban areas on imported water.
Israel	Soil aquifer treatment	Urban waste water treatment and water reclamation for agricultural use.
Vienna	Recharging wells	To raise water levels and improve water quality.
Oman	Recharge dams	To improve ground water potential.
Finland	Sprinkling infiltration	For dilution of nitrates.
United States	Aquifer storage recovery	To store large volumes of water to meet peak, long term and emergency demands.
England	Aquifer storage recovery	Decrease in concentration of Fluoride and denitrification.

many countries, there is need to plan trial of this technique at suitable locations in the country.

Efforts Made for Recharge

A number of artificial recharge studies have been conducted by the Central Ground Water Board. The details of these studies are summarised in Table 7.

Many state governments are also implementing artificial recharge projects. A number of percolation tanks, check dams, sub-surface dykes, underground bandharas, different types of weirs etc. have been built in various parts of the country. Chennai Metro Water Board has made roof-top rain-water harvesting mandatory by incorporating the same in building bye-laws. District

Table 7 : Details of Artificial Recharge Studies Conducted by Central Ground Water Board

Site	Method adopted	Details of experiment	Results
Tatiana village, Kurukshetra district., Haryana on the left bank of Ghaggar river	Induced recharge	A test well and 4 observation wells tapping unconfined aquifer of fine to medium sand with kankar and gravel were constructed. Pumping test i.e. pumping water from the test well @ 1728 m^3/ day was conducted.	Resistance of 94 m of the river bed indicated high degree of clogging of the river bed. If well is pumped @ 1728 m^3/ day, about 97% of well discharge is contributed by the river after 94 days of continuous pumping in the form of induced recharge. Periodic declogging of river bed is required to achieve better results.
Dabkheri, Narwana branch canal, Kurukshetra district., Haryana	Injection method	Two test wells and four Ows were constructed. Water was injected @ 40 lps. After 44.5 hours of injection, the rate was increased to 57.7 lps and continued for five hours after which injection was again continued @ 40 lps upto 389.75 hours. Injection rate was further reduced to 22 lps and was stopped after 413.75 hours.	Hydrogeological conditions of the areas are suitable for recharge injection method. Quality of canal water was suitable for injection.
State Seed Farm, Ananganadi, Kerala	Sub-surface dyke	160 meters long sub-surface dyke of plaster brick and tar rate sheets was constructed	Considerable increase in the availability of ground water on the upstream site.
Kamliwara, Mehsana Distt. Gujarat	Injection well	A 15-meter deep and 35 cm dia. source well constructed in Saraswati River Bank for supplying silt-free water to 125 meter deep injection well. Recharge performed @ 18 lps and 12 lps for the period of 100 minutes each. Same wells were used for injection of water for recharge through siphon @ 22.5 m^3/ day for 250 days.	A total of 173 m^3/ day was injected. Dissipation of recharge amount was complete after 45 hours. Build-up of 5m in the injection well and rise of water level from 0.6 to 1 m in wells 150 m away was recorded.
Mehsana, Gujarat	Spreading	Silt-free canal water was spread into a channel of 3.6 m width, 400 m length with 1 in 1 side slope.	Water was recharged @ 2605 m^3/ day. Build-up of 2 to 1.84 m in 50 days upto 15 m from the channel and 20 cm @ distance of 200 m from the channel was recorded.

Table 7 (Contd...)

Site	Method adopted	Details of experiment	Results
Chorwad and Malia area, Saurashtra Coast, Gujarat	Spreading and Injection	Recharge carried out through 1 km long and 1 m deep spreading channel and an injection shaft.	Water recharged @ 192 m^3/ day through spreading channel and 2600 m^3/ day through injection shaft.
Watershed T.E.17, Yaval Taluka, Jalgaon Distt., Maharashtra	Percolation tanks	6 percolation tanks of total storage capacity of 4.46 lakh m^3	A total of 6.81 lakh m^3 of water recharged. Rise of 1 to 5 m in ground water levels reported over an area of 545 ha.
	Recharge shafts	2 recharge shafts of 1920 m^3/ day recharging capacity.	12000 m^3 of water was recharged and an area of 4.7 ha was benefited.
	Injection well	1 injection well of 265 m^3/ day recharging capacity.	3770 m^3 of water was recharged and an area of 0.75 ha was benefitted.
	Dugwell recharge	1 dugwell of 960 m^3/ day recharging capacity	6580 m^3 of water was recharged and an area of 1.30 ha was benefited.
Watershed WR-2, Warud Taluka, Amaravati Distt., Maharashtra	Percolation tanks	3 percolation tanks of gross storage capacity of 4.90 lakh m^3.	2.98 lakh m^3 water was recharged and an area of 280 ha was benefited. Rise in ground water levels of 4 to 10 m.
	Cement plugs	10 Cement plugs with gross stoage capacity of 40050 m^3.	46743 m^3 of water was recharged and an 86 to 105 ha area was benefitted. Rise of 0.5 to 4 m recorded in ground water levels.
NCT of Delhi	Check dams	4 Check dams constructed in JNU, IIT and Sanjay Van Area. Catchment area varied from 0.45 to 1.26 sq km Reservoir capacity varied from 4600 to 22180 m^3 and water spread area varied from 9569 to 20243 sq meters.	Recharge of 75720 m^3 of water effected. Area of 75 ha benefited and rise of 0.33 to 13.7 m in ground water level recorded.
	Roof Top Rain Water Harvesting	Harvesting system constructed in IIT campus. Water harvested was recharged to ground through injection wells and an abandoned dug-well.	Rise of 2.29 to 2.87 m In ground water level reported over an area of 1 ha.
Chandigarh	Roof Top Rain Water Harvesting	Harvesting system at one of the CSIO buildings having roof top area of 3550 sq. m. Harvested water recharged through recharge well.	3794 m^3 of water recharged and rise of 2 m recorded in ground water levels.

Table 7 (Contd...)

Site	Method adopted	Details of experiment	Results
Gauribidanur and Mulbagal Talukas, Kolar Distt., Karnataka	Percolation tanks, watershed treatment, gravity recharge wells, point recharge structures and roof top rain water harvesting.		• Watershed management in Basakpura enhanced ground water recharged by 2 to 3 times. • Crop intensity increased to 2-3 crops per year. • Cash crops are being grown. • Higher crop intensity created more employment for agricultural workers. • Observation wells in the command recorded rise of 1 to 3.5 mts.

Administration in Dewas, Madhya Pradesh has also made roof-top rain-water harvesting mandatory for houses with tubewells. The water is collected from the roofs and recharged through tubewells. Several NGOs and VOs are also engaged in implementing rain-water harvesting and artificial recharge in different parts of the country. NGOs/VOs have played a catalytic role in mobilising the villagers to adopt rain-water harvesting and watershed treatment measures. They have also encouraged the farmers to revive the traditional water harvesting structures. The results of these efforts have been very encouraging. In West Bengal, recharge experiments conducted in the arsenic infested areas have proved to be effective in improving the quality of ground water by way of dilution.

Encouraged by the results of various recharge studies conducted so far, a scheme on artificial recharge in various parts of the country has been launched under which technical and financial assistance is being provided by the Ministry of Water Resources to the implementing agencies.

CONCLUSION

The present availability of 240 bcm of surface water (170 bcm created so far and 70 bcm to be created through on-going projects) and 432 bcm of replenishable ground water resources shall not be able to fulfil the projected water demands of 784 to 850 bcm in the year 2025. Augmentation of ground water through artificial recharge by harnessing surplus monsoon run-off is, therefore, the key option that needs attention of planners, administrators as well as individuals. Efforts are also needed to use the available water resources in an optimal manner so as to avoid wastage of water.

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WATER MANAGEMENT : SOME ISSUES

Dr. Rita Sharma*

India's land and water resources are under considerable stress as the race between food production and population growth surges relentlessly forward. With 4 percent of the world's water resources and 18 percent of its population, the country will be hard pressed to meet the water requirements of the various growing sectors. Estimates of water availability vis-a-vis requirement in 2050, present a not so optimistic picture. Water use will need to be rationalized through greater efficiency if the supply and demand is to match. Irrigation is the single largest user of water. The agriculture sector will, therefore, need to produce more food with less water. This article examines various aspects of water management as they relate to the agriculture sector. It is clear that water management is as much organizational and social as it is technical. There can be no easy, ready-made answers. A holistic approach encompassing a suitable mix of policy reform, institutional changes and technology options is required if lasting solutions are to be found. These may comprise the following: (i) watershed approach to rainfed farming, (ii) water pricing reflecting opportunity costs, (iii) water use efficiency, (iv) entitlements, (v) government and social regulation of over-exploitation and inequitable mining of groundwater, (vi) suitable legislation, (vii) conjunctive use of ground and surface water, (viii) improvements in on-farm water management, (ix) promotion of water-saving micro-irrigation technologies, such as drip-irrigation, (x) development of drought resistant varieties. Interestingly, the National Water Policy (1987) and the recently announced National Agriculture Policy encompass most of the aforesaid aspects of water management. The policy statements, though, do not have the back-up of institutional structures and mechanisms, enabling legislation, nor the supporting economic incentive structures. These must necessarily be provided by the State Governments where the policies are to be translated into action. At the cutting edge level, the task is made more complex by the large number of stakeholders each having with his own perceptions of what the problems are and each having his own vested interests. Implementation and enforcement of management measures are impossible, not to mention prohibitively expensive, unless stakeholders agree to the measures and assist in implementing them. The

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role of the State as an enabler and facilitator could create the opportunities for communities to participate in water management. By doing this, it would allow society as a whole to tap the wellsprings of management capabilities that exist both at local levels and in the government. Such a participatory approach could provide the framework within which lasting solutions may be possible.

BACKGROUND

With the dawn of a new millennium the biggest challenge faced the world over is one of sustainable use of the earth's natural resources. India's land and water resources are under considerable strain. The country accounts for only 2 per cent of the world's geographical area and 4 per cent of its water resources, but supports 18 per cent of the world's population and 15 per cent of its livestock. The availability of water to meet the demands of a growing population – while sustaining a healthy natural environment – has emerged as one of the primary resource issues that needs to be addressed. These concerns are based on uncertainties about the availability of supplies stemming from the vicissitudes of the Monsoon, a growing population and, more recently, the prospect that greenhouse-induced climate changes will alter the hydrologic cycle in uncertain ways.

The single largest demand for water comes from irrigation. There is a growing realisation that in the race between food production and population growth our search for ever-higher productivity is placing great strain on the natural resource base that supports agriculture. Increasing dependence on water for irrigation depletes aquifers and watercourses, causing shortages for other users and increasing waterlogging and soil salinity. Inefficient use of irrigation water puts pressure on other users and imposes environmental costs. The overuse of chemicals to intensify crop production is polluting both water and soil resources. This article examines issues related to growing water scarcity and the management of this natural resource in the context of agriculture.

WATER AVAILABILITY AND REQUIREMENT

The water availability per capita per annum presently is at a comfortable level of 2100m^3. This macro statistic, however, conceals the highly uneven spatial and temporal nature of water resources distribution in the country. Over 80 to 90 per cent of the runoff in Indian rivers occurs in the four monsoon months of the year and regions of harmful abundance co-exist with areas of acute scarcity. Excess rainfall in the catchments of eastern rivers leading to floods in the north-eastern states may well be as devastating as drought in Gujarat and Rajasthan caused by deficient rainfall. The country must grapple with several critical issues in dealing with water resource development and management.

The extent of variation in distribution of water resources is evident from the fact that the Ganga-Brahmaputra-Meghna basin, which accounts for 60 per cent of the total water resource flows, occupies 33 per cent of the geographical area. West flowing rivers south of Tapi account for 11 per cent of the total water resource, whereas the basin occupies only 3 per cent of area. The remaining 64 per cent of the area has a water resource of only 553 Km^3 i.e. 29 per cent.

The entire country has been divided by the Central Water Commission into 24 basins.[1] Annual mean flow in a river basin is estimated as water resource of the basin. The total water resource of the country is estimated now at 1953 Km^3. Of this, the utilisable flow is 690 Km^3. The total replenishable ground water is estimated as 432 Km^3. Of this, 396 Km^3 is estimated as utilisable – 71 Km^3 (18 per cent) for domestic, industrial and other uses and 325 Km^3 (82 per cent) for irrigation. Nearly 50 per cent of irrigation in the country is by ground water. Total quantum of utilisable water, including both surface and ground water, is estimated at 1056 Km^3

Estimates of water requirements, based on population growth, food demand, agricultural, industrial and civic needs, have been made for the years 2010, 2025 and 2050 at the national level. The total water requirement of the country, thus, would be 694 to 710, 784 to 850 and 973 to 1180 Km^3 by the years 2010, 2025 and 2050, respectively, depending on a low-demand and high-demand scenario. According to this estimate, in 2050 the country's utilisable water availability of 1056 Km^3 will scarcely be able to match the low-demand scenario (973 Km^3) leave alone the high-demand one (1180 Km^3). Irrigation would continue to have the highest water requirement, between 628-807 Km^3 (or about 68 per cent of total water requirement) followed by domestic water use, including drinking and bovine needs, at about 90-111 Km^3 (or about ten per cent of total water requirement). The projected water use per capita per year in the year 2050 would be about 725-750 m^3 as compared to about 650 m^3 at present[2]. The availability per capita per year currently estimated at a comfortable 2100 m^3 would be reduced to stress level of 1700 m^3 by 2025 and scarcity level of 1236 m^3 in 2050.

These averages hide important regional and temporal variations. Despite the apparent abundance and renewability, freshwater can be scarce virtually everywhere at some time, especially in the arid and semiarid regions of the western India and the deccan plateau. In areas where the balance between aggregate availability and aggregate requirement of water is tenuous, the issue of equity in the access to water between sections of population assumes greater importance. Since water resources are finite and demand from the various sectoral users is rising rapidly, wise stewardship of water resources and prudent management are required to overcome the inefficiencies that currently plague the water sector.

IRRIGATED AGRICULTURE

In the past three decades or so, the country has acquired a measure of drought-proofing against food scarcity consequent to the Green Revolution, which was propelled by irrigation. Without advances in irrigation technologies and the investments in the public and private sector, food security would have been tenuous. The spread of storage dams, canal systems, tubewells and lift pumps, more than doubled the net irrigated area, thereby enabling *rabi* foodgrain output to match *kharif* production. Tubewell technologies, in particular, were instrumental in spreading modern agricultural practices from Punjab, Haryana and western UP to the hitherto by-passed, high-groundwater potential, eastern regions. Development of active water markets enhanced access to groundwater. In this manner, food production became insulated from the adverse effects of water scarcity and drought. Compared to the droughts of the mid-1960s which witnessed food-aid and PL 480, the droughts of 1979-80 and 1987-88 were tided over with domestic supplies. Recently, despite the fact that large parts of Gujarat, Rajasthan and Andhra Pradesh suffered from a drought-like situation the nation achieved a record foodgrain production of over 205 million metric tons.

Irrigation technologies are proving to be as much Pandora's Box as cornucopias. Fifty per cent of irrigated area relies on traditional surface systems based on canals and gravity flows. Their design is often too inflexible to provide water with the timeliness and the predictability that farmers desire, as they adopt improved crop varieties and turn to intensified and diversified cropping systems. Instead, water is delivered on arbitrary schedules and for limited periods of time. With incentives for use further distorted by subsidised prices, farmers respond by taking as much water as possible while they can. The results are often wasted water, waterlogging, leaching of soil nutrients and excessive runoff of agricultural chemicals with drainage water.

Tubewell technology is also proving to be a double-edged sword. Careless on-farm water management and indifferent agronomic practices are leading to water scarcity and inequitable distribution of this common property resource. The cumulative effect of over-exploitation of water resources compounds the scarcity caused by deficient rainfall. Inequities get aggravated as high-powered irrigation tubewells bored by the resource-rich dry up the marginal farmer's dugwell. The over-exploitation of groundwater, often for water-intensive crops, is leading to rapid depletion of underground aquifers, even though replenishment is taking place either through rainwater harvesting in water scarce regions, or through canal and river water seepage in abundant rainfall areas.

In the present environment of growing water scarcity, there is need to rethink the role that advances in irrigation technologies have played in the past in achieving food security and must play in the future in continuing to ensure food security and also provide water security for the poor.

RAIN-FED AGRICULTURE

The Green Revolution was largely confined to irrigated areas which account for 37 per cent of the total cultivated land of 142 million hectares. Rain-fed area accounts for about two-thirds of this total net sown area. In fact, the rain-fed region at around 89 million hectares is almost double that of the irrigated tract. Yet, the irrigated area, about 53 million hectares (37 per cent) accounts for 55 per cent of total foodgrain production, whereas the rain-fed region, nearly 89 million hectares (67 per cent) contributes only 45 per cent.

Rain-fed agriculture is characterised by low levels of productivity and low input usage. Being dependent on rainfall, crop production is subjected to considerable instability from year to year. The bulk of the rural poor live in the rain-fed regions. These risk-prone areas exhibit a wide variation and instability in yields. Gaps between yield potential and actual yields are very high compared to the irrigated areas. The rain-fed regions of eastern India have the potential to achieve higher yields. Indeed, with the development of infrastructure and improvement of access to inputs, agricultural growth in parts of the eastern region has exhibited higher trend than in the traditional states of Punjab, Haryana and western Uttar Pradesh.

The watershed approach represents the principal vehicle for transfer of rain-fed agricultural technology. The key attributes of watershed management are *in-situ* conservation of rainwater and optimisation of soil and water resources in a sustainable and cost-effective mode. The watershed approach aims to optimise moisture retention and reduce soil erosion, thus maximising productivity and minimising land degradation. Cultivable areas are usually put under crops, while erosion-prone, less favourable lands are placed under perennial vegetation.

Improved moisture management increases the productivity of improved seeds and fertilisers, so conservation and productivity enhancing measures become complementary. This system-based approach distinguishes watershed management from earlier plot/field based approach to soil and water management.

The Central Government has accorded the highest priority to the holistic and sustainable development of rain-fed areas through integrated watershed management approach. The current strategy of various ongoing national, bilateral and internationally-aided projects for development of rain-fed areas is based on the concept of conservation of rainwater for integrated development of watersheds, promotion of diversified and integrated farming systems approach, management of common property resources, and augmenting family income and nutritional levels of participating watershed communities through alternate household production systems. Suitable institutional arrangements at various levels (e.g. state, district, watershed, village) constitute an integral component of these projects for promoting people's participation and ensuring sustainability. Lessons learnt from the successful pioneering efforts of social activists, voluntary organisations and public agencies in the development of watersheds, such as Sukhomajri, Tejpura, Nalgaon, Daltonganj Ralegon Sidhi, Jawaja, Adgaon, Alwar, etc. have been incorporated in various government-sponsored watershed programmes.

The Department of Agriculture and Cooperation, implements several centrally sponsored land-based conservation-cum-production schemes. These include National Watershed Development Project in Rain-fed Areas (NWDPRA), Soil Conservation in the Catchments of River Valley Projects (RVP) and Flood Prone Rivers (FPR), Watershed Development Project in Shifting Cultivation Areas (WDPSCA) and Externally Aided Projects on Watershed Development. Upto the end of the Eighth Plan period an estimated 16 million hectares of land had been treated under the watershed approach. Impact evaluation in these treated watersheds has revealed that there has been (i) recharge of ground water aquifers as evidenced by increase in water tables and rise in number of wells, (ii) increase in cropping intensity, (iii) changes in cropping pattern leading to higher value crops, (iv) increases in crop productivity, and (v) rise in overall bio-mass in the watershed.

ASPECTS OF WATER MANAGEMENT

The scarce nature of water is not fully reflected in the direct pricing of the resource either in its use as irrigation or as domestic supply. The under-pricing of this increasingly scarce commodity is the root cause for its profligacy.

Indirect pricing policies e.g. the case of electricity pricing for ground water, with low and flat rates of power tariffs, provide little incentive to conserve either water or power. There are scarcely any incentives to control pollution or encourage water saving. Technologies for recycling wastewater are still at a very nascent stage. Furthermore, agricultural price policies have often failed to take into account the scarcity value of water leading to distortion in cropping patterns and thereby water-use. A classic example is the administered prices for sugarcane in states prone to water scarcity. The net effect of these direct and indirect pricing policies is enormous fiscal burden on the states and their inability to cover full costs, resulting in inadequate funding of operations and maintenance, poor water service by providers, and service dissatisfaction and water-use inefficiencies at the users' end.

Irrigation consumes more than 80 per cent of the available water. If significant economies are to be effected in the use of water, the agriculture sector must produce more food with less water. Approaches to water management must, therefore, include the following:

Policy Issues: (i) an efficient and optimal use of scarce water resources, (ii) water pricing reflecting its scarcity value, (iii) realistic cost recoveries and user charges, (iv) legislation to prevent over-exploitation and inequitable mining of ground water, (v) entitlement of water users, and (vi) price mechanisms to induce suitable cropping patterns.

Strategy Options: (i) watershed approach to rain-fed farming, (ii) expansion of major irrigation projects, and (iii) improvement in the efficiency of canal irrigation systems.

Institutional Reforms: (i) greater involvement of user communities in ownership and distribution of water through Water User Associations, and (ii) restructuring/ reorienting of state irrigation departments for greater responsiveness to efficient management.

Technological Options: (i) promoting on-farm water management, (ii) low-cost micro-irrigation technologies, such as drip-irrigation, and (iii) development of new varieties that are drought-tolerant.

It would be clear from the above that water management is as much organisational and social, as it is technical.

ECONOMIC VALUE OF WATER/PRICING

During the 1970s when food scarcity of the mid-1960s had not completely faded from the collective memory, public investment continued to pour into expansion of irrigation facilities. Food self-sufficiency dominated the public psyche to the exclusion of issues, such as pricing and management of water. This situation continued well into the 1980s. By the mid-1990s, the meagre cost recoveries of water charges and power tariffs led to the State Irrigation Departments and the State Electricity Boards incurring heavy losses. It was becoming increasingly difficult to meet the operation and maintenance costs of the existing infrastructure leave alone mobilise resources for new investments. The principle underlying the pricing of irrigation water has been that farmers should be required to pay at least the operation and maintenance charges and 1 per cent of the interest on capital invested[3]. From the point of view of farmers who have been, lobbying against any increases in water and power rates, it has been argued that the actual costs incurred on publicly provided irrigation is bloated as a result of defective designing of projects, cost and time overruns, overstaffing and inefficiencies of management and, as such, it would be unfair to place the financial burden of these inefficiencies on the farmer.

Despite overstaffing, the actual expenditure on operation and maintenance per hectare of irrigated area is considerably below the accepted norms. Further, as against the generally accepted principle of appropriating as water charges between 25 to 40 per cent of additional net income generated per hectare on account of irrigation, only 2 to 5 per cent of such income is now being collected as water rates[4]. Therefore, political resistance apart, it appears that a five to six-fold increase in the existing water rates would be called for, whether on a theoretical plane or on practical considerations of managing the projects.

The electricity rates for pumping ground water are fixed at present as flat rates on the basis of horsepower, although, unlike in the case of surface water, it is technically more feasible to make them volumetric. Under the present system, the marginal cost of electricity has become zero so that there is incentive for overdrawing water even in drought-prone areas where there is acute scarcity of water, thus further accentuating the degradation of the environment. Low and flat rates for electricity have become fiscally as well as ecologically unsustainable, apart from being highly iniquitous as between the large and resource-poor farmers.

The emergence of ground water markets in the recent period has no doubt made water accessible to small farmers in certain situations. e.g. in certain areas of eastern Uttar Pradesh, water sold accounted for the bulk of the area irrigated from tubewells (58%), marginal farmers being the main buyers of water (57% of total water sold) and medium farmers the largest sellers[5]. The existing system of pricing electricity has made the extraction of water cheaper and, thus, the market rates for the sale of water may be lower than what they would have been if the pricing of electricity were volumetric[6]. Even so, the prevailing rates in most cases in eastern India are found to be much higher than the cost of extraction, especially when water is sold by the big farmers to the economically and socially disadvantaged sections of farmers. The rates charged reflect the productive value of water to the buyer, which is much higher than the cost to the seller who is highly subsidised.

WATER USE EFFICIENCY

Water use efficiency under the existing irrigation projects is estimated to be only about 40 per cent.[7] According to one study, experiments carried out on the actual losses in Upper Ganga Canal revealed that out of the water entering the canal, as much as 44 per cent was lost in the canal, in distributaries and in village water courses. Of the remaining 56 per cent actually entering the fields, the farmers wasted 27 per cent in excessive irrigation, with the result that water actually used by crops was only 29 per cent.[8] As against this, in the advanced systems of the west, as much as 60 to 70 per cent of the water diverted in large surface systems is available for plant use.[9]

The absence of financial accountability on the part of project authorities and the low rates charged for canal water which are unrelated to the quantity of water used, are responsible for large wastage of water both before and after it reaches the fields as well as for the excessive use of water for the crops grown.

The command area development programme was initiated to make efficient use of irrigation water. The programme covers on-farm development works comprising field channels, field drains, land levelling, and land shaping operations. It also envisages ground water development in the command areas, adoption of suitable cropping patterns, proper regulation of canal irrigation and provision of adequate drainage facilities. When these activities are undertaken in a coordinated manner with respective specialists in agriculture, forestry, animal husbandry together with the Water Users Associations, water use efficiency is likely to improve.

REGULATION OF GROUND WATER

Equity has suffered more in respect of exploitation of ground water than in the case of surface water. Whereas in the latter case one finds spatial inequity, i.e. between the irrigated and unirrigated areas on the one hand, and between the head reaches and the tail ends, on the other, inter-personal inequity, i.e. between the large and small farmers is glaring in the case of ground water exploitation. Insofar as the resourceful farmers are the first to extract water, they bring down the water table, leaving the small and less resourceful farmers with scanty water reserves for exploitation at a high cost. Governments must monitor aggregate use of ground water and regulate tubewell pumping to prevent excessive drawdown of aquifers. Both "direct" and "indirect" government regulations together with social regulation should comprise the strategy for sound ground water management.

"Direct" regulation that needs to be enforced in all areas of potential ground water scarcity would entail granting of licences for the construction of water extraction mechanisms. These should be subject to clear guidelines and open to public scrutiny with absolute transparency. The success of such regulation would depend upon its enforcement which could pose a major constraint. "Indirect" regulation which is a comparatively weaker instrument needs to be more effectively enforced through the following mechanisms: (i) institutional credit for water extraction mechanisms from all sources be banned in areas of severe ground water scarcity, defined 'dark' and 'grey' blocks, and reserved for only small and marginal farmers elsewhere; (ii) incentives given to various crops (e.g., through support prices) to take into account the need to discourage growing of water-intensive crops in areas of ground water scarcity; (iii) installation of sugarcane factories not to be allowed in areas of water scarcity and expansion of sugarcane cultivation to be discouraged in such areas; and (iv) in water scarce areas, the system of flat-rate electricity pricing should be abolished in favour of a mixed system of flat rates and *pro rata* charges.

"Social" regulation is a participatory process in the ground water management. In this process, the role of the State could be that of a facilitator and empowerer and the prescribing regulator and the role of the community organisation as that of an implementing regulatory agency of the scarce resource. This may be a more practical and workable via media.

ENTITLEMENTS

Poverty has thus far been associated with hunger and food security. The response has, therefore, been to produce more food by increasing crop yields and expanding irrigation. With the achievement of food self-sufficiency, poverty alleviation is no longer associated with food availability alone but also with the individual's access to food. Poverty line is based on daily per capita income. Poverty alleviation has become associated less with food production *per se* and more with livelihood, with employment, and with Amartya Sen's entitlements. Targeted Public Distribution System (PDS) with its subsidised foodgrain enables those below the poverty line to gain access to food. The growing scarcity of water relative to food in many parts of the country suggests that this may no longer be an appropriate yardstick. Realistic pricing of water for its allocative efficiency may not provide access or entitlement to the poor for domestic use or subsistence farming considering the present inequities in the system. Water security should, therefore, be made an important element of any poverty eradication programme.

While considerable knowledge exists about policy and programme design for food security, by contrast little is known about the appropriate mixes of policies, institutions and technologies that could help achieve water security in water stressed environments. Furthermore, because of the multiple uses of water, there are a large number of stakeholders among government agencies and private sector who have a keen interest in water allocations. As water becomes scarcer, the conflict over water allocations, rights and entitlements at the farm, system and basin level is bound to increase. There is need to address the issue in the revised National Water Policy.

LEGISLATION

There are a few acts like the Water (Prevention and Control of Pollution) Act, The Environment Protection Act 1986, and rules, such as The Hazardous Wastes (Management and Handling) in force to protect the environment and to safeguard against the disposal of toxic and hazardous wastes. Yet, there is a large-scale pollution in many stretches of various rivers. Basin states should accept the specific responsibilities for protection and control of pollution of inter-state rivers. For this purpose, more specific laws, appropriate institutional mechanisms and inter-state agreements on the lines of international agreements/ conventions are necessary.

A survey of the relevant legal provisions shows that the major irrigation acts do not provide for farmers' participation in irrigation management. Community involvement and participatory management implies arrangement wherein farmers can function as coequals in a participatory-cum-consultative mode. For this to happen, a number of changes will have to be made in irrigation statutes and the rules framed under them.

CONJUNCTIVE USE

Conjunctive use of surface and ground water: Many irrigation systems suffer from inadequate supplies whereas modern agriculture requires that supplies be both timely and adequate in volume and number of waterings. Conjunctive use assumes importance wherever surface flows fall short of requirement. In conjunctive use, ground water from shallow tubewells supplements canal supplies. In several rice growing states, farmers have installed their own shallow tubewells in the canal command, to raise paddy nurseries early in June, before the canal system becomes operational. Such practices lead to higher yields in paddy. At the tailend of the canal system which suffers from water scarcity often as a result of silting of the canals, farmers must augment their meagre surface irrigation with ground water supplies.

Conjunctive use of water for control of waterlogging and salinity in canal commands: A direct result of seepage from irrigation canals is the rise in ground water table to undesirable levels with consequent adverse effects, such as waterlogging and salinity resulting in significant reduction in yields. Sinking of tubewells along the canal, after taking into account the requirement for their spacing and capacity will provide the necessary drainage relief and lower the water table. In areas of salinity, mixing of canal water with saline ground water would mitigate the effect of salinity.

Conjunctive use of multi-quality and multi-sources of water: In large parts of Gujarat and Rajasthan, the ground water is of poor quality and sometimes unfit for irrigation (if used alone). Under such conditions, the poor quality water should be used in cyclic mode with fresh quality water. Good quality (harvested water or surface supplies) should be used during germination and initial growth stages; at later stages, the crop is generally able to tolerate irrigation with saline water.

Skimming fresh water in coastal areas. Due to strong influence of the sea, the ground water is generally saline in the coastal areas. However, in the upper soil layers the fresh water keeps on floating in the form of fresh water lens over the saline water. Efficient skimming of this fresh water can provide a valuable resource for providing critical irrigation to crops in the area.

ON-FARM WATER MANAGEMENT

Since water rates are low and also unrelated to the quantity of water used, farmers have no incentive to economise in the use of water. On the other hand, the prevailing pricing system provides an inducement to substitute cheap and abundant water for on-farm water management. In cases of improper levelling of fields, farmers are found to apply excess amount of water to ensure that enough water reaches plants situated on higher grounds. Farmers also resort to submergence of rice fields to check weed growth and thus increase yields. On-farm water management can reduce wasteful expenditure of water and, at the same time, lead to increases in productivity.

The states of Punjab, Haryana and western UP, one of the most intensively cultivated region of the country, in fact, the cradle of the Green Revolution, are confronted with the problem of plateauing off of yield increases and or/ declining factor productivity of the rice-wheat systems in some areas. Ground water tables are already receding in fresh water aquifer zones by as much as one metre per year. Serious waterlogging and secondary salinisation in low quality aquifer zones have already come to the fore in many irrigation command areas. Present water and energy pricing policies are adding to this problem of inefficient water use. Resource conservation tillage practices, using the zero till system in the rice-wheat systems, have demonstrated that on one hectare of land there would be a saving of 98 litres of diesel and approximately 1 million litres of water. This year, farmers used direct drilling with locally manufactured zero-tillage drills to plant 5000 hectares in Haryana. The area of adoption is increasing every year. The main constraint on more rapid expansion has been a lack of good quality, fairly priced seed drills. Small private shops are beginning to produce more drills in response to rising demand. Incorporation of machinery, such as the zero-tillage seed drill and the two-wheel tractor, extremely popular in China and Bangladesh, are also being included in the centrally sponsored schemes to enable a more rapid dissemination of these resource-conserving technologies and practices.

Another recently promoted technique – planting wheat on raised beds – improves yields, increases fertiliser efficiency, reduces herbicide use, saves seeds, saves on an average 30 per cent water and can reduce production costs by 25-35 per cent compared to permanent beds. This technique is being tested in the wheat growing areas. These are only a few examples of how on-farm management can result in water conservation and lowering of production costs without compromising with yields. The results of other All India Coordinated Research Programmes of the ICAR in Water Management network centres have successfully demonstrated that there is a great scope for ensuring water economy, increasing crop productivity and improving water use efficiency with through transfer of available irrigation and other agro-technology to farmers in irrigation commands.

WATER SAVING IRRIGATION TECHNOLOGIES

New techniques, such as drip and micro sprinklers have much higher water use efficiency as compared to surface irrigation methods. The new techniques work on a far smaller scale than the traditional surface irrigation, and the source of water is usually a privately owned tubewell rather than a publicly managed dam. Drip irrigation system applies water precisely to the root zone of every plant through a network of tubes, hence it is suitable for wider spaced row crops. These methods save 30 – 40 per cent of irrigation water and improve crop yields by 20-40 per cent. Although they are unlikely to supplant the large surface irrigation systems for grain crops, these techniques will become more important for future expansion of irrigation, partly because they can be employed with high value crops grown on unlevelled land and permeable soils where traditional surface irrigation is impossible.

At present, about 700,000 hectares are under sprinkler irrigation, largely covering oilseeds, pulses and plantation crops and 225,000 hectares is covered under drip irrigation under as many as 30 crops in the country. Under the All India Coordinated Research Project on Water Management of the ICAR, drip irrigation system has been evaluated for a number of crops at different network centres for its adoption. The plant geometry is an important factor in influencing the initial cost. While the use of drip irrigation in fruit, vegetable and other row crops is now being increasingly adopted, in crops, such as sugarcane and cotton also its benefits are being recognised. In case of sugarcane trials evaluated at State Agriculture University, Rahuri, Maharashtra, it was demonstrated that application of drip irrigation at 1, 2 and 3 days intervals produced 20, 16, 13 per cent higher yield, respectively, by using 43.2 per cent less water, in comparison to surface irrigation. Compared to alternate furrow irrigation, drip irrigation in the cotton crop produced about 14 per cent more yield with the same quantum of water at Prabhani.

These water saving technologies are being disseminated to farmers through centrally sponsored schemes which provide for demonstrations on farmers' fields as well as incentives in the form of subsidies on the equipment. Credit linkages are also facilitated. In addition to fruit crops, assistance for drip irrigation is being provided under the Oilpalm Development Project and Sugarcane Based Cropping Systems. Similarly, assistance for sprinkler irrigation is being provided under schemes such as Integrated Cereal Development Programme, National Pulses Development Project and Oilseeds Production Programme. A further impetus to extension of these technologies is being provided by the private sector. Manufacturers are promoting these systems because more marketable equipment is involved in them than in surface canal systems.

DROUGHT RESISTANT VARIETIES AND CROPPING PATTERNS

Crops sown in rain-fed and drought-prone regions largely comprise coarse cereals, pulses and oilseeds. Presently, 95 per cent area under coarse cereals, 91 per cent under pulses, 80 per cent under oilseeds and 65 per cent under cotton is rain-fed. A number of drought resistant, improved varieties of these crops have been developed by the research systems and evaluated from time to time at the All India Coordinated Research Project for Rain-fed Areas in order to identify the most suitable ones to match the growing period and the water availability. Specific varieties have also been identified for intercropping and sequence-cropping situations. The yield benefits from adopting the improved varieties were 20-40 per cent higher depending on the crop and seasons. Crops, such as pearl millet, guar, melons, cumin, moth, castor, isabgol, and a host of other medicinal/commercial crops can be grown with lesser amount of available water.

The age-old practices of mixed cropping, intercropping, interculturing, mulching, using appropriate quantities of essential nutrients, timely sowing, effective control of pests and diseases are being revived to deal with the moisture scarcity conditions. In addition to drought resistant varieties, research systems have tested the most suitable cropping patterns, intercropping systems and efficient double-cropping sequences for dryland conditions. Long duration crops and varieties have been replaced by short duration ones in order to escape the terminal drought.[10]

NATIONAL WATER POLICY (NWP) AND NATIONAL AGRICULTURE POLICY (NAP)

The National Water Policy[11] (1987) of the central government recognises water as an economic good. It emphasises a holistic and integrated river basin oriented approach to water development, the promotion of conjunctive use of surface and ground water, water-conserving crop patterns and irrigation and production technologies. The New Economic Policy of 1991 and subsequent policy statements relating to liberalisation of the economy, market-based approaches to economic management, privatisation of urban water and decentralisation of irrigation management, have established a broader and more economically oriented environment for water policy debate. The policy statements, though, do not have the back-up of institutional structures and mechanisms, enabling legislation, nor supporting economic incentive structures. Moreover, the national policy is neither reflected in corresponding and state-specific water policies, nor in basin-level policies and action plans.

The Draft National Water Policy Document (2000) which came up for discussion before the Water Development Council in July 2000 failed to reach a consensus as it floundered on the inability of the centre and the states to agree on the setting up of river basin organisations. In the past, state governments have not always been up to the task of managing water resources efficiently. They have found it difficult to enforce cropping patterns as well as to charge economically viable water rates. Inter-state river water disputes have proved next to impossible to resolve. An effective river basin organisation, on the other hand, would involve the farmers who earn their livelihood from the basin. They would have a direct interest in more efficient water management. Since they would be the direct beneficiaries of this efficiency, they may be more willing to meet the costs involved. Any deals made among themselves for exchange of water for power might also be easier to implement.

The National Agriculture Policy[12] (2000) also places high priority on the rational utilisation and effective conservation of the country's water resources. Conjunctive use, on-farm management, in-situ moisture management, promotion of water-saving technologies all are emphasised in the policy document.

CONCLUSION

It is clear that between the NWP and the NAP almost all issues related to water management are suitably addressed. However, the critical question is how to translate the intent into action. Water Management is a complex subject because of the large number of groups of stakeholders, each with its own perceptions of what the problems are and each having its own vested interests. What might be a solution for one group may be a problem for another. Even one unhappy or dissatisfied group can block the process of solving problems for the majority. Implementation and enforcement of management measures are impossible, not to mention prohibitively expensive, unless stakeholders agree to the measures and assist in implementing them. There is a need for evolving an approach to management that can bring in all the stakeholders to agree on problems and solutions and to participate in management and enforcement.

Successful sustainable management of water resources requires that those who are the multifarious users of water change their ways of resource use. Thus, water management will require resource users to become resource managers. A fundamental element of policy is to enable and facilitate the efforts of the stakeholders of the water regime to better manage their resources. Groups at the level of watersheds concerned with land and water use, such as farmers of different types, landless people who work the land, others who use land for non-agricultural purposes, traders, money-lenders, wholesalers, retailers, consumers, government agencies, agencies concerned with agriculture, forestry, fisheries, animal husbandry, water and environment, local government, civil society and NGOs could be brought together to identify the problems facing the water regime and its causes from different points of view, to discuss their needs and aspirations and the capacity of the environment to address these needs, to come up with (negotiated) mutually acceptable solution options and management plans, to implement and monitor the management measures and to enforce the law.

The role of the State as an enabler and facilitator could create the opportunities for the communities to participate in water management. By doing so, it would allow society as a whole to tap the wellsprings of management capabilities that exist both at the local levels and in the government. An enabling approach would not immediately address the full range of environmental and equity problems that are emerging with regard to water resources. It could, however, provide a framework and set in motion a negotiating process that would lead to their ultimate resolution.

NOTES

1. Estimates are based on the Draft Report of National Water Commission constituted by the Ministry of Water Resources, Government of India, 1999.
2. The water balance basin-wise and water requirements state-wise have been estimated keeping in view the overarching objective of achievement of food self-sufficiency at the national level. The basins' and states' projections are based on major assumptions and should be treated as first approximations. They do not and cannot take into account impact of unforeseen technologies. It would be desirable to review these estimates regularly, say, at the interval of 5-10 years.
3. This view has been reiterated by the Committee on Pricing of Irrigation Water appointed by the Planning Commission, 1992.
4. In a majority of states, incidence of liability for irrigation charges relative to productivity of irrigated land ranged between 1 to 2.5 per cent (*Report of the Committee on Pricing of Irrigation Water*, p.35).
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URBAN WATER SUPPLY AND SANITATION SECTOR IN INDIA : NEED FOR A NEW APPROACH

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The level of urban water supply and sanitation services and access needs to be increased in order to improve public health and support economic development of the country. Since public funds for the services are inadequate, urban organizations have to look for alternative sources of funding from financial institutions and from the capital markets through municipal bonds, which are available at competitive costs. In order to access these funds, there is a need to develop commercially viable urban infrastructure projects, which are bankable. In addition, private sector participation (PSP) in the management of the urban services can reduce costs, improve operational efficiency and increase customer satisfaction. This paper briefly describes the changing urban situation, options that have emerged, and identifies the need for a new approach. It suggests that the focus of new investments in this sector should shift from bulk water supply to improved management of existing water and sanitation systems by addressing the issues of unaccounted for water revenue, energy management and billing and collection. In addition, there is need to introduce appropriate pricing of the services and strengthen the urban institutions so that they could work on commercial basis and improve customer satisfaction.

INTRODUCTION

Urban water supply and sewerage services in India are characterised by inadequate access, low levels of service and low customer satisfaction. The level of services and access needs to be increased in order to improve public health and support economic development of the country. To achieve these results, huge investments in infrastructure will be required in the sector. The traditional approach of funding these investments has been through public grants and budgetary support. However, such funds are grossly inadequate to meet the needs of the sector. Therefore, urban organisations have to look for alternative sources for funding such as financial institutions and capital markets. In order to access these funds, urban infrastructure projects must be developed in a commercial format and should be bankable like other commercial projects. In addition,

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savings in the operation and maintenance of urban services can be achieved through private sector participation (PSP) which can also improve operational efficiency, bring in new technology and improve customer satisfaction. A number of options have emerged in the financing and management of urban services in India. This paper briefly describes the changing urban scenario, identifies the options that have emerged, and spotlights the need for a new approach.

CHANGING URBAN CONTEXT

The urban population in India is likely to be twice its present size in the next two decades; it is expected to increase to 436 million by 2011. National and state level enabling legislation and policies, such as the passage of the 74th Constitutional Amendment (CA) and the introduction of various economic reforms, have changed the urban context in India. The changes that have come about are described below :

Decentralisation : In 1992, Government of India (GOI) enacted the 74th CA, which called for the decentralisation of certain powers to urban local bodies (ULBs). It recognised ULBs as the third tier of government and emphasised the democratisation of ULBs through regular elections, curtailment of state government powers to supersede them, and enhancement of adequate representation of the weaker sections and women. It also provided for the assignment of specific civic functions to ULBs. The CA is designed to improve the financial and administrative management of ULBs and enlarge the urban sector resource base through improved taxation, user-charge collections and efficient rule-based transfer of resources to replace the former discretionary and unpredictable system. The CA further provides for the creation, every five years, of state finance commissions whose function is to recommend to their legislature measures to improve the financial health of the municipal bodies.

Economic reforms : In 1991, GOI introduced a number of economic reforms. The major objectives of the new economic policies were to increase economic growth, improve market efficiency and competitiveness, and integrate the Indian economy with global markets. The most significant offshoot of the concomitant financial sector reforms was the emergence of the capital market as an important source of funds for public and private sector entities.

Private sector participation : GOI has recognised infrastructure as an essential element of the development process. It set up in 1994 the Expert Group on Commercialisation of Infrastructure, known as the Rakesh Mohan Committee. It recommended private sector participation (PSP) in urban infrastructure development and in the accessing of capital markets, including the issuance of municipal bonds (GOI, 1995). Most state governments have now accepted PSP in delivery of urban services.

Accessing capital markets : The Indo-US Financial Institutions Reform and Expansion (FIRE) project was initiated in 1994 to develop a commercially viable infrastructure financing system in India. The FIRE project organised a national workshop on municipal bonds in December 1995, which identified the emerging policy issues for accessing capital markets (NIUA-FIRE, 1995). Following these initial pathbreaking efforts, many state finance commissions have recommended market borrowing through municipal bonds for urban infrastructure financing.

Willingness to pay : Recent studies on assessing peoples' willingness to pay for urban services indicate that they are willing to pay much higher prices than they are currently paying when reliable and good quality services are provided (Vaidya, 1995 and WSP, 1999). There is a need to operationalise the expressed willingness to pay in the pricing structures.

Despite opportunities for ULBs to improve the level of urban water supply and sewerage sectors, there still remain many constraints that have to be overcome. Improvements are required in the areas of tariff and cost recovery, financial management, and capacity to develop commercially viable projects.

INVESTMENT REQUIREMENTS AND COMMERCIAL VIABILITY

Most new investments, due to the new economic policies, have taken place in urban areas. This has placed heavy demands on urban services. While India's urban centres are considered as engines of economic growth, they are characterised by gross inadequacies in levels and coverage of infrastructure. The urban infrastructure bottlenecks pose serious impediments to increased economic productivity.

According to the National Institute of Urban Affairs (NIUA), the annual investment required to augment the present level of infrastructure is estimated to be Rs.3,980 crore at 1995 prices for the years 1991-2001 (NIUA, 1996). At present, the total flow of resources through budgetary allocations, institutional resources, and external aid is estimated to be only Rs.1,608 crore. The internal resources of municipal bodies and infrastructure agencies are not sufficient to meet the estimated gap of Rs.2,372 crore per annum through 2001. Resources of this magnitude are unlikely to be available, thereby increasing public health problems related to inadequate water and sanitation services.

Innovative financial mechanisms are, therefore, required to increase investments in this sector. These increases can be achieved by accessing capital markets and financial institutions. However, this will require a discipline of commercial viability and or development of bankable projects with efficient project management systems. In this perspective, commercially viable projects would essentially be those which would be able to raise resources from the capital and financial markets largely on the basis of revenue streams from specific service-linked user charges and dedicated sources (such as property tax and octori) (Mehta and Satyanarayana, 1995). Commercial viability requires that there should be :

- adequate rate of return on investment;
- appropriate institutional structure; and
- a risk assessment and mitigation plan.

Moreover, project development in a commercial format is a very complex and time-consuming process and requires dedicated political and administrative leadership.

PRIVATE SECTOR PARTICIPATION (PSP) OPTIONS

Various cities have adopted different options for PSP in the sector. The main options can be distinguished by how responsibilities are allocated regarding ownership of assets and capital investment (Brook Cowen, 1998). The more the responsibilities are given to the private sector the greater will be its incentive to operate services better. The main PSP options with corresponding allocations of responsibility are presented in Table 1.

For successful implementation of different PSP options, an analysis of various pre-conditions is necessary. These include: stakeholder support and political commitment, cost recovery and pricing, information base about the system and regulatory framework. Service contracts require limited information on an existing system and minimal monitoring capacity; whereas options such as build, operate and transfer (BOT) and concession require high political support, a good information base about the existing system and a strong regulatory framework. A public agency may start with a service or management contract and progressively introduce the lease, BOT and concession options that transfer more responsibilities to the private sector.

PSP PROJECTS IN INDIA

As mentioned above, a number of options have emerged in PSP in the financing and management of urban services in India. Seven options have been

Table 1 : Salient Features of Private Sector Participation (PSP) Options Project – Water Supply and Sanitation (WS&S) in India

City	Services	Management Option	Capital Finance Arranged by	Time (Years)	Project cost (Rs. in crore)
Chennai	O&M WS&S (pumping stations & tubewells)	Service contracts	Public agency	1-5	NA
Ahmedabad	Augmentation of WS&S	Private project consultant	Public agency	NA	490
Tiruppur	Bulk WS and new sewerage	Joint sector company/BOT	Joint sector company/BOT	30	1200
Pune	Augmentation of WS&S	Construction contract, management contract for O&M of new facilities and part billing and collection	Public agency	5 for O&M	715
Bangalore	Bulk WS	BOT	Private agency	25-30	800
Alandur	*i.* Sewage collection *ii.* Treatment plant	*i.* Construction contract *ii.* BOT	*i.* Public agency *ii.* Private agency	*i.* NA *ii.* 15-20	*i.* 40 *ii.* 8

NA : Not Applicable

identified in India: (a) service contracts (Chennai); (b) local body financing through municipal bonds and other sources (Ahmedabad); (c) joint sector company to implement and finance the project (Tiruppur); (d) fixed price and fixed time contract with local body finance and a management contract for operation and maintenance (O&M) (Pune); (e) BOT contract (Bangalore); and (f) construction cum BOT (Alandur). Salient features of these project options are presented in Table 1.

Chennai O&M Contracts : The Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) has made a significant advance in the use of service contracts for PSP in O&M of water supply and sewerage systems in the city. Out of the 119 city sewerage pumping stations, 70 have so far been given to private contractors for operation and maintenance. The system is working very well and has resulted in an increase in the contract period from one to three years. The Board has also given service contracts for O&M of two sewage treatment plants for a period of three years. The cost savings have worked out to be 33 to 40% as compared to estimated costs if the Board had undertaken the management itself.

Ahmedabad Water Supply and Sewerage Project : In January 1998, the Ahmedabad Municipal Corporation (AMC) issued Rs.100 crore in bonds to partially finance a Rs.439 crore water supply and sewerage project. This was a remarkable achievement as it was the first municipal bond issued in India without a state guarantee and represented the first step toward a fully market-based system of local government finance (Johnson and Vaidya, 2000). The AMC had previously instituted significant fiscal and management reforms, including improved tax collection, computerisation of the accounting system, strengthening of AMC's workforce and its financial management, and development of a comprehensive capital improvement programme. These reforms laid the necessary groundwork for AMC's bond issue and the successful implementation of the water supply and sewerage project.

AMC had also agreed to appoint private project management consultants to facilitate the process of project design, approval, tendering, construction supervision, quality control and payments. However, AMC did not carry out this commitment essentially because the AMC project staff felt that they could supervise the implementation process themselves. Lack of specialised project management support tended to delay the project implementation schedule.

The project initially envisaged that bulk water would be available from the Narmada main canal. However, implementation of the Narmada project was delayed. Unable to count on Narmada water and facing a major shortage of water due to failure of the monsoon rains, the state government gave approval to AMC to obtain bulk water from the Shedi Canal (Mahi River). AMC implemented an emergency bulk water supply scheme known as the Raska project during October 1999 to March 2000 with partial funding from bond proceeds. The total cost of the Raska project was Rs.1,100 million, which involved the laying of a 32-km transmission main and improvement of a water treatment plant. This emergency scheme provides 300 mld of additional water to the city. It was implemented in a record five months using two turnkey contracts. AMC staff (led by the municipal commissioner) and the state government worked closely together to implement the project. The bond proceeds allowed AMC to implement the emergency bulk water supply project in time.

AMC took two years to utilise most of the bond proceeds, which is within the typical US norms. AMC is criticised for the negative arbitrage implications of having to pay a higher rate of interest to the bondholders than the interest it was receiving on bond proceeds. AMC claims, however, that it was able to obtain highly competitive tenders from private contractors as they knew that the Corporation had the cash flow for timely payment of vouchers. In the past, payments had been delayed due to non-availability of funds. According to the AMC, the tender quotes came in at 10 to 15 percent below the estimated cost. This more than offset the loss of interest on the debt.

Tiruppur Area Development Project (TADP) : Tiruppur city, which had a population of 235,000 in 1991, is located in Tamil Nadu. It accounts for over three-fourths of India's cotton knitwear exports. Water is key to the operation of this industry and private tankers currently supply most of it since adequate supply of piped water is not available. Realising its needs for water to survive in a highly competitive international market, the Tiruppur Exporters Association (TEA), supported by the state and local governments took the initiative to involve the private sector in meeting its water requirements. As a result, a public limited company with private sector participation, the New Tiruppur Area Development Corporation (NTADCL), was formed to implement the project.

Investments in the water supply and sewerage systems are to be recovered through a composite water charge. The pricing of water supply to industry has been determined on the basis of opportunity cost which is considered to be the rates paid to private tankers. The price fixed for industry is 5 to 6 times the corresponding figure for domestic users. The NTADCL will contract the construction and maintenance of the systems to a BOT contractor. The NTADCL is presently negotiating with the selected contracting consortium.

Pune Water Supply and Sewerage Project : Total estimated cost of the proposed project is Rs.735 crore and is to be implemented through an integrated turnkey construction contract within a fixed price and time format. It is proposed to have a five-year management contract for O&M of the new treatment and pumping facilities as well as a five-year contract for the billing and collection of water charges in one-third of the city. Pune Municipal Corporation is likely to arrange for financing the construction through its internal resources, grants from the state government and loans from various financial institutions. Selection of the private operator has been postponed since October 1998, while the technical components are being revised.

Alandur Sewerage Project : This project in Aladur, Tamil Nadu, is under construction. It has a construction contract for the sewage collection system, whereas the treatment plant is on a BOT basis. In addition, there is an O&M contract for the collection system as well as for the treatment plant. The operator is expected to make capital investment for the treatment plant and recover it over a period of 15 to 20 years. The local body will recover the cost through a combination of sewerage tax, sewerage charge, connection charge, general revenues and state government support.

Bangalore Bulk Water Supply Project : The Bangalore Water Supply and Sewerage Board (BWSSB) has proposed to implement the Cauvery Water Supply Scheme Stage IV (Phase 2), which will provide bulk supply of 500 million litres of water per day to the city, on a BOT basis. The selected private firm will be responsible for construction and O&M of source, treatment as well as transmission of bulk water supply over a long period (25 to 30 years). Total cost of the project is estimated at Rs.1,600 crore. The BOT operator will arrange the capital financing and may enter into a 'take or pay agreement' with the Board. The Government of Karnataka is likely to guarantee payments by BWSSB for the bulk supply. A consortium led by a UK-based company has been identified as the preferred bidder for the project.

NEED FOR A NEW APPROACH

The focus of new investments in this sector has been on provision of bulk water supply. However, BOT projects in most Indian cities are either unfundable or delayed. *Each of these projects has caused international bidders to incur several millions of dollars in the submittal of bids (Price, 1999).* In addition, the BOT projects do not address problems of existing water supply and sanitation systems, such as high proportion of unaccounted for water, high expenditure on energy and low cost recovery. Adding more bulk supply without improving existing distribution systems will further increase the proportion of unaccounted for water and energy consumption leading to additional financial burden on the urban organisations. As such, there is need for a new paradigm for encouraging PSP in water and sanitation sector in India.

Shift focus from bulk water supply to improved management of existing systems : There is need to shift the focus from increasing bulk water supply to improved management of existing systems. PSP can first help to improve operational efficiency of existing systems through controlling unaccounted for water, improving billing and collection, and energy savings. Some cities, such as Hyderabad, Mumbai and Chennai have introduced leak detection mechanism in their water distribution systems. The Ahmedabad Municipal Corporation is implementing an energy savings project in regard to water supply and sewerage services with assistance from the US Agency for International Development.

An example in support of the need for a new approach is the Goa BOT bulk water supply project for which offers were invited in 1996. The proposal originally conceptualised to supply 165 mld for which the state government was required to pay Rs.100 crore for the next twenty years regardless of actual collection of revenue from the consumers. The Angalian Water Company offered to take responsibility for retail distribution, as well as billing and collection. Under this option, the government was under no obligation to provide guarantee for bulk purchase of water. This bid was 40% lower than the BOT bid, since the company found that it could take the existing facility and reduce the leakage from 42 to 20 per cent thereby reducing overall costs and increasing revenue from water (Dutt, 1998).

Additional revenues resulting from operational efficiencies can be utilised to make capital investments. Moreover, improvements in the existing systems, as opposed to the implementation of large bulk water projects, can be initiated with small investments but have huge pay-off.

Commercial orientation to existing institutions : Urban utility boards and urban local bodies providing water supply and sanitation services in the country are, generally, not operating on a commercial basis. In the context of the changed economic situation of the country, there is a need to restructure these organisations to operate on a commercial basis and improve customer service and satisfaction. Water supply and sanitation departments of urban local bodies could work separately on a profit centre basis (MPJ and FIRE Project, 1998). In this regard, the Chennai Metropolitan Water Supply and Sewerage Board, which was formed as a statutory body by an Act of the state legislature, has proposed to restructure the organisation and is considering three options (CMWSSB, 1998). Under option one, the Act could be amended so that the board could work on a commercial basis. Under option two, the board could be reformed as a company under the Companies Act. Over time, it would be possible to gradually divest the equity of the company. Under option three, water and sanitation services in the metropolitan area could be given on concession and management contracts to private companies and the board could act as a regulator rather than a provider of the services.

Appropriate pricing : This is the most crucial issue for urban local bodies and the utility boards. Present prices do not reflect the actual costs or willingness to pay for services. Some states, such as Karnataka and Tamil Nadu have, however, taken steps to introduce economic water charges at the local level.

Regulatory framework : There is need to develop a state-level regulatory framework for the level, quality and price of the services provided as well as criteria and rules for PSP in the water supply and sewerage sector, just as independent regulatory commissions have been set up for the power sector at the national and the state levels.

Project development : The process of developing urban projects in a commercial format is a relatively new trend in India. Unlike conventional projects, this type of project development requires considerable effort in preparing project documentation, developing institutional arrangements for project structuring, getting approvals, financial structuring, selection of contractors and management of project implementation. Detailed risk assessment and mitigation measures will need to form part of the project development process. This procedure is time-consuming and costly. ULBs often do not have the necessary human resources to carry out these tasks. It is in recognition of this problem that the State Government of Gujarat has set up the Gujarat Infrastructure Development Board and a project development fund, and adopted a legal framework for infrastructure investment. Utilisation of this framework and the fund for development of urban infrastructure projects will increase as the state's water supply and sanitation sector moves towards commercial viability. The Governments of Rajasthan and Andhra Pradesh have also set up infrastructure project development funds.

Selection of private operator : Various options for selection of the private operator of urban water supply and sanitation services need to be developed. The competitive bidding process adopted by most cities in the country does not, according to the private operators, leverage their full expertise in the project development process. One innovative selection option for private operator has been introduced in the state of Karnataka, where operators for various cities have been selected through a memorandum of understanding (MoU) process. This process has been facilitated by the state infrastructure policy which has a provision for such an approach. Another possible approach could be that a private operator is selected based on past experience. The operator would study the existing systems for sometime and then the public agency and the operator would agree on certain targets that the private operator would achieve to improve the existing systems. The operator would also be responsible for developing capital investment programme, which would be awarded through competitive bidding and the operator would not be permitted to bid.

In conclusion, it may be reiterated that there is need to shift the focus of new investments from increasing bulk water supply to improving the management of existing systems, institutional strengthening and appropriate pricing of the services. This approach will strengthen the role of urban utilities to provide urban services more effectively and efficiently and will help in realising the decentralisation objective of the 74th Constitutional Amendment.

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WATER AND AGRICULTURE

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Water is more crucial to Indian agriculture than is commonly perceived. It is not only the irrigated agriculture that accounts for nearly two-thirds of production but, more so, the rain fed farming from where a sizeable chunk of additional output is to come that relies vitally on water. While so far we have been "developing" the sources of water and their gainful exploitation, the approach from now onward would have to shift to "managing" water resources for optimisation of their use. For, even after harnessing all possible sources of irrigation, over 50 per cent of the arable land would still depend on rainwater for crop production. Rainwater harvesting through approaches like watershed management would assume greater significance from the farm production point of view. In the case of irrigated agriculture, be it with the use of surface or ground water, water use would have to be managed scientifically to prevent wasteful and ecologically injurious use and to improve its output efficiency. Already over-use of water due to faulty pricing and legal regimes have created a plethora of problems, including land degradation. He land-use pattern would have to be recast, taking into account the capability of land and availability of water. The cropping systems, too, would have to undergo a drastic change, dictated primarily by the availability and quality of the soil and water resources. Newer systems of economising on the water-use by putting it in the root zones in precisely needed quantities would help save water while measures for harvesting rainwater would help augment this resource for meeting the enhanced demand. All these aspects have been discussed in some detail in this article.

INTRODUCTION

Historically, water has been viewed as a renewable natural resource available in abundance. Among its various uses, irrigation has invariably got top preference. The Indian agriculture sector now accounts for about 83 per cent of the total consumptive use of water. The priority was largely justified as the country was woefully short of food grains, leading a precarious ship-to-mouth existence. Rapid development of agriculture was deemed impossible without irrigation. Besides, the new high-yielding crops that ultimately brought

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about the green revolution could show optimum performance only with assured inputs like water and fertilisers. The importance of rain-fed agriculture for achieving the much-needed stability in production and also for sustaining agricultural growth even after exhausting the production potential of irrigated farming was realised much later.

Another reason for the agricultural sector getting a greater share of available water was the slow pace of industrialisation which kept water demand within limits. The water consumption of other sectors, including the socially significant drinking water supply and domestic sectors, has also not increased as rapidly as it normally should have for want of development effort and resource deployment in these fields. A sizeable number of villages still lack potable water supply. Water scarcity in urban areas, especially metros and big towns, is rampant.

However, with the acceleration of the pace of industrialisation – the industrial growth rate is now more than double that of agriculture – the water requirement of this sector has started rising at a relatively faster pace. So has, of course, the water demand of other sectors, causing a situation of conflict between various claimant sectors, such as agriculture, industry, domestic needs in rural and urban areas, energy, ecology, navigation, fisheries, recreation, ceremonial, religious, etc. Official projections point to a three-fold increase in the water consumption of industrial and domestic sectors alone in the first quarter of this century – their total share in consumptive use is estimated to rise from 8 per cent now to 25 per cent by 2025.

This, along with the expansion of irrigation is bound to bring water availability under considerable strain, exposing the fragile nature of this resource. The threat is all the more grave from the misuse of irrigation water due to low tariffs and deficient legal control. At stake is the overall ecological health of the entire region and its obvious economic implications.

According to a recent report prepared jointly by the World Bank and the Union Water Resources Ministry (India: Water Resources Management, 1999 – part of the World Bank's South Asia Rural Development Series), per capita water availability has fallen drastically since Independence – from over 5,000 cubic meters per year to about 2,000 cubic meters. By 2025, it is projected to go down further to 1,500 cubic meters, or 30 per cent of the availability level at the time of Independence. At the water basin and local levels, the situation is already critical in 6 of the 20 major river basins. In these basins, per capita availability has already dropped to less than 1,000 cubic meters a year. Localised water shortages are endemic in almost all basins. By the year 2025, five more basins will become water scarce and by 2050, only the Brahmaputra, Barak and west-flowing rivers from Tadri to Kanyakumari would be water-sufficient (Indian Water Resources Society paper for Water Resources Day, 1997).

Indeed, an analysis of the overall water scenario based on this kind of a water availability index gives only a part of the picture because this index takes only surface water availability into account. Ground water is equally important under the Indian conditions where it constitutes a major source for domestic and drinking water and an important component of irrigation sources. It is generally believed that about 80 per cent of water for domestic use in rural areas and about 50 per cent water for urban and industrial uses comes from the ground water aquifers.

IRRIGATION

The pace of expansion of irrigation has varied depending on the priority accorded to this sector by different governments. Irrigation schemes having cultural command area of more than 10,000 hectares are usually categorised as major projects; those between 2,000 and 10,000 hectares as medium and less than 2,000 hectares as minor. Since the beginning of the era of planned development, 278 major, 894 medium and 146 extension/renovation/modernisation (ERM) schemes have been taken up throughout the country. Of these, about 120 major, 668 medium and 51 ERM projects have been completed. On the whole, the irrigation potential has more than quadrupled between 1950 (22.6 million hectares) and now (roughly 90 million hectares). A massive investment of around Rs. 92,000 crore is estimated to have gone into this sector till 1996-97.

There is a big gap, which is widening gradually between the potential and the actual utilisation of irrigation capacity. While in the initial phase of the green revolution (1966 to 1974), the under-utilisation of the irrigation potential was to the extent of around two million hectares, it has risen to nearly 10 million hectares during the Eighth Plan. This gap is confined largely to the medium and large irrigation projects where the command area development work invariably lags far behind the pace of creation of potential. The minor irrigation sources are being tapped quite optimally; indeed being over-tapped in many cases, resulting in rapid depletion of water. In any case, the country's actual requirement of irrigation seems insatiable and the trend of expansion of irrigation is likely to endure for quite some time.

There are actually no reliable and universally accepted figures about the country's overall irrigation potential. Till a few years ago, the ultimate irrigation potential from all conceivable resources was estimated officially at 113.5 million hectares. This included 58.5 million hectares from major and medium irrigation schemes, 40 million hectares from ground water and 15 million hectares from minor surface irrigation. A reassessment of this resource by the Union Water Resources Ministry a couple of years ago raised the figure of ultimate potential to 139.9 million hectares due largely to higher estimation of ground water potential at 64.05 million hectares and surface irrigation at 17.38 million hectares. But even this estimation may merit revision after the impact of the possible inter-basin transfer of water is fully gauged. Some preliminary estimates place the final figure at around 175 million hectares. Uttar Pradesh, Bihar, Madhya Pradesh, Andhra Pradesh and Maharashtra together account for around 58 per cent of the total ultimate potential of major and medium irrigation. Andhra Pradesh and Bihar lead the other states in the potential for minor irrigation.

Enhanced use of ground water for irrigation through tubewells, especially since the availability of the water and fertiliser-responsive crop production technology that spurred the green revolution in the mid-1960s, has contributed handsomely to the country's agricultural progress and economic development. With nearly 17 million energised tubewells, ground water now accounts for nearly half of the country's total irrigated area. Since this is a relatively more dependable resource under the direct control of the individual, its utility to the farm sector and contribution to agricultural production is far higher than surface water. Besides, it is essentially the ground water-based irrigated agriculture, especially tubewell irrigated agriculture, that has lent a degree of stability to production and resilience against the vagaries of nature.

The expansion of irrigation, though an important factor in boosting farm production, has brought in its wake several problems as well. The unsatisfactory command areas development, especially the historic blunder of not providing for adequate drainage in irrigated tracts, has cost the country dear in terms of ecological degradation besides, of course, huge recurring loss of the resource water. In most command areas, as much as 50 per cent of the water released at the project headworks is lost during transmission to the fields. Most of this loss occurs in water courses and is directly proportional to the length of channels and the time it takes to reach the destination.

The heavy seepage, coupled with lack of efficient drainage systems and excessive use of water in crop production due to faulty pricing policies, is leading to widespread waterlogging and land degradation. The Delhi-based Centre for Science and Environment had estimated way back in 1988 that about 7 million hectares of land had gone out of production due to waterlogging and salinity and another 6 million hectares was critically affected by this menace. Taken together, it represented about a fifth of the total canal irrigated potential created till then. The situation has since worsened further.

In the case of ground water irrigation, too, the problems like salinity and degradation are cropping up due to faulty crop selection and over-irrigation. But the biggest problem in this sector is that of fast depletion of ground water aquifers. In many arid and hard-rock zones, overdraft is becoming quite common. Blocks classified as "dark" or critical (which are virtually unfit for further exploitation of ground water) have been increasing at a continuous rate of 5.5 per cent since the mid-1980s. At this rate, over 35 per cent of all blocks would become over-exploited in the next two decades unless regulatory and recharge measures are taken expeditiously.

WATER PRICING

Populist approach to water pricing is the main culprit for rampant misuse of water and its consequential ill-effects. The practice of charging for water in one form or another, notably as part of land revenue, is believed to have existed even in the pre-British period in many areas. The British rulers of India treated irrigation projects purely as commercial ventures. They priced water on the basis of internal rate of return commensurate with the interest rate prevailing in the London money market. These rates, therefore, kept changing, usually rising, with time. According to one account, the internal rate of return (and hence water rate) was pegged at 4 per cent in 1919, 5 per cent between 1919 and 1921 and 6 per cent after 1921 (Economic and Political Weekly, vol 26, No. 46, 1991).

The British originally tried volume-based approach for pricing canal water, but gave it up subsequently because of practical difficulties due to technological inadequacies. They switched over to an area-based approach for determining the water rate. This approach also took into account factors like crop and season while fixing rates.

The criteria for water pricing in the post-Independence period underwent a complete change. The commercial venture perception of irrigation gave way to viewing it purely as an instrument of development for augmenting farmers' income, employment and food grain output. Consequently, the internal rate of return, which was initially lowered to 3.9 per cent in 1949, was abandoned in 1958. In its place, benefit-cost ratio was used as project selection criterion. The minimum benefit-cost ratio was assessed at as low as 1 per cent for drought-prone areas and merely 1.5 per cent for other areas. The applicable water rates, therefore, dropped sharply (Institute of Economic Growth Study No. 63, 1996).

A good deal of diversity has since cropped up in the methodology for calculating water rates in different states. The only common denominator is that they remain woefully low, making this money-spinner sector of the past a virtual drag on the economy today. This is despite the fact that the national water policy adopted in 1987 (which is technically yet in vogue as the current exercise of revising it is still incomplete) categorically states that the water rates should make the user realise the scarcity value of this natural resource. Since water is a state subject, the Centre has little role to play in this. State governments usually lack the political will to hike water rates for fear of its adverse impact on their electoral prospects, especially in rural areas. Water rates have consequently remained unchanged in most states since the 1980s. In some states, the rates fixed in the 1970s are still in force. And the ground reality in most states is that even these ridiculously low charges are not being collected from the users.

As a result, even the working expenses for operating the irrigation projects are not being met from the collection of the water charges. At the all-India level, the recovery of working expenses has declined from 64 per cent in 1974-75 to a mere 8 per cent in 1988-89. States like Madhya Pradesh, Maharashtra and Uttar Pradesh could not recover even 35 per cent of their working expenses. The collections in Bihar and Rajasthan are so low that they do not even cover the collection cost. The collection of water charges has, thus, to be abandoned periodically by the irrigation administration in these states (Institute of Economic Growth Study No. 63, 1996).

On the other hand, populist power tariff for the farm sector, notably for energised tubewells, is also leading to widespread misuse of ground water. State governments are either waiving the power charges for tubewell irrigation (as in Punjab) or are keeping them at an extremely low level. The system of charging flat rates for tubewell connections is equally responsible for over-withdrawal of ground water. Instances are legion where even crop production has suffered on account of over-irrigation and precious fertiliser nutrients have been lost due to leaching and run-off of surplus water.

WATER LEGISLATION

Most laws governing the individual and society's rights over water and its use are archaic and need to be amended. Ground water is still governed by legislation enacted by the British in the 19th century. This outmoded statute grants a landowner an absolute right to water beneath his land. An individual, therefore, is free to extract any quantity of water from the ground. This and other obsolete laws continue to exist chiefly because water has been listed in the Constitution as a state subject and the Centre can do little about it.

A "model bill" to control and regulate the development of ground water was, however, framed and circulated to the states by the Union government way back in 1970. But the response of the states has been rather lukewarm. It postulated a kind of water permit system, giving the state governments the right to acquire powers to restrict the construction of ground water extraction structures, including wells, borewells, tubewells, etc. by individuals or the community. The only exception was extraction of water for drinking purposes.

This model bill was revised and sent to the states again in 1992. Though the revised bill extended the scope of the proposed law to cover all uses, including drinking and domestic use, but it provided for exemption to small and marginal farmers from obtaining prior permission for constructing ground water extraction structures provided these were for their exclusive use. This model bill also elicited a limited response. Even in the states, that opted to put some curbs on indiscriminate use of ground water by envisaging well-spacing regulations and prior permission for digging of wells, the observance of these provisions is more honoured in breach than in compliance.

Water law experts feel that the doctrine of riparian rights, the basis of water legislation in India, needs to be reinterpreted in the light of perceived societal necessities of the time and, more importantly, in tune with the constitutional values (Water Law : Policy Directions – a paper presented in the Second Agricultural Science Congress, New Delhi, 1995). By interpreting article 21 of the Constitution to include the right to water as a fundamental right to life, the Supreme Court has given a new dimension to the principles governing water laws. It has made it incumbent on the state to ensure that the ownership and control of the material resources of the community are so distributed as to subserve the common good. Water being a precious natural and common resource, the law must take into account the principles of access, justice and equity.

There is, thus, scope for recognising the hydrological unit of water resources and providing for conjunctive use of surface and ground water, resulting in integration of the administration of surface and ground water rights. All ground water should be presumed to be a tributary to the natural stream. There is a need to make region-specific legal regulations on ground water. These could be different in water abundant regions than in hard rock or scarcity regions.

RAINFALL AND CROPS

Indeed, even after tapping all the possible sources and means of irrigation, sizeable part of the arable land – over 50 per cent till the foreseeable future – will continue to depend exclusively on rainfall. Traditionally, the farmers' choice of crops in different regions was determined by the availability of rainwater, especially the length of the season in which the precipitation is greater than the loss of water due to evaporation. In the coastal and eastern regions, where the average weekly rainfall is more than twice the evaporation loss for a period of above 12 weeks, rice is grown under rain-fed conditions. But the cultivation of this water-loving crop is done only in lowlands in the regions where rainfall is 1,000 to 1,200 mm in a year and the average weekly rainfall remains more than twice the evaporation losses for 10 to 12 weeks at a stretch. In very high rainfall tracts (higher than 1,200 mm), rice is grown on uplands as well. Crops like sorghum, castor, sunflower and groundnut are usually sown in regions with an annual rainfall of up to 800 mm. In areas getting more than 800 mm, finger millet, maize, soybean, pigeon pea, etc., are grown as rain-fed crops.

In the deserts and other arid zones having an annual rainfall of less than 200 mm, silvipastoral (combination of grasses and trees), agro-forestry and agri-horticultural (combination of crop and hardy fruit trees) systems are deemed ideal. While the trees improve the total biomass production by providing top feed without much additional inputs, grasses serve the dual purpose of providing fodder and acting as soil cover to intercept rainwater for *in situ* conservation. Species like prosopis cineraria, hardwickia binata and tecomella undulata have been found suitable for plantation in range lands. The grasses suitable for planting along with these trees under arid silvipastoral system include cenchrus ciliaris and lasiurus sindicus. Under agri-horticultural systems, crops like mung bean, moth bean, cluster bean can be grown along with these fodder trees. In semiarid areas, fruit trees like *ber* and pomegranate can be planted for good economic returns.

CROPPING SYSTEMS

Though, on the whole, some 250 cropping systems are prevalent in the country in both irrigated and unirrigated areas, 30 of them are the most common. There is much greater diversity in cropping systems in rain-fed areas than in the irrigated ones. This is due to higher risk element. Most farmers go in for inter-cropping (putting an extra crop in between the rows of the main crop) and mixed cropping in the hope that if one crop fails, the other might yield.

In the areas with assured irrigation, the two major cropping patterns are rice-wheat (covering nearly 10 million hectares) and rice-rice (over two million hectares). The other common crop sequences include cotton-wheat, maize-wheat, pearl millet-wheat, sorghum-wheat, soybean-wheat and sugarcane-wheat.

Multiple cropping which involves raising more than two crops in a year in the same piece of land is gaining ground in irrigated areas in a bid to maximise production and returns. The notable examples are rice-potato-wheat cropping sequence in western Uttar Pradesh, rice-wheat-cowpea in Orissa, rice-frenchbean-groundnut in Maharashtra, rice-cabbage-potato in north-western hills and rice-radish-pea-frenchbean in the mid-Himalayas.

Cropping systems and irrigation practices followed by the farmers have been found to influence the overall water balance of a region significantly. Heavy water consuming crops, such as paddy and sugarcane, can create ecological and other problems if grown in the regions unsuitable for their cultivation. They can also create imbalances in the allocation of water for different crops. For instance, in Maharashtra only 3 per cent of the total cropped areas planted with sugarcane account for about 76 per cent of irrigation water. This leaves very little water even for giving life-saving irrigation to some other crops.

Similarly, the spread of paddy cultivation in Punjab and Haryana is creating hydrological imbalances, marked by receding water table in tubewell-irrigated areas and growing waterlogging and salinisation of canal-irrigated tracts. Rice has not been a traditional crop of this region, though *Basmati* has been grown in certain pockets for long. But the availability of green revolution technology, including short duration varieties, and the price support policies of the government, have made the wheat-rice rotation profitable in this area. Ecologically, this is a disastrous cropping pattern for this area because the additional paddy crop is grown in the dry, summer period when the requirement of water is about 40 per cent higher due to high evapotranspiration. So, the farmers have to use 40 to 50 per cent extra water to raise this crop. This would lead to even faster depletion of the ground water, besides creating other environmental hazards. The insect-pest scenario of these tracts is also undergoing a change because of continuous inundation of paddy fields.

The Indian Council of Agricultural Research (ICAR) has suggested economically viable alternatives for the rice-wheat rotation in the north-western part of the country. Field trials have shown that under irrigated conditions at

Hissar (in the arid tract of Haryana), intensive cropping of pearl millet-potato-tomato is more productive and remunerative than rice-wheat. The alternative cropping systems suggested for semiarid tracts include rice-wheat-green gram, soybean-wheat, pearl millet-cabbage, soybean-safflower and hybrid cotton-sunflower. The promising alternative cropping sequences for sub-humid tracts are maize-pea-potato, rice-potato-wheat, rice-berseem and rice-tomato-okra.

ON-FARM WATER MANAGEMENT

Apart from modifying the cropping pattern, changes in the irrigation practices are of utmost importance. Efficient use of irrigation water can be ensured by putting the needed quantity of water in the field at the right time, depending on the stage of crop growth and its requirement. Agriculture experts have already worked out optimum irrigation schedules for different crops in various regions. More research is in progress to fine-tune these schedules to further reduce the use of water. For instance, it has been discovered that the yield of paddy remains the same even if the soil is kept wet all the time rather than keeping water afloat, as is the case at present. This discovery can result in substantial saving of water. Similarly, in the case of wheat, four to six applications of water at the crucial stages of the crop are as good as 8 to 10 or even the 12 irrigations that most farmers give this crop now. In the case of sugarcane, a water-loving crop, drip irrigation involving wetting of only 50 per cent of the area has been found to give higher yield than the usual irrigation.

WATER APPLICATION SYSTEMS

Flooding of the entire field, the traditional method of irrigation, is indeed the most inefficient way of water application as only water in contact with the root system of the crop plants is actually of use; the rest goes virtually waste.

Modern methods of irrigation that can cut down water use by half or even more are now available. These are broadly of three types: surface application of water with check basins and border strips; overhead application with sprinkler systems; and continuous micro-application of water to the root zones through drip irrigation. These are ideally suited to areas where water is already deficient or is on the verge of being so.

Drip and sprinkler irrigation systems, also called pressurised irrigation systems, involve the use of equipment for forcing out water through small outlets like nozzles and emitters. They allow the needed quantity of water to be applied more uniformly and precisely at the desired location. The water loss, in this case, is considerably reduced. Since the initial cost of equipment and other needed infrastructure is high, the government is offering subsidy to help farmers switch over to these systems, especially in areas where water availability is limited. Already, about 2.25 lakh hectares of area is estimated to have come under drip irrigation and about thrice as much under sprinkler irrigation.

Besides, techniques like mulching (covering or camouflaging the surface in between the crop plants) with suitable material is another way of economising on water. Experiments conducted by the Indian Council of Agricultural Research (ICAR) scientists in Bhubaneshwar have indicated that application of straw mulch (15 tonnes per hectare) helped in maintaining soil moisture better and even with reduced irrigation frequency resulted in 21 per cent increase in the yield of pointed gourd. The net return from this plot turned out to be Rs.60,962 per hectare higher than the crop without mulch. The cost of mulch, about Rs.9,260 per hectare, was recovered from the savings in labour for weeding alone (ICAR Annual Report, 1998-99).

RAINWATER HARVESTING

Rainwater availability may be uncertain, both in time and space, but it is the most crucial resource that needs to be conserved. At present, of the total average annual precipitation of about 400 million hectare meters in the country, only about 150 million hectare meters enter the soils; the rest run off, causing soil erosion and other problems. Experts feel that the bulk of this water can be conserved *in situ* as well as *ex situ*.

In situ water conservation is a relatively more practical proposition for agriculture though *ex situ* is also essential. Practices like deep tillage and sub-soiling have been found useful for this purpose in normal rainfall years. Shallow inter-row cultivation and contour farming have also been found effective in conserving rainwater in the soil. *Ex situ* conservation of rainwater is possible by constructing ponds at farm level or by utilising natural depressions for storing it. The watershed approach has been found to be best for this purpose and is now being vigorously promoted under various agricultural, rural and forest development schemes. A watershed is essentially a contiguous land mass, which drains into a common destination. This offers scope for impounding the water at a suitable site and utilising it gainfully.

The experience of the past ten years in implementing these projects has led to the evolution of the joint natural resource management or participatory management approach for watershed development. Under this, various departments of the central and state governments, non-governmental organisations and the local communities – the actual stakeholders – jointly prepare and implement the plans for conserving soil and water resources, improving the forest cover and utilising the conserved water for agriculture.

The term 'watershed development' may be of recent origin, but the use of its basic principles in harvesting, conserving and storing rainwater has been in vogue since ages. The tanks or the village ponds used this approach for storing and utilising water. Even the arid and semiarid areas have traditionally been meeting their irrigation and domestic needs by collecting rainwater in structures like khadins (bunding the natural depression in the catchments to impound water), nadis (community ponds) and individual or community tankas (cisterns).

Indeed, The best way to conserve water is by storing it in the underground aquifer through the process of recharge. Though the impounding of water in surface structures like ponds, khadins, nadis, unlined canals and field channels also helps replenish groundwater through seepage, several other avenues are now available specifically for conveying water down into the subsurface aquifer. "Anicut", a structure constructed across a stream (nala) to intercept flash floods and steer the water to the soil profile, has been observed to be an effective way of recharging ground water.

CONCLUSION

Having already achieved a comfortable level of foodgrain production at the present income levels-driven consumption needs, Indian agriculture would have to reorient itself to non-food crops. This change would also be necessary due to the opening up of the this sector to international competition in the post-World Trade Organisation era. This would necessitate higher efficiency of agricultural production to reduce production costs and improve competitiveness in the international market. Hence, the pressures on natural resources like water and land by the new agriculture are bound to be different from the present ones. Policy planners, therefore, need to be constantly engaged in modifying agricultural practices so as to keep them as natural resource friendly as possible. Water would, of course, continue to play a key role. The national water policy of 1987, drafted with the aim of ensuring sustainable use of water, has failed to serve the desired purpose, as it was not backed by suitable regulatory and other measures. It needs to be recast taking into account past experience and new data on water resource availability. The future approach to sustainable exploitation of water would not only have to imbibe the technology that is constantly being upgraded the world over, but also integrate this technology with the traditional wisdom that is available in plenty within the country.

WATER POLLUTION : NEED FOR A PARADIGM SHIFT

Ramesh Jhamtani*

INTRODUCTION

Water Pollution is defined (Ashworth, 1991) as the presence in water of *harmful foreign* substances. That is, the material must be harmful; it must have the potential of damaging the health of humans or the environment; and it must be foreign. In this wider and holistic sense, adverse impact of water pollution needs to be considered across all component elements of the eco-system rather than merely in an anthropocentric sense confined to material damage or human morbidity and mortality. Water pollution has already started affecting the unique and diverse eco-systems. Unfortunately, our knowledge about full impact of water pollution remains far from adequate.

THE HEALTH DIMENSION

It is estimated that about 2.3 bn people in the world suffer from water-related diseases. About 60% of all infant mortality is linked to infectious and parasitic diseases, most of them water-related. In some countries, water-related diseases make up a high proportion of all illnesses both among adults and children.

Burden of Water-related Diseases

According to a World Bank Report (Brandon and Hommann, 1995) contaminated water supplies in both rural and urban India pose significant problems. About 30.5 mn Disability Adjusted Life Years (DALYs)+ are lost each year in India due to poor water quality, sanitation and hygiene (Table 1). WHO data shows that about 21 per cent of all communicable diseases in India (11.5% of all diseases) are water-related.

Table 1 : Burden of Water-related Diseases in India, 1990

(DALYs)

Disease	Total
Diarrhoeal Disease	28.03
Intestinal Helminthes	2.06
Tarchoma	0.11
Hepatitis	0.31
Total, Water-Related Diseases	30.51

Source : WDR, 1993

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\+ *A measure of morbidity and mortality.*

Economic Dimension of Health Impacts

Surface water pollution accounts for about 60% of the major environmental cost in India (Total US$ 9.7 bn). It is also significant to note that (according to the World Bank estimates) 100% provision for clean water and sanitation could, on average, meteralise in economic benefits (health damages avoided/ abated) amounting to US$ 8.3 bn annually.

Social Dimension of Health Impacts

Disproportionately higher burden of ill health falls on poor people since they are exposed to greater health risk both at home and at work. Being malnourished, they are prone to illness and slow to recover (Table 2).

Table 2 : Prevalence of Diseases

Disease/ Condition	Ratio of Poor to Rich
T.B.	4.5
Malaria	3.2
Leprosy	2.8
Mortality (under 2)	2.2

A high percentage of infant mortality has been associated with water-borne infectious and parasitic diseases. In 1990, 18% of the total burden of disease in India was the result of diarrhoeal diseases, hepatitis, tropical cluster diseases, intcothnal nematode infection and respiratory infection for babies and young children under the age of 5 years, largest part being on infants under 1 year (Murray & Lopez, 1996 Annex/Table 9C).

INTEGRATED NETWORK FOR MONITORING WATER QUALITY

Water quality data is generated by the following organisations : (i) Central Pollution Control Board (CPCB); (ii) Central Water Commission (CWC); (iii) Central Ground Water Board (CGWB); and (iv) Department of Ocean Development (DOD)

In addition, large volume of data is published by the National Institute of Hydrology, Roorkee and independent researchers. Based on information generated by these sources some aspects of water quality are briefly summarised as follows:

Surface Water Quality

An analysis of water quality monitoring results obtained during 1998 is given in Table 3.

Table 3 : Water Quality Status in India (1998)

State	BOD (mg/1)			Total (MPN/1000ml)		Coli-form	Fecal (MPN/100ml)		Coli-form
	<3	3-6	>6	<500	500-5000	>5000	<500	500-5000	>5000
Andhra Pradesh	202	56	19	16	25	0	37	0	0
Assam	113	4	9	15	49	23	22	21	0
Bihar	146	3	1	15	48	82	35	106	2
Daman & Diu	28	0	0	11	13	0	12	9	0
D & N Haveli	16	0	0	3	11	0	6	7	0
Delhi	11	4	14	0	6	14	10	5	5
Gujarat	224	82	125	200	63	164	214	90	116
Goa	33	15	0	48	0	0	44	0	0
Himachal Pradesh	88	1	0	61	27	1	83	6	0
Haryana	28	4	9	0	0	0	0	0	0
Karnataka	247	49	52	94	283	0	113	136	1
Kerala	275	1	0	10	238	24	71	192	12
Lakshdweep	6	2	0	3	5	0	6	2	0
Maharashtra	0	326	123	375	73	0	391	0	0
Manipur	30	2	0	27	5	0	0	0	0
Meghalaya	0	4	16	12	6	2	9	8	0
Madhya Pradesh	345	114	48	373	124	0	209	0	0
Orissa	22	298	57	234	143	0	299	78	0
Punjab	26	26	20	72	0	0	71	1	0
Pondicherry	15	1	3	0	0	0	0	0	0
Rajasthan	71	5	2	36	42	0	78	0	0
Tamil Nadu	260	38	6	168	72	63	219	53	31
Tripura	30	1	1	4	17	0	18	3	0
Uttar Pradesh	210	165	176	29	123	161	114	123	49
West Bengal	110	24	0	89	0	0	89	0	0

A study of some stretches of a few major rivers has revealed that none of our major rivers or their tributaries carry water which is fit for drinking or even bathing. In their natural forms, most of these waters are fit only for irrigation, industrial cooling and controlled waste disposal, although some of the stretches can still support propagation of wildlife and fisheries.

Ground Water Quality

Heavy metal related pollution is also present in ground water and there is every danger of toxicity crossing prescribed limits. Some data generated in this regard is given in Table 4.

Table 4 : Districts with Heavy Metals in Ground Water

State	Districts	Heavy Metals Present in Ground Water
Andhra	Anantpur, Mahboobnagar,	Molybdenum, Zinc, Lead, Arsenic, Cadmium,
Pradesh	Prakasam, Visakhapatnam, Cuddaphah, Nalgonda	Iron, Copper, Mercury, Manganese
Bihar	Dhanbad, Muzaffarpur, Begusarai	Iron, Manganese, Chromium, Zinc, Copper, Mercury and Cadmium
Haryana	Faridabad	Copper, Lead, Zinc, Chromium, Cadmium, Iron, Manganese, Nickel
Karnataka	Bhadravathi	Zinc, Iron, Manganese
Madhya Pradesh	Bastar, Korba, Ratlam, Nagda	Copper, Chromium, Cadmium, Iron, Lead
Orissa	Angul, Talcher	Copper, Chromium, Iron, Cadmium, Lead
Punjab	Ludhiana, Mandi, Gobindgarh	Copper, Chromium, Irion, Cadmium, Lead
Rajasthan	Pali, Udarpur, Khetri	Lead, Zinc, Iron, Manganese, Cadmium, Cobalt, Molybdenum, Silver, Copper
Tamil Nadu	Manali, North-Arcot	Mercury, Nickel, Cadmium, Copper, Arsenic, Zinc, Lead, Iron, Manganese
Uttar Pradesh	Singrauli, Basti, Varanasi, Kanpur, Jaunpur, Allahabad, Saharnapur, Aligarh	Iron, Chromium, Copper, Manganese, Lead, and Molybdenum
West Bengal	Durgapur, Howrah, Murshidabad & Nadia	Lead, Cadmium, Copper, Zinc, Chromium, Iron, Manganese, Mercury, Aresnic
Assam	Digboi	Iron, Manganese, Nickel, Zinc, Cadmium, Chromium, Lead
Himachal Pradesh	Purwanoo, Kalaamd	Cadmium, Lead, Iron, Manganese
NCT Delhi	Blocks-Alipur, Kanjhawala, Najafgarh, Mehrauli City, Shahdara	Cadmium, Chromium, Copper, Lead, Nickel, Iron, Zinc

Coastal Waters Quality

Areas of low, medium and high concentrations of pollutants have been identified in coastal waters. Findings are briefly given below :

Areas of clean sea water quality

The sea coast beyond 2 km along the coastline of India, except off Bombay, is clean and conforms to quality of clean waters. This is primarily due to the fact that the levels of dissolved oxygen and other parameters fulfil the requirements of clean sea water.

Areas of low concentration of pollutants

In the case of Bedi, Vadinar and Kandla in Gujarat, Ratnagiri in Maharashtra, Mandavi and Zuari in Goa, Mangalore Port in Karnataka, Calicut in Kerala, Cuddalore in Tamil Nadu and the West Bengal coast, the concentrations of dissolved oxygen were fairly high while other toxic elements like ammonia, heavy metals in sediments and biota were only slightly higher (about 15%) than the clean waters and, hence, they have been classified as areas of low concentration of pollutants.

Areas of moderate concentration of pollutants

In Porbandar, Damanganga Estuary, and Vapi industrial estate in Gujarat, Thana Creek in Maharashtra, Mangalore coast in Karnataka, Kochi backwaters, Alleppey, Kayamkulam, Quilon, Paravur and Veli in Kerala and Tuticorin and Arumuganeri in Tamil Nadu, the levels of dissolved oxygen were moderate to normal. However, some of the elements like ammonia nathogenic (about 25%) were more than the normal values. Hence, these areas have been classified as regions of moderate concentration of pollutants.

Areas where concentration of pollutants may become high in near future

In Veraval Port, Hazira and Tapi estuary in Gujarat, Versova Creek, Mahim Bay and Thane Creek in Maharashtra, Madras Harbour and Ennore Estuary in Tamil Nadu, Visakhapatnam Harbour and Kakinada Bay in Andhra Pradesh, and Puri in Orissa., the concentrations of dissolved oxygen were nil to low during the low tide period and improved their levels only moderately (30-50%) during the high tide period. Further, the levels of toxic metals like cadmium and lead were high in sediments in some locations (like Thane Creek). If no control measures are taken now, the areas will become regions of high concentration of pollution in another 5 to 6 years.

IS THERE A PATTERN IN WATER POLLUTION?

An in-depth analysis of observed values of water pollution parameters tends to suggest a pattern, which is reflective of the nature and scope of economic development. Some of the features are given below:

- The geological features impose their characteristic footprint. Widespread presence of arsenic, fluoride, iron and manganese in water are well documented.
- In areas, such as the North East, rural Rajasthan and Himachal Pradesh and the mountains, which have not yet seen either commercial agriculture or industrial growth and where demographic changes have been the primordial aspect, only feature of water pollution has been the rising levels of BOD in water bodies.
- In areas, such as Haryana and Punjab which have seen agricultural growth due to green revolution, water bodies have been affected by high BOD, COD, nitrates and pesticides.

- Areas, such as Maharashtra, Gujarat, Tamil Nadu, Kerala, Andhra Pradesh which have experienced rapid industrial growth, tend to be characterised by problem of acute toxicity. Red and yellow colour, heavy metals have been reported in water.
- Worst affected are the urban industrialised agglomerations, which have a cocktail mixture of pollutants.

Surveillance System for Water Pollution

A national surveillance system on security and health aspects of water is required. In a way, water is more strategic than oil. Although it is a renewable resource, its availability is not infinite. Desalination of sea water is not only energy intensive but also costly.

SURFACE WATER QUALITY INITIATIVES

River Action Plans

The first concerted action to tackle water pollution was the Ganga Action Plan (GAP-I). It was launched in 1985 to cover interception, diversion and treatment of 873 mld (out of 1340 mld) of sewage generated in 25 class I towns of UP, Bihar and West Bengal. It had the mix of schemes indicated alongside.

	Cost (Rs. In crore)
Interception, diversion	88
Sewage Treatment Plans	35
Low cost Toilets	43
Electric crematoria	28
River front improvements	35
Miscellaneous	32
Total	261

This was a 100% centrally sponsored scheme meaning that the entire funds were provided by the central government, but execution was done though the state agencies and assets were to be owned and operated by the latter. In subsequent stages, phase-II and other river action plans have also been launched. These have now been merged under the National River Conservation Plan (NRCP) (see Table 5).

Table 5 : River Action Plans

Title & Year of Launch	Towns	States	Rivers	Capacity (mld)	Cost (Rs. in crore)
Ganga Action Plan : Phase I 1985	25	3	1	873	462
Ganga Action Plan: Phase II 1995	29	3	1	588	396
Ganga Towns, Supreme Court Directed 1996	30	3	1	162	221
Yamuna Action Plan 1993	21	3	1	744	510
Gomti Action Plan 1993	3	1	1	269	61
Damodar Action Plan 1996	12	2	1	68	24
National River Conservation Plan 1995	46	10	18	1928	737

National Lake Conservation Plan (NLCP)

Urban lakes in ten states have been identified for conservation under a Proposed National Lake Conservation Plan. Domestic financial resources have become a constraint (the programme requires more than Rs. 600 crore) and external funding opportunities are being explored. Bhoj Lake in Madhya Pradesh is already covered by OECF, Japan. Project report on Dal Lake (J&K) is under preparation.

Kolleru Lake

The Kolleru lake is a natural depression of land between the two major rivers, the Godavari in the East and the Krishna in the West. It is listed in the Ramsar Convention proceedings as the largest fresh water lake and wetland in Asia. It drains a catchment of about 2,000 sq km. The water-spread area of the lake as +10 contour is about 890 sq km, meeting the flood levels about 32.2 km away from the sea. The lake is connected to the sea through a narrow waterway called 'upputeru'. The eco-system of the Kolleru Lake has been badly affected:

Causes

- Silting of the lake and subsequent loss of water holding capacity.
- The lake is receiving water from 15 main feeding drains, which carry agricultural, domestic and industrial effluents from the free catchment areas.
- Encroachments of aquaculture and agriculture into Kolleru lake have caused serious drainage problems. Also, seasonal backups of water flood the surrounding towns in monsoon.
- Aquaculture has affected the natural habitats both for the birds and the fish.
- Pesticides and fertilizer residues run-off affects the lake. Excessive nutrient flow causes eutrophication in parts of the lake.

Effects

- BOD levels are exceeding the permissible limits.
- pH is between 7.0 to 7.5
- TDS recorded is 600 mg/1 to 640 mg/l and it is within the permissible level of drinking water standards.
- Maximum DO is 6.0 mg/l and minimum is 0.6 mg/1.
- Nutrients are exceeding the permissible limits and hence there is excess weed growth in the lake.
- Trace metals are well within the permissible limits.

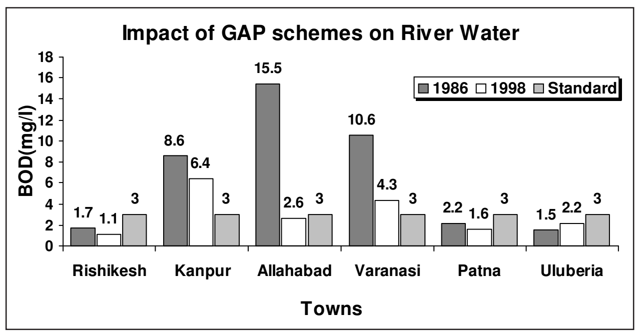
(*Source* : SOE, AP 1999-2000)

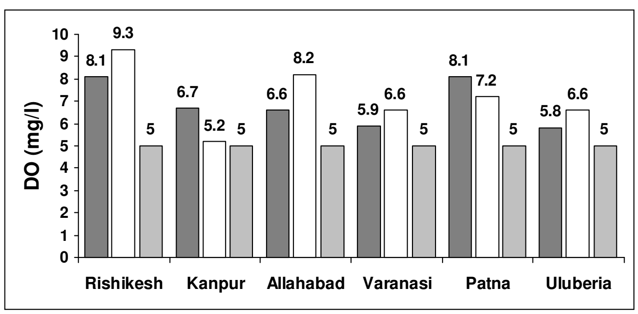
Management of Wetlands

These are a highly productive eco-system. They harbour a rich diversity of plants and animals including migratory birds. Apart from being sometimes used as sources of water for drinking, bathing and irrigation, wetlands perform important functions of flood control, natural sewage treatment, recharging of aquifers, etc. Most wetlands have been drained and reclaimed for agricultural and urban uses. Siltation and eutrophication are their particular problems apart from stress due to pesticides and chemicals. Management plans have been prepared for some of the wetlands, but no action has been taken on ground. A national wetlands policy and a dynamic approach are the need of the hour.

REVIEW OF SURFACE WATER QUALITY INITIATIVES

It appears GAP-I – a complex programme – was launched without adequate preparatory work or community participation. It has suffered cost and time overruns of serious proportions. Worst, assets created are not being effectively utilised as operation and maintenance costs are not forthcoming from the state governments. A part of this is also attributable to inappropriate technological choice, location, scale and absence of an integrated approach with the result that the programme could not cope up with indiscriminate dumping of solid waste, half burnt and unburnt dead bodies, open defecation on river banks apart from clogged sewerage system and, most important, non-availability of minimum environment flow in rivers. Non-availability of electric power to completed crematoria, pumping stations and sewage treatment plants has also been a major constraint. While more recent river action plans are attempting to address these issues, the NRCP continues on the basic model of Ganga Action Plan with interception, diversion and treatment as its core.





It must, however, be recognised that these programmes are extremely complex intrinsically and because of a 'trial and error' approach followed, improvements are evolving. A cost-benefit analysis of GAP-I conducted by a consortium under the overall supervision of Prof. Anil Markandya, an eminent international environmental economist, has established that the exercise has been worth its costs.

At the same time, it cannot be said that the river action plans have achieved their broad socio-economic objectives optimally. Following facts illustrate this point:

GAP - I : Summarized Results of Economic Analysis (@10% Disc. Rate.)

PV of Costs (Rs. crore)		511
PV of Benefits (Rs. crore)	Without N/U	686-1195
	With N/U	1755-2621
Net Present Value (Rs. crore)	Without N/U	175-684
	With N/U	1244-2110
Economic Rate of Return (%)		11.9-15.7

Source : A Cost Benefit Analysis of The Ganga Action Plan* (N/U: Non User)

1. Alternatives with regard to sanitation have not been explored. There is an urgent need to reconsider use of treated clean municipal water for conveying human excreta thereby first magnifying a problem, then further multiplying its scale by discharging semi-treated and untreated water into water bodies. This procedure spells an ecological disaster. Research and development in alternate dry technologies should be the central focus of the programme, particularly in view of the fact that our sanitation needs remain substantially unfulfilled so far. A more cost-effective approach would be to deal with and manage the 'demand' side.

2. It has not been possible to tackle industrial pollution through direct regulation of command and control kind. Enforcement of regulation in a poor and large country with inefficient governance structure is a formidable problem. Paradigm change built on a combination of wider community participation, moral suasion, creation of water and sewage markets and economic instruments (pricing and user charges on 'polluter pays principle' basis) alone can surmount our uniquely deep-rooted problems. It is pertinent to mention here that some industrial units already purchase sewerage from the Municipal Corporation of Chennai and upgrade it to meet their substantial water requirements and find it a cost-effective option. Similarly, the issue of equity arising from water pricing can be effectively addressed through the issue of coupons, as has been suggested by some eminent economists. Other innovative ways of cross-subsidizing the marginalized sections of society may also be available.

3. Agricultural run-off containing pesticides, inorganic fertilizers and other harmful chemicals requires an integrated river basin management wherein all surface and ground water sources and conjunctive use of water are simultaneously addressed in a holistic framework. It is possible to consider this approach in a more disaggregated manner at sub-basin, watershed or micro watershed level. Apart from holistic consideration, this problem calls for institutional changes with clearly defined quality-related water

rights and obligations under which no upstream agent may pass on to a downstream agent water of quality inferior to that it receives from an upstream agent. Principles and modalities of compensation as well as dispute resolution also need to be evolved.

4. Research, development and utilization of fertilizers and Integrated Pest Management (IPM) techniques need to be encouraged by a combination of a fiscal instrument and effective farm extension practices.

5. Municipal bodies, with rare exceptions, are just about able to break even in cash terms. It is suggested that essential functions of water and sewage disposal should be taken out of the Municipal bodies and placed in the hands of reputed community-based NGOs who should be entrusted with the management of these facilities efficiently and given power to levy user charges. Several studies and surveys have revealed willingness on the part of citizens to pay reasonable charges provided efficient and reliable services are provided.

6. Rainwater harvesting and recharging of aquifers should be encouraged through “carrot and stick” policy. Water has a quality context; different uses impose different qualitative specifications. Harvested rainwater or recycled water is quite suitable for cleaning, washing, gardening, toilet flushing and several other applications.

7. Community participation has been missing in River Action Plans. Generation of environmental awareness through interesting televised documentaries for the public at large has not received the attention that it deserves. Deep cultural beliefs require a soft ‘suasive approach’.

SEWAGE TREATMENT: TECHNOLOGY CHOICES

Following alternative technologies for the treatment of sewage are available:

- Activated Sludge Treatment Plant (ASTP)
- Oxidation Ponds
- Aerated Lagoons
- Upward Anaerobic Sludge Blanket (UASB)
- Duckweed and Fish Culture Technology
- Karnal Technology
- Trickling Filters

Conventional mechanical sewage treatment plants, such as ASTP are largely inefficient in removing coliforms, which can cause diseases. Oxidation ponds can ensure more efficient removal of coliforms.

Table 6 : Comparative Techno-economic Parameters of Sewage Treatment Alternatives

Technology	Land required Hectare/ mld mld	Capital costs Lakh rupees/ mld/year	Operation & maintenance costs lakh rupees/
Activated Sludge Treatment Plant (ASTP)	0.4	35-40	3.0
Oxidation Ponds	1.0	12-15	0.5
Aerated Lagoons	0.6	15-20	2.75
Upward Anaerobic Sludge Blanket (UASB)	0.2	23-28	1.5
Duckweed and fish culture technology	0.7-1.0	10-12	0.5-1.0
Karnal Technology	1.0-1.5	0.6-0.8	0.25-0.3
Trickling filter	0.4	35-40	3.0

Source : IGIDR booklet on Water

Comparative techno-economic parameters of these alternatives are given in the Table 6. Of the available technologies, oxidation ponds and aerated lagoons are land-intensive, whereas the conventional alternatives are capital-intensive. Former require 3 to 5 times more land than latter. At the same time, initial capital costs of an Activated Sludge Treatment Plant (ASTP) and an Upward Anaerobic Sludge Blanket (UASB) technologies are in the range of Rs. 23-40 lakh per mld. In these mechanical and energy-intensive technologies, O&M costs are also higher by Rs. 1-2.5 lakh per annum. Availability of large parcels of land and high land prices are said to be major constraints to wider application of oxidation pond technology in existing urban agglomerations. Even assuming the validity of these techno-economic parameters, the most conservative estimated switchover point (expressed as land price below which oxygen ponds remain a more cost-effective alternative) works out as more than Rs. 50 lakh per hectare (Rs. 20 lakh per acre), once the alternatives are made comparable in terms of costs of treating for coliforms through ultraviolet radiation, gamma radiation, chlorination and biological alternatives using Zooplankton. Barring a few metros, such a high economic price for land may not apply anywhere in the country. The quantum of area required for oxidation ponds is directly proportional to volume (1 ha per mld is the thumb rule). The oxidation pond technology requires low-lying lands. Very few cities are devoid of such lands although these may be under encroachment by the marginalized communities. Second, Indian cities always have a rural periphery where land prices are much lower. Finally, oxidation ponds do not depossess landowners of their only source of livelihood (land) – by viewing sewage as an ‘economic resource’ rather than as nuisance (source of pollution), they tap/recycle the nutrients available, thereby raising the productivity of these lands. Additional income generation and employment are thus supported. Most important, the otherwise intractable coliform problem gets effectively addressed.

In the case of new towns, land use planning should earmark land requirements of oxidation ponds just as is done for other infrastructural requirements. The possibility of replicating this successful technology, demonstrated by East Calcutta Wetlands both in rural and urban areas, needs to be explored seriously and objectively.

POLLUTION CONTROL BOARDS

Water (Prevention and Control of Pollution) Act, 1974 lays down under Chapter 2 (Article 3) that Central and State Pollution Control Boards would be constituted. The composition, functions and powers of the Boards are also prescribed. Although these Boards appear to be powerful statutory bodies, they have been rendered ineffective largely due to interference of the bureaucracy and politicians. As things stand, their technical, financial and professional resources are not commensurate with their responsibility.

The information generated by the system is anything but accurate; it is not analyzed for meaningful interpretation and is often outdated. Professionalisation of these boards with induction of people drawn from technical and non-technical disciplines and introduction of a system of accountability are urgent requirements. Amendments in the Water Act are also called for.

SOURCES OF WATER POLLUTION

Polluters of water can be broadly classified into:

- *Point Sources* : Organised sources of pollution with measurable heavy concentration of pollution load. These fall broadly under two sub-groups: (a) sewage sources i.e. surface drains/nullahs, sewage treatment plants and pumping stations; and (b) industrial effluent sources.
- *Non-point Sources* : Non-measurable individually small contributors to pollution characterised by tyranny of numbers, viz agricultural run-off carrying chemicals and fertilizers, open defecation along banks of water bodies.

Industrial Pollution

Industrial pollution has been addressed through regulatory measures by mandating installation of effluent treatment plants in large and medium organised industrial sector.

For the small scale sector, a scheme called 'Common Effluent Treatment Plant' (CETP) has not been uniformly successful, as different units within the same complex release different types of effluents which cannot be treated through a single technology. More important, pooling of resources for this common cause has not found favour with the small scale industry/cottage industry.

Effluent treatment plants have no doubt been set up. But the extent to which they have been operated is rather uncertain. Suggestions have been made that electric supply to the plant should be in series with ETPs to ensure their joint operation. Dr. Imberger, the 1996 Stockholm Water Prize winner has developed the concept of flax path which regards our earth as operating like a "fish tank". Some large environmentally committed transnational companies have adopted this concept in their operations now. They return the water in at least as pure a state as it was when they received it. In order to demonstrate that the effluent water more than meets the prescribed standard, the outlet is connected to tropical fish tank.

K Subrahmanyam, Scientist at NGRI, says that the Total Dissolved Solid (TDS) levels in ground water have been reported to be as high as 2,310 mg/1 in Patancheru borewells. The permissible limit for TDS is 500 mg/1, and the TDS concentration in the natural ground water (from aquifers that have not been affected by human activity) in the area is 300-350 mg/1. The characteristics of these effluents are alarming. Independent studies show that various parameters, such as COD levels, are exceeding the prescribed limits. "The common effuent treatment plants (CETPs) at Patancheru and Ballaram do not work up to the required efficiency. So, effluents with TDS levels of more than 20,000 mg/1 are only treated up to 8,000-9,000 mg/1 levels. And many a time, these CETPs discharge the effluents in the nearby streams without treatment," Chatterjee reveals.

Given the scope for reducing industrial water requirements, the main challenge lies in devising instruments, which make it attractive for the corporate sector to conserve and recycle water by adopting less water-intensive processes and encourage material recovery (Table 7).

Table 7 : Wastewater Generation from Different Types of Industries and Achievable Reuse

Industry	Average Volume of Wastewater per Unit of Product	Per cent reuse achievable
Thermal Power Plant	155Kl. lit/hr/MW	98
Pulp & Paper	250Kl. lit/tonne	50
Iron and Steel	150Kl. 1000 lit/tonne	40
Pharmaceutical	4.5 Kl.lit/tonne	40
Distillery	15 lit/lit of alcohol	25
Textile	250lit/Kg cloth	15
Tannery	34 lit/Kg of raw hides	12

Direct regulation of the ‘command and control’ type has not worked due to weaknesses in enforcement coupled with low level of penalty. Under a regulation of this kind, perceived benefit from conservation must be more than the cost of compliance. The latter, in expected value terms, is the product of magnitude of penalty if non-compliance is detected. That market based economic instruments/fiscal policies are substantially more cost-effective and easier to implement has been known in environmental economics literature for a very long time. This has also been demonstrated in India during the implementation of the World Bank aided Industrial Pullulation Control Project (phase-1). Many funded caustic soda manufacturers have switched over from mercury-based process to the membrane technology. This has manifested itself in substantial reduction in the level of mercury found in coastal areas. Access to concessional funds and other tax incentives brings about a convergence between environmental concerns and business priorities. Coupled with appropriate prices of water, cess and market friendly instruments, these measures are certain to provide a fillip to conservation of water in industry.

Agricultural Run-off

The agricultural run-off releases harmful pesticides, chemicals and fertilizers in the water bodies. The complexity of the problem has not so far been addressed. Resource constrains are said to prevent even systematic monitoring. Here, it may be pointed out that the problems of toxicity and bio-magnification take several years to appear in their recognizable manifestations

Integrated River Basin Management with adoption of market-based economic instruments, such as pricing of water and electricity based on their real resource cost and fiscal instruments e.g. taxes and subsidies on chemicals, inorganic fertilizers and persistent pesticides are some of the instruments available for tackling this rather complex form of water pollution. These latter measures have double dividend yielding potential. They can not only significantly discourage inefficient allocation of water resources but also provide a fillip to water conservation technologies/practices and encourage research, development and substitution of chemical toxins with environmental benign manures, bio-fertilizers and integrated basin management techniques.

REGIONAL WATER TRANSFER AND HUMAN RIGHTS :
Some Reflections on Sardar Sarovar Project

Dr. Rajiv K. Gupta*

INTRODUCTION

Historically, civilisations have flourished along or around the sources of water. However, due to geographical, technical, social, cultural and political reasons, boundaries of demographic regions do not coincide with the basin boundaries. This has resulted in spatial variations in the distribution of this prime natural resource and formation of 'water surplus' and 'water deficit' regions.

Regional water transfer is an attempt to redistribute water across the regions to ensure that sustainable water resource development is achieved in consonance with broader planning of socio-economic development. Depending upon social desirability, technical feasibility and economic viability, regional water transfer could be intra-basin, inter-basin or a merger of both. It is true that issues connected with equitable distribution of dwindling fresh water supplies could become a major source of strife at the regional, state, national or international level. However, if managed carefully, it may lead to better cooperation among competing water users.

WORLDWIDE EXPERIENCE OF REGIONAL WATER TRANSFER

Regional water transfer (RWT) has a long history as a means of addressing water scarcity in one region by transporting additional supplies from water surplus areas. It has been attempted as a viable water management alternative in both developed as well as developing countries, all over the world. Amongst the existing RWT projects in USA, California State Water Project, completed in 1973, is an outstanding example, transferring 4000 MCM of water from the northern to the southern part of the state (Verghese, B. G., 1999). Growing water scarcity in the arid and semi-arid west has fostered a number of RWT proposals to divert northern rivers of largely uninhabited areas of Canada and Alaska, e.g. the proposed North American Water and Power Alliance

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The views expressed in the article are author's own and do not reflect those of the organisation he works for.

(NAWAPA) to transport 1,35,683 MCM of water annually, equivalent to about eight times the average annual flow of Colorado river (Frederick, Kenneth D., 1995). Incidentally, it may be mentioned here that Canada has twice as much surface and ground water as the US, with one tenth of the USA's population and industry. Other proposed ambitious RWT projects, consistent with the North American Free Trade Agreement (NAFTA), are the Great Replenishment and Northern Development Canal (Grand Canal), the Alaska California Subsea Pipeline Project and the Garrison Diversion Project. According to NAFTA, natural resources, such as water, are also covered among the goods and services for free trade. As a result, local, provincial or even national attempts to prevent or restrict Canadian water exports to the US or Mexico would be subject to the review of an international panel (Koftinoff, Jeff, 1997). In Rio de Janeiro state of Brazil, a total of 160 cumecs of water is transferred from the Rio Pariba do Sul to the Guandu River Basin via the Light-Guandu system for drinking (The World Bank Policy Report, 1996).

By the mid-1970s, it was clear to the South African authorities that the need for water in the arid industrial heartland of the country, mainly in the Vaal River Supply Area (VRSA) and in Gauteng and Mpumalanga would in future become so great that the possibility of diverting water from Lesotho to South Africa would have to be considered, To address the immediate shortage of water in the VRSA, various transfer schemes, such as the Tugeal/Vaal Transfer Scheme between KwaZulu-Natal and the Free State, the Usutu-Vaal Government Water Scheme and the Slang River Transfer Scheme between the KwaZulu-Natal and Mpumalanga were commissioned (Frank, Smith, 1997). South African Water Resources Management Policy states : "Current planning predictions suggest that this (Inter-basin transfer scheme) will have to continue if the economic growth and the social development of the country is not to be stunted" (South Africa, National Policy, 1997). Inter-basin water transfer has been attempted in Kenya also. The area of water supply for the capital Nairobi city, falls in the Athi River Drainage Basin. Similarly, the 60 km long Yatta canal built during the colonial times, transfers 1 cumec of water from the Thika river downstream of the DelMonte to the semi-arid lands of the Machakos district in the Athi river basin (Nyararo, John Rao, 2000). The erstwhile Soviet Union too had made several inter-basin diversions from the Volga, Amu Darya, Dnieper and Irtysh (Verghese, B.G., 1999). There are 37 inter-basin flow diversion systems with a volume of more than 15,000 MCM per year and total extension of 3,000 km (Mikheev, N. *et al.*, 1998).

In France, RWT projects have been taken up to cater to the water demand of large cities. A recent example is the proposed water transfer from the Rhone River in Languedoc-Roussillon region of France to Catalonia region of Spain

– the LRC Aqueduct, a possible structural response to water shortage in Barcelona. Ebro-Tarragona projects and Tajo-Segura project in Spain are other examples of inter-basin water transfer (World Bank Policy Report, 1996). Sharing of Danube river waters is a unique example of international water sharing, involving twelve out of fifteen riparian countries (Dinar, Ariel, 1997). The Environment Agency, Government of UK announced its R & D strategy in September, 1998, which also includes promotion of inter-basin transfer of water where the scientific basis to do so is sound (UK Environment Agency Document, 1998). Urban centres of Germany too have resorted to RWT for their water needs (World Bank Policy Report, 1996).

In Venezuela, 85% of demand for water was in the north, while 85% of supply was in the south. Water, therefore, had to be transferred across the country. HIDROVEN, the national water management body of Venezuela, has adopted a holistic approach to ensure that water is made available equitably to all in society (Commission on Sustainable Development, 1998).

In Middle East, 'need-based' rather than 'right-based' paradigms are used for negotiating water disputes. The Nile Waters Treaty involving nine riparian countries is an example of 'hydro cooperation'. As regards RWT, Israel's National Water Carrier, which pumps Jordon River inflows into the Sea of Galilee southwards into the Negev desert is another notable example. In an era of peace, development of the shared water resources of the Jordon River Basin and contiguous water systems, in a programme of regional cooperation including economically feasible projects for water transfers, can bring benefits to all riparian partners (Shuval, Hillel I., 2000).

The distribution of people and arable land in China does not match the distribution of water resources – 44% of the population and some 58% of the cultivated land are in Northern and North-eastern regions, whereas only 14.4% of the total water resources (surface and ground water) can be found in these regions (Heilig, Gerhard K., 1999). The Chang Ziang (Yangtze) and Zhu Jiany (Pearl) rivers in the South account for just about half the total run-off of all the rivers in China, while many northern cities are faced with acute water shortage. Yangtze, which is often called 'Equator of China', taken literally, should "make things equal", but it appears that the direction is just the opposite! (Ollis, Varis and Pertti Vakkilainen, 2000). Hence, water transfer from the south to the north is the only realistic solution for the scarcity of water resources in North China. China has a history of inter-basin projects, among the oldest of these being the Lingua canal linking the Xianjiang and Guijiang rivers for shipment of armament during war (241 B.C.) and the Grand Canal, linking the Yangtze and Yellow rivers for navigation and irrigation (605 A.D.) (Verghese, B.G., 1999). Recently, a major project to divert Yangtze waters north to the Yellow river has been under study for some time. Three Gorges Project, a mega project is at present under construction on Yangtze river. West, Middle and East Route Projects of South-to-North water transfer will annually transfer 10,200 MCM, 14,500 MCM and 8,860 MCM of water, respectively (Liu, Zhaoyi, 2000).

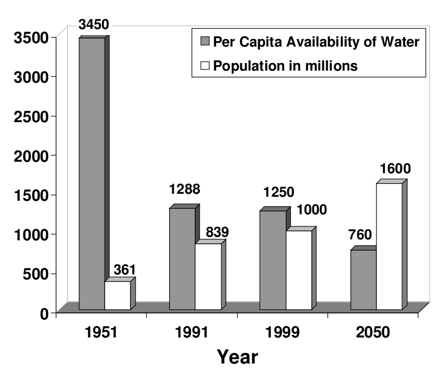
In Asia, Japan has to its credit a detailed River Law and comprehensive administrative set-up to implement regional water transfer. Small capacity dams with a copious inflowing water volume in a large river basin are linked with the large capacity dam with a small inflowing water volume in a small river basin by creating an interconnecting waterway to store water that is used in drought situations by inter-basin transfer of water through specially created water conveyance channels (Gupta R. K., 2000). The South Asia Water Vision has identified the Ganges, Brahmaputra and Meghna (GBM) basins as a single basin. This vision of GBM basin is certainly pushing towards the Indian idea of Indo-Bangladesh inter-basin water transfers (Mirza, Monirul Qader M., 2000). Bangladesh has off and on contemplated a Brahmaputra-Ganga transfer within its own territory and Nepal has likewise identified certain deficit zones which might at some stage import water from surplus basins.

INDIAN EXPERIENCE OF REGIONAL WATER TRANSFER

Water Availability

India has 1/3rd of its territory drought prone and 1/8th of its territory liable to flooding. About 80% surface water of rivers goes to the sea unutilised, while the country reels under the flood-drought-flood syndrome. The per capita availability of utilisable water has been reducing progressively owing to increasing population (361 million in 1951 to about 1 billion presently). It has come down from 3450 m^3 in 1951 to around 1250 m^3 presently and by 2050 with a projected population of 1.6 billion it would only be 760 m^3 as a national average (Figure 1).

Figure 1 : Per Capita Availability of Utilisable Water in India



Source : Ministry of Water Resources, Government of India, 1999)

In the broad five-fold categorisation of global water scarcity developed by International Water Management Institute (IWMI), Sri Lanka, the drier region of western and southern India falls in the first category, which includes those countries that are most water scarce and in 2025 will not have enough water to maintain the 1990 levels of per capita food production from irrigated agriculture (Seckler, David, 1998).

According to the FAO criteria, any situation of per capita water availability of less than 1000 m^3 is considered as a scarcity condition (FAO Report, 1993). There are already six river basins in the country, namely (i) the Cauvery, (ii) the Pennar, (iii) the Sabarmati, (iv) the east-flowing rivers between Mahanadi and Godavari, (v) the east-flowing rivers between Pennar and Kanyakumari, and (vi) the rivers of Kutch and Saurashtra, that fall in the water scarcity category where per capita water availability is less than 1000 m^3. Here water shortage is absolute whereas scarcity is relative. There are degrees of scarcity – absolute, life threatening, temporary, cyclical, etc. However, scarcity is not necessarily inevitable or immutable (Winpenny, J.T., 1999).

Most of the county's water is being used for irrigation. A small proportion is used for household consumption while the industry uses about 12% of the total water. More than 1,50,000 villages in India (out of around 5,87,000 i.e. 25%) still have acute water problems and many more have unreliable water supply. Over-exploitation of ground water has become a very serious problem as water tables are steadily falling in many parts of the country. There are more than 4.79 million electric and 7.5 million diesel pumps drawing ground water across the country. Of the ground water extracted, about 90% is used for irrigation and only 6% for domestic purposes. It is estimated that by the year 2050 the requirement of water will exceed the utilisable water resources of 11,22,000 MCM in the country (Varma, C.V.J., 1999).

Legal Provisions

According to Article 39 of the Indian Constitution, "The State shall …. direct its policy towards securing …. that the ownership and control of material resources of the community are so distributed as best to subserve the common good". The expression is wide enough to include natural resources (1984 S.C. 374). In India, water is a state subject. Under Article 246(3) of the Constitution, every state government has power to legislate and exercise authority in respect of water within its territory. Article 262 of the Constitution authorises Parliament by law to provide for the adjudication of any dispute or complaint with respect to the use, distribution or control of the waters of any inter-state river or in any river valley. Under Inter-State Water Disputes Act, 1956, which was enacted under Article 262 of the Constitution, an Inter-State Water Dispute Tribunal can be constituted under the Chairmanship of a Supreme Court Judge, with its award being beyond judicial review. River Boards Act, 1956, also provides for the constitution of River Management Boards.

Policies and Projects

Within this framework of legal provisions, RWTs have been made since long and will continue to take place in view of the compulsions of growing demand, with population growth and development, and the high degree of imbalance in water availability over space and time (Verghese, B.G., 1999). The Periyar diversions across the Western Ghats to Tamil Nadu established the principle of inter-basin transfer a century ago, although within the same larger Ganga basin, the Ghaghara has been diverted to the Sharda (Sharda Sahayak Project). Through Bhakra Project, which brought green revolution in India, the Ravi-Beas have been diverted to the Yamuna. Inter-basin transfers have also been made from the Krishna, Godavari, Mahanadi, Cauvery, Tapi and Mahi (Gulati, N. D., 1972). Indira Gandhi Canal Project, a relatively recent one, has transformed the once barren land of Thar desert into an agriculturally productive land by bringing water from the Harike barrage on Indus river. The Canal which has rounded Jaisalmer and is being hewn through dunes and arid, sand-blown wastes along the desert, marches towards Gadra Road, about 1500 km from the Himalayan storages and upstream diversions that feed it (Verghese, B. G., 1994).

During the last quarter of the 20th Century, several RWT proposals received impetus. Noteworthy among these were the National Water Grid proposals made by Dr. K. L. Rao (Ganga-Cauvery Link, 1972) and by Captain D.J.Dastur (Garland Canal Project, 1974). Prohibitive costs of these proposals have relegated them to the realm of science fiction, at least for the foreseeable future.

National Perspective Plan for Water Development in India (1980) comprised two components, namely, Peninsular Rivers Development and Himalayan Rivers Development. Through such inter-basin water transfer this plan is expected to give additional benefits of 25 million ha of irrigation, 34000 MW of power, apart from the benefits of flood control, navigation, water supply, fisheries, salinity and pollution control, etc. (National Perspective Plan, India, 1980). National Water Policy (1987) categorically states that, “Water should be made available to water short areas by transfer from other areas including transfers from one river basin to another, based on a national perspective, after taking into account the requirement of areas/basins” (National Water Policy, India, 1987). This policy is being updated to cover issues like inter-sectoral water allocation, environment problems, inter-state water disputes, farmers’ participation, private sector participation, etc. The updated draft National Water

Policy has been approved by the National Water Board by general consensus and is to be placed before the National Water Resources Council for adoption (Parliament News, India, 1999). Integrated Water Resources Development Plan (1991) also includes inter-basin transfer of water as an integral part of water management (IWRD Plan, India, 1999). National Water Development Agency (NWDA) and Ministry of Water Resources have prepared a perspective plan for inter-basin transfer of surplus water to augment availability of water by about 224 MCM. The river links identified for this purpose are Pamba-Achankovil-Vaippar link involving Kerala and Tamil Nadu, Par-Tapi-Narmada link involving Gujarat and Maharashtra and Ken-Betwa link involving Madhya Pradesh and Uttar Pradesh.

CONTROVERSIES

Despite being an option to address imbalances in water supply and demand, RWT has generated many controversies both nationally and internationally. Environmental (rehabilitation of eco-system), social (rehabilitation of the displaced people), legal (sharing of water) and ethical (value, belief and culture bound) including spiritual issues have been raised and debated in the context of RWT projects. Water is so important for human life that it makes definition of surplus water difficult and precludes simple agreement as to when water transfer is desirable. The water use efficiency in the recipient regions is also an important consideration. RWTs have been attempted in the developed countries mainly for catering to the urban needs of water including those for recreational activities, whereas such attempts in the developing countries aim at supplying water to the poor rural areas for their sustenance. These issues have been discussed and debated in recent times at various international fora. While the debate may be justified either way, the will to cooperate remains the deciding factor. To have water when it is deficient is a basic human right (South Africa Bill of Rights, 1998) and it has been proposed for universal acknowledgment that a basic supply of water to allow a healthy lifestyle is a fundamental human right (World Commission on Water, 2000). Recently, the Hague Declaration (March, 2000) also recognised that access to safe and sufficient water and sanitation are basic human needs and are essential to health and well-being, and to empower people, especially women, through a participatory process of water management.

HUMAN RIGHTS

This leads us to the examination of larger context of human rights and its linkage to sustainable water development. It is widely acknowledged that sustainable human development aims at alleviating poverty, promoting human dignity and providing equitable opportunities for all through good governance, thereby promoting the realisation of various human rights – economic, social, cultural, civil and political (UNDP, 1998). Therefore, human rights and sustainable development are interdependent and mutually reinforcing. Development is unsustainable where a large number of people live in abject and degrading poverty. Poverty is a human rights violation and freedom from poverty is an integral and inalienable human right (UN Millennium Declaration, 2000).

Right to Development

Right to Development is implicit in Universal Declaration of Human Rights and in the Covenant on Economic, Social and Cultural Rights. The UN Declaration on Right to Development (1986) reaffirmed its existence and it was reiterated as a "Universal and Inalienable Right" and an integral part of fundamental human rights. Recently concluded Millennium Forum of the UN has also urged all governments, the UN and civil society to cooperate in appropriate actions to effectively realise the right to development as a matter of utmost urgency.

Thus, there is no doubt that right to development is not a mere pipe dream or ideological slogan but is guaranteed by International Law. It includes the rights of people, such as right of exercise of full and complete sovereignty over their natural wealth and resources; right to be the central subject of development; right to self-determination; right of participation (in the process of development), etc. In this process, the state also has certain obligations (as per UN Declaration on Right to Development) like (i) to ensure full exercise and progressive enhancement of right to development (Article 10); (ii) to formulate appropriate national development policies (Article 2[3]); (iii) to undertake, at the national level, all necessary measures for the realisation of the right to development (Article 8[1]); (iv) to create national conditions favourable for the realisation of the right to development i.e. to create enabling environments (Article 3[1]).

Rights of Women

That women's rights are human rights, has been recognised in the Convention on Elimination of all forms of Discrimination against Women (CEDAW), 1979; UN World Conference of Human Rights (Vienna), 1993; The Beijing Platform of Action of the UN Conference on Women and Development, 1995; and Women 2000: Gender Equality, Development and Peace for the 21st Century, UN, New York, 2000.

Rights of Children

The UN Convention on the Rights of Child, the most widely ratified human rights instrument, recognises several crucial rights of children including right of survival, right to protection, right to development and right to participation.

REALISATION OF HUMAN RIGHTS THROUGH REGIONAL WATER TRANSFER IN GUJARAT ?

Harnessing the untapped waters of river Narmada by Sardar Sarovar Project and the regional transfer of water from water surplus to water scarce regions has been seen as an attempt to fulfil the right to development for millions of people by a strategy of poverty alleviation through water development. These efforts have been questioned by some individuals on the grounds of violation of human rights of the oustees. This school of thought holds that human rights of those subjected to involuntary displacement cannot be impaired on the grounds of national sovereignty and national economic interest. They hold that such considerations may justify a project, though these may not justify nullification of basic human rights (Morse, Bradford, 1992). One needs to understand the peculiar climatic, geographical, geological, and socio-economic conditions in the state of Gujarat before arriving at any conclusion.

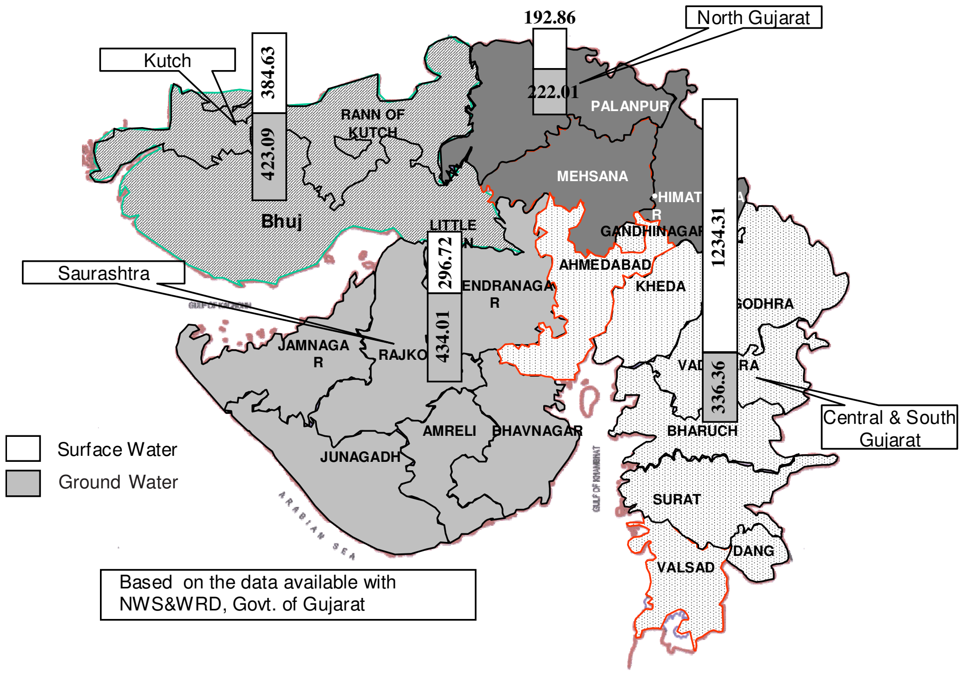
Water Situation in Gujarat : Past, Present and Future

Gujarat state, situated on the West Coast of India, covers an area of 196024 sq.km and has a population of about 47 million that is growing at an annual rate of 2.12%. It is relatively urbanised and has a large and fast growing manufacturing sector. Agriculture accounts for more than one-third of the state's income. The state, which has 6.39% of the geographical area of the country and 4.88% of the country's population, is endowed with just 2.28% of the country's surface water resource. Added to this is the fact that out of the 185 rivers, the state has only 8 perennial rivers and all of them are located in the southern part. Around 25% of the geographical area of the state (central and southern Gujarat) has got about 80% of the surface water resource.

Average per capita availability of water (considering both surface and ground water) is around 980 m^3 per year. However, this varies from 414 m^3 in North Gujarat to 1570 m^3 in South and Central Gujarat (Figure 2).

Gujarat has a tropical monsoon climate with temperature that is suitable for year-round cropping. It is characterised by a low, uneven and unreliable

Figure 2 : Per Capita Availability of Water in Gujarat



rainfall with high coefficient of variance. The irony of nature is glaringly stark as far as the erratic behaviour of rainfall is concerned. On 28th April, 2000, as against a total storage capacity of 4,512 MCM in all the dams of Saurashtra, Kutch and North Gujarat, the storage available was hardly 79 MCM (1.75%) (Table 1). On the other hand, during September, 1999 as much as 24,700 MCM of Narmada water flowed down to the sea without any use. On an average, three years in a cycle of ten years are drought years. During the last 15 years, the state has had a very bad spell of twelve drought years and about 5645 million rupees (~US $ 140 million) were spent to mitigate drinking water problem. During this period, the state had spent more than Rs. 600 million (US $ 15 million) on temporary measures to provide drinking water (through tankers) which do not yield any permanent relief (Gujarat Drinking Water Master Plan, 2000).

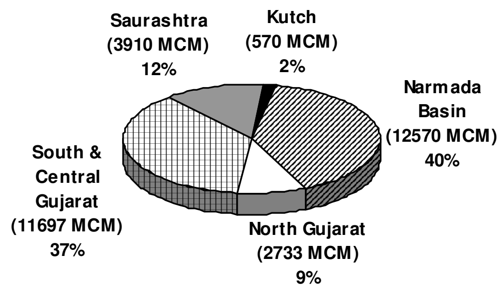
Table 1 : Water Availability in Dams in Scarcity-hit areas of the State

Region	No. of Dams	Storage Capacity		Current Storage Available	
		(MCM)	(%)	(MCM)	(%)
North Gujarat	13	2,018	(13.48%)	6	(0.30%)
Saurashtra	113	2,229	(14.90%)	55	(2.47%)
Kutch	146	4,512	(30.15%)	79	(1.75%)

Source : Narmada, Water Resources & Water Supply Department, Government of Gujarat, May, 2000.

Pattern of surface water availability within three different regions of the state, is quite skewed from water abundant to totally water scarce regions. Surface water available through the Narmada basin is of substantial quantity – which underscores the state's dependence on Sardar Sarovar Project on river Narmada for its water requirements (Figure 3). As per the Report of the world-renowned Tahal Consulting Engineers Ltd. (Israel), the effective storage of existing and ongoing major, medium and minor schemes including lift, check dams and percolation tanks is roughly equal to surface water potential (Water Resources Planning Report, Gujarat, 1997). Therefore, no surface water is available for further exploitation except the Narmada waters.

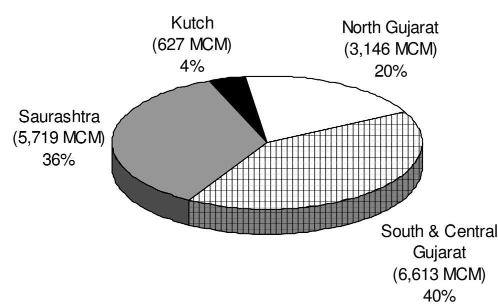
Figure 3 : Utilisable Surface Water (31500 MCM) in Gujarat



Source : Narmada, Water Resources & Water Supply Department, Government of Gujarat, 1997

In Saurashtra, due to over-exploitation of ground water resources, the natural balance between the sea water and ground water level has been disturbed and salinity ingress has become a major problem. In North Gujarat, due to ground water exploitation the fast depletion of ground water has led to ground water mining. In Kutch, the non-availability of water has caused advancement of desert, environmental degradation and national security problems due to long Indo-Pak border in this area (Figure 4). Lower percentage of dense forest in water deficit districts and higher density of forest as compared to state average in water surplus districts adequately proves the detrimental effects of water scarcity on the environment.

Figure 4 : Ground Water (16105 MCM) in Gujarat State



Source : Narmada, Water Resources & Water Supply Department, Government of Gujarat, 1997

The water scarcity has assumed serious dimensions in the state. At this rate, in the next 25 years, even during normal monsoon the state would face shortage of around 7000 MCM. The underground water is available at an average depth of 700 to1000 feet in North Gujarat. The quality of drinking water has become a serious concern for the state. Out of 18028 villages, around 2800 have excessive fluoride, nearly 800 suffer from excessive nitrate and about 1000 have

CHINA WATER VISION IN THE FIRST QUARTER OF TWENTYFIRST CENTURY

Rusong Wang & Zhiyun Ouyang*

Having long tradition of sustainable water management and human ecological philosophy, the water vision in China has both optimistic and pessimistic perspectives. This China water vision studies from the Chinese Academy of Sciences shows both water crisis and opportunity, including water states (quantity and quality), water stresses (flooding, drought, eutrophication, desertification, ground subsidence), water security (on food, health, environment, ecosystem, economy and society), water system(water-man complex social-economic-natural ecosystem combining production, consumption and natural service) and water strategies(from technological innovation, institutional reform and behavioral inducement). Four scenarios (business as usual, technological innovation, institutional/cultural reform, and comprehensive one towards sustainable development) were carried out for different sectors (agricultural, industrial, domestic and environmental use) regions (North, Northeast, Northwest, Southeast and Southwest) and watersheds (Yangtze and Yellow River) in the next 25 years. The results were reported at the special session for China Water Vision, in the Second Water Forum held in Hague, the Netherlands, on March 17-22, 2000.

Rapid industrialisation and urbanisation is taking place in China since it opened up to the world and began the transition from a planned to a market economy. The pace, depth, and magnitude of this transition, while bringing prosperity and hope to many citizens, has exerted severe ecological stresses on both local living conditions and regional ecosystems. During the past 20 years, both the GNP of industry and the number of cities and towns has increased by three times. Nearly every kind of environmental problem seen in early-industrialised countries and the ecological deterioration seen in developing countries has emerged in China. These have exerted a major impact on people's health and the local and regional life support ecosystem. The high pressure of population growth, rapid economic development, and a strong desire to improve life quality, fragmented institutions, low eco-awareness in policy-making are threatening both water availability and security.

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Water sustainability can only be assured with a human-ecological understanding of the complex interaction of environmental, economic and social/cultural factors and with comprehensive planning and management grounded on ecological principles. In dealing with the fatal issue, a transition from physical engineering to ecological engineering, from reductionism to holism, and from man domination to man-nature harmonization is needed. Therefore, increasing people's understanding of the eco-sphere of "the man-water complex", probing the scientific mechanisms and methods for addressing water problems, and searching for effective technological instruments for sustainable water use are to be considered the keys to China's sustainable development.

WATER STATES

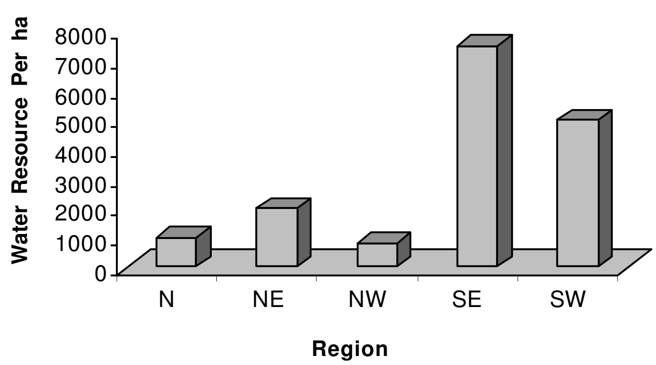
China has abundant water resources. There are more than 1500 catchments each with an area larger than 1000 km^2. There are 17 major rivers each with an annual runoff exceeding 50 billion m^3 (bn m^3) and 130 lakes each with surface area exceeding 100 km^2. The total amount of surface water and ground water resources is around 2800 bn m^3, which ranks China the sixth largest in the world.

China has the largest population in the world: 1.24 bn in 1997. Water resources per capita are estimated at 2245 m^3, which corresponds to one-third of the world's average value and ranks among the lowest in the world. Water resources per hm^2 of land are 2871 m^3, which corresponds to two-thirds of the world's average value. With 7 per cent of the world's total fresh water resources, China has to support more than 21 per cent of the world's population.

The main characteristics of the water issues in China are extraordinary uneven geographical distribution; 80.2 per cent of the water is located in the Yangtze River basin and its southern area (15 southern provinces), which accounts for only 58 per cent of the total population and 40 per cent of the total land. The per capita water availability in South China is 3 times more than that of North China, and its per hectare water resource is 6 times greater. In South China, 60 per cent of the annual precipitation is in April to July, and in North China 80 per cent of the annual precipitation is in July to September. The per capita available water in Huaihe, Haihe and Yellow River basins is below 1000 m^3, the internationally accepted definition of water scarcity. The runoff in the Haihe river basin, for example, is particularly low, being only 245 m^3 per capita.

The water for nature service in North China is far from nature's demand. In 15 of North China's provinces, available water for the total land is only

Figure 1 : Water Resources per ha in Different Regions



962 m^3 per hectare, while in 15 southern provinces, it is 5829 m^3 (Figure 1). This explains why water shortage is one of the main factors for the weak nature service function in the North. If we take 1500 m^3 per ha, a quarter of the average level of water availability in South China, as the minimum demand for nature service function in North China, we need at least 470 bn m^3 more water.

Every 10,000 m^3 water feeds about 4.46 persons in China. Taking this average figure into consideration, the seven provinces in North China can support 75 million (mn) persons, which is only 23 per cent of the present actual population. The water carrying capacity in North China has been overloaded by 3 times compared with the nation's ave
70 per cent of available water resources
West region, only 6 per cent of the re

Figure 2 : Five Regions in China Water Vision

WATER STRESS

The driving forces of the water issue are: high pressure of population growth, rapid economic industrialisation and urbanisation, a strong desire to improve life quality, fragmented institutions, and low eco-awareness in policy-making, which threaten both water quantity and quality. The inappropriate use of water has caused severe qualitative and quantitative water shortages. The unusual hydrological and inappropriate anthropological processes have resulted in the acceleration of flooding and drought, desertification, soil erosion, biodiversity loss, and service function declination.

Water usage was 103.1×10^9 m^3 in 1949 and 556.6×10^9 m^3 in 1997. That is, the population of China has doubled, while water use for human purposes has multiplied 4.5 times during the past 50 years. The agricultural water consumption ratio in 1949, 1965, 1980, and 1997 was 97.1 per cent, 92.7 per cent, 88 per cent, and 70.4 per cent of the total water use, respectively. In the past 50 years, agricultural, industrial, and domestic water consumption has increased by 3, 46, and 41 times, respectively.

Agricultural water use efficiency on average in China is about 0.4-0.5. In North China, for example, the irrigation quota is 7,500-12,000 m^3/hm^2, 2-5 times greater than that of actual crop needs. If the average efficiency is raised to 0.65 through some technological measures, reaching the level of advanced areas in China, 130 bn m^3 of water could be saved every year for the same area.

Irrigation works in China were mostly built between the 1950s and 1970s, and have been in use for 30-40 years. For a long time, the works have deteriorated due to lack of maintenance. Of all the large and medium reservoirs, three-fourths are dangerous and sedimentation in their case is very severe. According to an investigation, of the 231 large reservoirs, for example, the average annual sedimentation rate is 2.3 per cent, and cumulative sediment takes 14.3 per cent of the total capacity.

In 1997, total drainage of wastewater was 416×10^8 m^3, of which 54.6 per cent was industrial and 45.4 per cent was domestic sewage. At present, the urban domestic sewage treatment ratio is only 13.6 per cent, while most sewage is discharged directly to rivers and lakes without any proper treatment.

There are 7.9 mn factories in China. In 1997, the total amount of industrial wastewater discharged in China was $22.7\text{x}10^9$ tons. Industries at the county level and above discharged $18.8\text{x}10^9$ tons, while town and village industries discharged $3.9\text{x}10^9$ tons. The ratio of wastewater discharged meeting quality standards from county level or above was 61.8 per cent. Furthermore, the increasing use of chemical fertilisers and pesticides, the raising of livestock, and heavily polluting rural industries have accelerated water pollution and ecosystem deterioration. This non-point source pollution accounted for 70 per cent of the total pollutant load in China's water bodies.

In China, the rivers are widely polluted. According to a nation-wide water quality survey in the nineties (in total 5.3×10^4 km surveyed rivers), fish were extinct in 45 per cent of surveyed rivers because of water pollution, while water in 23.3 per cent of surveyed rivers could not be used for irrigation. This means that 68.3 per cent of surveyed rivers were polluted very severely. Main pollutants included organic matter, ammoniac nitrogen, petroleum chemicals, and heavy metals.

Over-exploitation of ground water and rapid water table decline have become a critical ecological issue in many parts of China. In North China, about 87 per cent of water resources have been withdrawn from ground water, over-exploiting about 30 bn m^3 of ground water annually. The total area of ground water table decline in North China is over 23,000 km^2, and ground water resources in some regions have been exhausted. Since the ground water table has declined as a result of over-withdrawal of ground water, sea water intrusion and land subsidence has occurred in 75 per cent of coastal cities and surrounding areas.

During the last few decades, wetlands and lakes have been dramatically lost due to water resource exploitation and land use change. About 800 lakes, a total of 13,000 km^2, have disappeared since the 1950s. Especially in West China, water resource exploitation is usually the main cause for lake degradation.

Since the 1990s, river dry up has attracted more and more attention, and is considered a critical ecological problem in China. When rivers dry up, the river habitat is completely destroyed and wetlands related to the rivers disappear. River drying up not only occurred in North and West China, but also in South China. The Yellow River, the second longest river in China, dried up in 1972 for the first time. Annual average dried up time was 13 days in the 1970s. In 1997, the dried up time lasted 226 days, and the length of dried river was 700 km. The duration and length of dried up river had increased very quickly.

There is a fragmentation of water management institutions in China. The Ministry of Hydraulic Engineering takes charge of surface water and flood control; the Ministry of Geology and Minerals is in charge of ground water; the Ministry of Construction is in charge of the urban water supply and drainage; the Bureau of Environmental Protection is in charge of wastewater discharge and water quality protection; and the Ministry of Agriculture is in charge of agricultural water use. There are no integrative institutions for the management of the water system.

In China, urban drinking water is taken from rivers, lakes or reservoirs, of which 90 per cent are polluted. Around 145 mn citizens in small towns have no access to a safe water supply. The area of the Dongting Lake, which was the largest lake in China, shrank from 4350 km^2 in 1949 to 2691 km^2 in 1978 and its water capacity decreased from 29.3 bn cubic meters in 1949 to 17.4 bn cubic meters in 1978, reducing 38.2 per cent and 40.6 per cent, respectively. On an average, the bottom of the lake rose 3.6 cm per year, and the area of beaches amounted to 120,000 hm^2, with 666.7 hm^2 annual expansion speed. Under the condition of enclosure for cultivation and sand deposition, the loss of water capacity was one-fifth of the total. This enhanced the threat of floods.

REGION-WISE STATUS OF WATER RESOURCES

North China (7 provinces : Inner-Mongolia, Hebei, Beijing, Tianjin, Shanxi, Henan, and Shandong)

Total water resources in this region are about $168.5x10^9$ m^3, about 6.14 per cent of the national total. The average amount of water resource per capita and per hectare is 523 m^3 and 5621 m^3, respectively. The exploitation ratios of surface water and ground water in 1997 were 66.8 per cent and 78.9 per cent, respectively, with 75.2 per cent of the water being used for agriculture, 14.6 per cent for industry, and 10.2 per cent for domestic purposes. Serious deficits of water resources, major conflicts between water supply and water demand, deterioration of water environment, low water utilisation efficiency and alarming water resources waste, irrationality of industry structure and arrangement, high drainage rate of waste or polluted water and low disposal rate, and frequent appearance of drought and waterlogging are the main problems in this region.

Northwest China (5 provinces : Xingjiang, Gansu, Ningxia, Qinghai, Shaanxi)

Total water resources in this region are about $223.51x10^9$ m^3, which is 8.14 per cent of the national total. The average amount of water resource per capita and per hectare is 2538 m^3 and 19604 m^3, respectively. The exploitation ratios of surface water and ground water in 1997 were 36 per cent and 12.6 per cent, respectively, with 89.8 per cent of the water being used for agriculture, 6.9 per cent for industry, and 3.3 per cent for domestic purposes. Main problems in water usage are: severe water shortage for nature service, water environment deterioration (not only industrial pollution but also desertification and loss of soil and water), low efficiency of irrigation, and a positive feedback of poverty-over-exploitation-severe poverty.

Northeast China (3 provinces : Liaoning, Jilin, and Heilongjiang)

Total water resources in this region are about $152.90x10^9$ m3, mere 5.57 per cent of the national total. The average amount of water resource per capita and per hectare is 1454 m^3 and 9358 m^3, respectively. The exploitation ratios of surface water and ground water in 1997 were 29.8 per cent and 52.5 per cent, respectively, with 69.5 per cent of the water being used for agriculture, 22.5 per cent for industry, and 8 per cent for domestic purposes. The major water problems in this region are: water deficit due to uneven distribution of water resources, serious flood risk, over-exploitation of wetlands and forests, and heavy water pollution.

Southeast China (11 provinces : Shanghai, Jiangsu, Zhejiang, Fujian, Anhui, Jiangxi, Hunan, Hubei, Hong Kong, Guangdong, and Hainan)

Total water resources in this region are about 925.92x10^9 m^3, which is 33.72 per cent of the national total. The average amount of water resource per capita and per hectare is 1981 m^3 and 39378 m^3, respectively. The exploitation ratios of surface water and ground water in 1997 were 25.3 per cent and 4.8 per cent, respectively, with 64.2 per cent of the water being used for agriculture, 25.5 per cent for industry, and 10.3 per cent for domestic purposes. Serious water pollution and high flood risk are the major problems in this region.

Southwest China (6 provinces: Sichuan, Chongqing, Yunnan, Guizhou, Guangxi, and Tibet)

Total water resources in this region are about 1275.18x10^9 m^3 i.e. 46.44 per cent of the national total. The average amount of water resource per capita and per hectare is 5302 m^3 and 92,832 m^3, respectively. The exploitation ratios of surface water and ground water in 1997 were 6 per cent and 1.1 per cent, respectively, with 66.1 per cent of the water being used in agriculture, 21.2 per cent for industry, and 12.7 per cent for domestic purposes. The problems in water usage in this region include: low rate of water resources utilisation, widely distributed calcareous rocks, serious water pollution, and maldistribution of water resources vis-à-vis their utilisation.

WATER SYSTEM

A water-centred eco-sphere is a kind of artificial ecosystem dominated by technological and social behaviour, sustained by natural life support system, and vitalised by ecological processes. It was named by S.Ma as a Social-Economic-Natural Complex Ecosystem. The material metabolism through human society is just within the “five-element” flow between water, soil, wood, metal and fire. Where the flow is blocked or deteriorated, there is problem.

The water-ecosphere is driven by four fundamental forces: energy (physical agent), money (economic agent), power (institutional agent) and spirit (cultural agent). Water could also generate or stimulate energy, money/wealth, power/governance and spirit/culture and their interwoven product, namely, human society.

Man is the key constructive and destructive agent in the water issues of China. It drives its positive and negative feedback through competition for water efficiency, symbiosis for water equity and self-reliance for water sustainability.

Poverty is the most acute driving force generating water problems. The positive feedback is exaggerating the loop of "poverty – over-exploitation – ecosystem deterioration – severe poverty".

There is a long tradition of water saving and conservation in China which is based on Daoli, Shili, Qingli, Five-Elements, Ying and Yang, and Feng-Shui theory (wind and water).

WATER SCENARIOS

'Business-As-Usual' Scenario (BAU)

China's economy will have accelerated development during the next 25-30 years: the total GDP in 2025 will be 6.1 times of that in 1997, the industry output value will be 7.7 times of that in 1997, and the grain yield will increase by 31.8 per cent. Population growth is a critical factor with regard to water demand. It will keep increasing until 1.54 bn by 2025. In the meantime, nearly one half of the population will be living in cities and towns with the urbanisation ratio rising from 29.2 per cent in 1997 to 48.8 per cent in 2025. Cultivated land in China will be about 91×10^6 hm^2 in 2025, which would be about 3.91×10^6 hm^2 less than the current cultivated land, while irrigated area will be about 56.34×10^6 ha – an increase of 19.8 per cent. By that time, irrigated area will account for 62 per cent of the total cultivated land – 12 per cent greater than that in 1997.

However, this economic development will pay the price of increasing water stress and a high degree of vulnerability. Water shortage will be 96.8 bn cubic meters and grain shortage 48.1 mn tons. By 2025, the water sector would most likely be in a crisis situation in this scenario. This water shortage will be increasingly severe during the period from 1997 to 2015 as the water demand for economic development would exceed water supply. However, the situation will improve slightly after 2015 with significant social, economic, and technical progress.

The increase in water demand in the next 25-30 years in China will mainly come from industry and households. The agricultural water demand ratio in the total demand will be reduced from 70 per cent in 1997 to 53.5 per cent in 2025, while the absolute figure will remain nearly unchanged, increasing only by 3.7 per cent (from $421.6 x 10^9$ m^3 in 1997 to $437.5 x 10^9 m^3$ in 2025). Other demands will get doubled in these 28 years. The industrial water demand will increase from $126.7 x 10^9$ m^3 in 1997 to $270.8 x 10^9$ m^3 in 2025 and the domestic water demand will increase from 53.9 $x 10^9$ m^3 in 1997 to 108.6 $x 10^9$ m^3 in 2025. Six industries, namely, thermal power industry, papermaking, chemical, metallurgical, printing and dyeing, and food and drink, make the greatest contribution to water consumption in China. The ratio of these high-water-consuming industries will decline in the next 25-30 years, although reduction will be limited.

All conclusions here are based on the average hydrological regime. If a large-scale drought happens in China, the water shortage will be critical and grain yield will fall below the security line, with an import ratio larger than 10 per cent of the total grain production.

Under BAU scenario, China will have serious water and food regimes in the next 25-30 years. So, the government should take effective measures to make sure that its economic development is consistent with its water resource capacity, ensuring water security and sustainable development in China.

Towards Sustainable Development Scenario (TSD)

The current irrigation efficiency in China is only 40-50 per cent compared to 80-90 per cent in some of the industrialised countries. If by 2025 the ratio increases to 65 per cent, the area of irrigated land will increase by 7 mn hectares without additional water.

The current ratio of cereal yield to water in China on average is only 1.17 kg/m^3, much less than that of the industrialised countries. If it increases to 1.59 kg/m^3 by 2025, which is only 80 per cent of the western countries' current level, 51.8 bn m^3 water could be saved in 2025. If the annual increase rate of grain yield is changed from 1.3 per cent to 1.5 per cent through various technological and ecological measures, the grain yield would reach 6639.7 kg/hm^2 and the total grain output will touch 684.36 mn tons in 2025.

Compared to developed countries, the water-saving potential in China is large. The water re-use ratio could be 57.29 per cent and 68.28 per cent in

2010 and 2025, respectively. If the water consumption coefficient decreases to 25.60 m^3 per 10^4 RMB industrial output in 2025, the industrial water demand will decrease by 44.6 bn m^3.

The irrigated area could be 51.80 and 57.93 mn ha in 2010 and 2025, respectively. The ratio of irrigated land to total arable land could be 56 per cent and 64 per cent, respectively.

If the proportion of cereals, cash crops, and feed crops is gradually changed from 5:3:2 in 1997 to 4:3:3 in 2010, and 3:3:4 in 2025, and grain consumption per capita and the grain for industrial use are maintained at the level of 1997, then grain for feed will increase by 140 mn tons. This is equivalent to 45 mn tons of extra meat production with an increase of 30 kg per capita. Furthermore, there are roughly 400 mn hectares of pastures, grasslands, and arable desert lands in China that are not appropriately exploited or managed (30 per cent of higher quality, 30 per cent of average, and 40 per cent of bad quality). Annually, 600 mn tons of crop stalks/straw and other alternative biomass could be used as substitute for grain in livestock raising and industrial production.

In the TSD scenario, the ratio of high-water-consuming industries is estimated to decrease from 74 per cent in 1997, to 68 per cent in 2010 and 64 per cent in 2025. The industrial water demand will decrease to 203.4 bn m^3 and 236.3 bn m^3 in 2010 and 2025, respectively. That is to say, about 18.5 bn m^3 and 24.5 bn m^3 water could be saved and water use per 10^4 *RMB* industrial output will decrease to 55.58 m^3 and 27.09 m^3 in 2010 and 2025, respectively.

If the structure of domestic livestock is changed from grain-fed to herbivorous domination, and alternative protein is produced without consuming so much grain (such as insects, mushrooms, and other micro-organisms), then meat production will increase four-fold compared with that of 1997.

If the water use quota and re-use ratio are maintained at the same level as in BAU, but the industrial growth rate slows down from 13 per cent in 1997 to 7 per cent in 2010 and to 5 per cent in 2025, then industrial water demand would decrease to 209.7 m^3 in 2010 and to 255.5 m^3 in 2025, i.e., there could be about 12.2 m^3 and 15.3 m^3 of water saved in 2010 and 2025, respectively. In 2010 and 2025, the corresponding industrial output value would be 34.60 trillion RMB and 82.29 trillion RMB, respectively.

In the total grain production, the proportion of surviving food would reduce slightly, the proportion of feed would increase, and the proportion of the grain used in industry would decrease as it would be substituted by other kinds of wild bio-masses. According to our estimation, at present, the proportions of food, feed, and industrial use are 50 per cent, 30 per cent and 20 per cent, respectively. The grain demand per capita will be 428.6 kg and 420.8 kg, and the total grain demand would be 581.5 and 668.9 mn tons in 2010 and 2025 respectively, i.e., about 6.8 and 26.8 mn tons grain or about 4.76 bn m^3 and 17.99 bn m^3 water could be saved according to the corresponding grain-water equivalent.

If the domestic water use per capita is estimated at 230.0 L/d and 255.3 L/d in urban areas and 100.5 L/d and 122.0 L/d in the countryside in 2010 and 2025, respectively, the domestic water demand will be 74.9 and 105.3 bn m^3. This means, about 1.1 bn m^3 and 3.3 bn m^3 of water could be saved. Water exploitation from other alternative resources, such as salt and rain water, could be 36.1 bn m^3 in 2010 and 59.0 bn m^3 in 2025, and 512.4 bn m^3 and 566.0 bn m^3 could come from surface water in 2010 and 2025, respectively.

Saving one ton of grain is equal to saving 1,000 tons of water, and switching 1000 tons of water from agriculture to industry will create 50-70 times more GDP than that from agriculture, at around 50,000 RMB. If 100 mn tons of grain is saved or substituted, it is equal to tapping 100 bn tons of additional water and creating 5000 bn RMB of GDP. At the same time, 20 mn ha of cropland or one-fifth of the total cropland in China could be changed to grassland, forestry, or wetland, which will significantly enhance the nature service function (see Table below).

Total Water Use in the First Half of 21st Century

Year	Agriculture water use			Industry water use			Urban life water use			Total (10^8 m^3)	Total (10^8 m^3)
	Water amount (10^8 m^3)	Increment rate (%)	Ratio (%)	Water amount (10^8 m^3)	Increment rate (%)	Ratio (%)	Water amount (10^8 m^3)	Increment rate (%)	Ratio (%)		
2000	4848	-0.41	85.0	665	3.34	11.7	189	3.56	3.3	5702	–
2010	4653	-0.13	79.5	929	3.64	15.9	268	2.69	4.6	5850	6748
2030	4530	-0.43	65.8	1899	3.00	27.6	456	2.38	6.6	6885	7350
2050	4157	–	49.9	3436	–	41.3	730	–	8.8	8323	7590

In TSD scenario, we hope to keep three-fourth of the total cropland or 100 mn ha, the current official figure, for grain production, which is equal to raising productivity by one-third, and to transfer another one-fourth or around 30 mn hm^2 for other types of bio-mass production, which are more ecologically sound, as is now taking place in the upper reaches of the Yangtze and Yellow rivers.

WATER STRATEGIES IN THE NEW ERA

- The measurement of water should not only be by its economic value, but also by its comprehensive value in terms of wealth, health and faith.

- The critical missing ingredient for handling the water issues more effectively is institutional change and development in the broadest sense; this is necessary to improve water management at both macro and micro levels. Increased high-level policy support and investment for institutional development to improve "software" in the water resources sector is needed. At the macro level, the overriding institutional issues concern river basin management and fragmentation of responsibility for water resources management. At the micro level for irrigation and water management, key institutional issues relate to institutional development for efficient self-financing and self-management of irrigation and drainage based on farmer participation, such as SIDDs, provision to farmers of engineering, agricultural and management methods for improved irrigation as an integrated package, and filling the agricultural engineering skills gap.

- Encourage ecological engineering for sustainable water cultivation, combining hardware, software and mindware. Beijing, for example, is currently facing a severe water shortage, and a water diverting plan from the Yangtze River is being worked out. While, according to an investigation made by the local water saving agency, about 0.414 bn m^3 of current water use in Beijing could be saved, 0.257 bn m^3 of rain water and 1.0 bn m^3 of treated waste water could be recycled annually if appropriate measures are taken, which would help in meeting the 1.262 bn m^3 annual deficit of water needed for the future development of Beijing. This could help relieve the stress of diverting water from the Yangtze river basin on the local natural ecosystem and on local socio-economic development with a huge saving of money from the cost of engineering the diversion of water from the Yangtze River.

- Agriculture being the key sector in water use, the priorities are:

  - To address the temporal and spatial imbalance of water resource distribution by withstanding natural aridity and floods, constructing water conservancy works, and developing irrigation and drainage utilities.

- To enhance the capacity building activity in water legislation, water pricing and water policy-making
- To reform the institution for ecologically sound water management structures with an emphasis on inter-sectorial and inter-regional management.
- To encourage water-saving technology, biological technology and ecological engineering.
- To explore ecologically alternative water resources, such as rainwater, waste water and trans-basin water diversion. For example, 33 per cent of the Chinese population in 1992 lived in some 30 per cent of the total land area, where the average precipitation between 1958-1988 was in the range of 400mm - 800 mm. This is just a semiarid and semihumid area with a dense population badly in need of water. Collecting 1 per cent of the rainwater in 1 per cent of this kind of land will provide about 180 bn m^2 of water annually.
- To enhance eco-zoning and regional planning to optimise the agricultural water use by adjusting the pattern and structure of crops according to local ecological conditions and water-carrying capacities.
- To resolve water conflicts between industrial, urban and agricultural use, between upper and lower reaches, and between generations, by introducing eco-mechanisms of incentive compensation, social cooperation and self-reliance.
- To raise the awareness of decision-makers, entrepreneurs and the public regarding water ecology and its effects on the economy.
- To enhance regional and international cooperation in scientific research and technological transfer related to water issues.

- Let every one have safe water and hygienic conditions.
- Saving more water for nature is saving more water for ourselves and our offspring.
- Promoting regional cooperation, networking, ecologisation and globalisation in respect of water issues.
- The centralised policy-making mechanism has both disadvantages and advantages for destroying or restoring the water-ecosphere. Its disadvantages could be overcome by combining appropriate scientific evaluation, public participation and social supervision.

- Emigration from regions which have overloaded water-carrying capacity and are ecologically fragile is necessary but needs careful human ecological planning and management.
- To divert water from South to North is necessary and beneficial to both man and nature in the North but needs sound and comprehensive ecological planning especially concerning the impacts on and compensation to the South.
- An ecologically sound watershed management structure should be enhanced by integrating ecosystem conservation with local (especially upper reach area) economic development, and by adopting the strategy of compensation for their contribution to enhancing the nature service.
- To enhance the adaptability of human activity to uneven water distribution and the high frequency of flooding and drought through ecological engineering.

CONCLUSION

The word 'Crisis' (Wei Ji) in Chinese has both the meaning of risk (Wei) and opportunity (Ji). Having a long tradition of sustainable water management and human ecological philosophy, in China the water vision, has both optimistic and pessimistic perspectives. Though the per capita water resource in China is only 35 per cent and 75 per cent of the average level of the world and Asia, respectively, the spatial and temporal distribution is extremely uneven. Overloaded human activities are threatening regional food, health, life, economic, social and environmental security, but there are also big opportunities for alternative water resource exploitation and water saving. Through the above-mentioned strategies, China can feed its 1.54 bn people with improved life quality and limited water resources by 2025 without significant grain imports from outside, though some (less than 10 per cent) grain imports will benefit both China and the world. Here, the key is technological innovation, institutional reform, lifestyle change, water diversion, ecological engineering and intelligent governance. Facing this challenge, China is standing on the crossroads towards either a miserable or a prosperous future with the water-related fortune in its own hands.

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