

Water Resources Management in India

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ABSTRACT

India is likely to face a major challenge in the management of freshwater in view of rapidly rising population and increasing agricultural, industrial and other requirements. As the economy of the country is currently witnessing rapid growth, management of freshwater resources becomes all the more important. This paper reviews the status of freshwater resources, their quantity and quality, demands as well as the management related problems in India. A series of actions that are necessary for a long-term solution of the problem are suggested with a view that scarcity of freshwater does not become a hindrance in national economic development and food security.

Keywords:- Water resources, India, management, demands, governance.

1.0 INTRODUCTION

India supports about 1/6th of the world's population, 1/50th of the land and 1/25th of the water resources. There is a general feeling that the country with its mighty rivers and vast aquifers has abundant freshwater resources. But keeping in view the uneven spatial and temporal distribution of water resources, this impression is not correct. Moreover, India has large population which is increasing rapidly and a high GDP growth of more than 8% is putting enormous pressure on its water resources.

1.2. Precipitation

The long-term average annual rainfall for the country is 1160 mm (Lal 2001), which is the highest in the world for a country of comparable size. In terms of volume, India receives an average annual precipitation of about 4000 km³. Rainfall is dependent on the South-West and North-East monsoons, on shallow cyclonic depressions and disturbances and on local storms. In India, precipitation has very high spatial and temporal variations. Most of it (about 3000 km³) falls under the influence of South-West monsoon between June and September, that too within 100 hours of rainy days. Regarding spatial variation, the highest rainfall of about 11,690 mm per year is recorded around Cherrapunji in Meghalaya. Many places on the windward side of the Western Ghats record up to 6000 mm rainfall per year. In the northern plains, annual rainfall decreases from 1500 mm in West Bengal to 150 mm in Jaisalmer (Rajasthan). About 21 percent of the country's area receives less than 750 mm of rain annually while 15 percent receives rainfall in excess of 1500 mm. Figure 2 shows the distribution of normal annual rainfall in India (IMD, 2004).

1.3. Streamflows

Several organizations and individuals have estimated water availability for the nation. The National Commission for Integrated Water Resources Development (NCIWRD, 1999) estimated the basin-wise average annual flow in Indian rivers as 1953 km³ (see Table 1). These estimates are quite old now and questions have been raised about the methodology followed and their correctness. It would be necessary to review and finalize the methodology and periodically update the estimates since the catchment conditions and climate keep on changing. Utilizable water res

Several organizations and individuals have estimated water availability for the nation. The National Commission for Integrated Water Resources Development (NCIWRD, 1999) estimated the basin-wise average annual flow in Indian rivers as 1953 km³ (see Table 1). These estimates are quite old now and questions have been raised about the methodology followed and their correctness. It would be necessary to review and finalize the methodology and periodically update the estimates since the catchment conditions and climate keep on changing. Utilizable water resource is the amount of withdrawable water from its place of natural occurrence. Given the limitations of physiography, socio-political environment, legal and constitutional constraints, and technology available, utilizable quantity of water is less than availability. According to NCIWRD (1999), the utilizable annual surface water of the country is 690 km³ (Table 2).

Sr.no	River Basin	Average Annual Flow	Utilizable Flow
1.	Indus	73.31	46
2	Ganga –Brahmaputra-Meghna Basin		
	2a Ganga	525.02	250
	2b Brahmaputra sub-basin	629.05	24
	2c Meghan (Barak) sub-basin	48.36	
3	Subarnarekha	12.37	6.81
4	Brahmni-Baitarani	28.48	18.3
5	Mahanadi	66.88	49.99
6	Godavari	110.54	76.3
7	Krishna	69.81	58
8	Pennar	6.32	6.86
9	Cauvery	21.32	19
10	Tapi	14.88	14.5
11	Narmada	45.64	34.5
12	Mahi	11.02	3.1
13	Sabarmati	3.81	1.93
14	West Flowing river of Kachchh and Saurashtra	15.1	14.98
15	West flowing rivers south of Tapi	200.94	36.21
16	East flowing rivers between Mahanadi and Penna	22.52	13.11
17	East flowing rivers Between Pennar and Cauvery and rivers south of Cauvery	16.46	16.46
18	Rivers draining into Bangladesh	8.57	NA
19	Rivers draining into Myanmar	22.52	NA
20	Total (Rounded)	1953	690

1.4 Ground water resources

Total replenishable groundwater resource of the country is assessed as 433%. After allotting 15% of this quantity for drinking, and 6 km³ for industrial purposes (total 71 km³), the 3 remaining (433-71=362 km³) can be utilized for irrigation. Out of this, the utilizable quantity (90%) is 326 km³. Total Utilizable Ground Water Resource = 326 + 71 = 397 km³. The statewise estimates of dynamic ground water (fresh) resource made by the CGWB are given in Table 2. Table 2

2.0 WATER REQUIREMENTS FOR INDIA

Traditionally, India has been an agriculture-based economy. Hence, irrigation sector was assigned a very high priority in the 5-year plans. Giant schemes like the Bhakra Nangal, Hirakud, Damodar Valley, Nagarjunasagar, Rajasthan Canal project etc. were taken up to increase irrigation potential and thereby agricultural production. Long-term planning has to account for population growth. Many projections of the population by the year 2025 and 2050 have been made. Keeping in view the human and livestock consumption, losses in storage and transport, seed requirement, and buffer stock, projected food-grain and feed demand (for cattle) for 2025 is likely to be 320 million tonnes (high demand scenario) and 308 million tonnes (low demand scenario). The requirement for the year 2050 would be 494 million tonnes (high demand) and 420 million tonnes (low demand). Estimated annual water requirement for various sectors for the years 2025 and 2050 are shown in Table 4 for two scenarios: low growth and high growth. Note that the available water will be just enough to meet the projected requirements and if the population grows at higher rates, there might be shortages. Table 4: Annual water requirement (km³) for different uses. Uses Year 1997-98 Year 2025 Year 2050 Low High % Low High % Irrigation 524 561 611 72 628 807 68 Domestic 30 55 62 7 90 111 9 Industries 30 67 67 8 81 81 7 Power 9 31 33 4 63 70 6 Inland Navigation 0 10 10 1 15 15 1 5 Environment – Ecology 0 10 10 1 20 20 2 Evaporation Losses 36 50 50 6 76 76 7 Total 629 784 843 100 973 1180 100 Population (million) 1286 1333 1346 1581 Source: NCIWRD (1999). As per the National Water Policy (2002), water allocation priorities should broadly be: (i) drinking water, (ii) irrigation, (iii) hydropower, (iv) ecology, (v) agro-industries and nonagricultural industries and (vi) navigation. In view of the current status of freshwater use in India and the problems that are likely to arise in future, a well-planned long-term strategy is needed for sustainable water use.

3.0 CAUSES OF WATER RELATED PROBLEMS

For socio-economic growth and prosperity it is essential that enough water of good quality is available to meet the requirements of agriculture, industries, domestic sector, etc. Unfortunately, inadequate planning, lack of

awareness and non-implementation of desired measures, have created a difficult-to-manage situation. Hence, an alarming scenario of water scarcity and environmental degradation is gradually unfolding in India. Intense competition for water among different sectors is depleting raw water sources. Widespread pollution of surface and groundwater is degrading the quality of these. In a nutshell, the root causes of the water crisis in India are:

- Highly uneven availability of water, both in space and time, often leading to floods and droughts.
- Rampant pollution of freshwater resources mainly by the agricultural, industrial and municipal sources.
- Highly unreliable municipal water supply with poor quality.
- Laws which give unlimited ownership of groundwater to the landowner and coupled with uncontrolled use of bore-wells that has allowed extraction of groundwater at very high rates, often exceeding recharge.
- Inadequate attention to water conservation, efficiency in use, water re-use, groundwater recharge, and eco-system sustainability.
- Very low water prices which do not discourage wastage.

4.0 SUSTAINABLE WATER MANAGEMENT IN INDIA

In this section, we discuss the main water related problems and strategy for sustainable water management.

4.0 Dealing with Variabilities Water availability

India has a large variation – both spatial and temporal. Basin wise per capita water availability varies between 13,393 m³/year for Brahmaputra-Barak basin to about 300 m³/year for Sabarmati basin. Fig. 3 depicts per capita water availability in selected river basins, highlighting huge disparities. As per international norms, if the water availability is > 1,700 m³ per capita/year then the country is categorized as water stressed and if it is > 1,000 m³ per capita/year then the country is classified as water scarce. Although India is not in the water stressed category, the real situation of per capita water availability is more serious than that depicted by the average figures. As can be seen in Fig. 3, many basins are already water stressed and more will become so in future. 6 Spatial and temporal variation in precipitation has been explained earlier. Out of 8760 hours in a year, most of the precipitation is received in about 100 hours. Such a high concentration of precipitation and streamflows makes it imperative to regulate river flows by the use of storages (surface or sub-surface). Highly skewed water resources distributions result in seasonal abundance and devastating floods in some areas while large tracts in other regions are chronically drought affected. These two problems are discussed next

4.1.1 Floods

Floods are the most frequent natural calamities faced by India in different magnitudes. As about 80-90% of the annual precipitation occurs during the four months of monsoon, this is also the season when floods are experienced. Major causes of floods in India are: inadequate capacity within river banks to contain high flows, bank erosion and silting of river beds, poor natural drainage in the area, and cyclone and associated heavy rainstorm/ cloud bursts.

The Rashtriya Barh Ayog (RBA) estimated that an area of 40 Million ha (mha) is flood prone (see Fig. 4). The average area affected by floods annually is 7.52 M-ha. The area which can be given reasonable protection is 32 mha; 16.45 mha area was given protection till 2004. According to NCIWRD (1999), during the second half of 20th century, on an average, 1,515 lives were lost and 95,285 heads of cattle were lost every year. Every year floods kill nearly 1,600 people, submerging 8 million ha of fertile land and causing huge economic damages.

There is a general perception that notwithstanding large expenditure, flood damage is increasing. Analysis shows that the area affected by the floods has not increased much with time. The population affected by floods exhibits large fluctuations and, expectedly, is increasing with time due to population growth. At constant prices, neither the crop damage nor the total damage shows a definite trend.

A commission, known as the Rashtriya Barh Ayog (RBA or National Flood Commission) was set up by the Government of India to cover the entire gamut of flood problem in the country. The National Commission for Integrated Water Resources Development also studied this problem and gave recommendations (NCIWRD 1999). NCIWRD rightly pointed out that there is no possibility for complete protection against floods. Important recommendations are:

- Basinwise master plan for flood management in each flood prone basin should be prepared;
- To the extent feasible, flood control schemes should fit in with other water related plans;
- Future multi-purpose projects should simultaneously consider flood control aspects;
- Properly designed, executed and maintained embankments are satisfactory means of flood protection. Flood management activities can be broadly classified into two groups: structural and non-structural. Structural measures attempt to prevent flood waters from reaching potential damage centres. These consist of reservoirs, embankments, flood walls, detention basins, drainage improvement, and diversion of flood waters. Reservoirs store floodwaters and gradually release it when the flood has receded. Many Indian reservoirs have specific storage spaces allocated for flood control, e.g., Hirakud (Mahanadi), Bhakra (Sutlej), and Ukai (Tapi). Embankments restrict the flow of a river in a defined

course.

Non-structural measures strive to keep people away from flood waters, bearing in mind that flood plains belong to the river. These contemplate judicious use of flood plains and vacating the same for use of the river whenever necessary. These measures include: flood plain zoning, flood proofing, flood forecasting and warning, disaster preparedness, and flood insurance.

For effective flood management, sincere efforts are needed to understand the problem and plan mitigation measures. This strategy should consist of: a) Building a scientific database, b) Building a large R & D capacity, c) Human resources development, d) legislation for scientific use of flood plains, and e) Preparing inundation maps and evacuation plans.

Flooding in urban areas is a common occurrence in India. Many cities, witness flooding even after moderate rainfall. Improper planning, design and poor drainage management is the main reason for urban flooding. Urban drainage problems also lead to unhygienic conditions and spread of epidemics. The problem can be handled by: a) preparing master drainage plan for each urban area and implementing it, b) rejuvenation of lakes and ponds, and c) proper maintenance of drainages.

Flash floods which usually occur in hilly regions (at times due to cloud burst) are characterized by very fast rise and recession of flow of small volume and high discharge. Large reservoirs with sufficient vacant space upstream of areas prone to flash floods can absorb the flood wave. Melting of glaciers sometimes creates glacier lakes which may hold large quantities against a dam created by ice or debris. Breakage of this dam leads to sudden release of water from the temporary lake. This results in glacier lake outburst floods (GLOF). This phenomenon is common in Himalayas and is a concern for hydropower projects or settlements.

4.1.2 Droughts

In India, droughts mainly occur due to: i) delay in the onset or failure of monsoons, ii) large variability of monsoon rainfall, and iii) long break in monsoon. According to the norms of IMD, a meteorological subdivision is considered to be drought affected if its total seasonal rainfall is less than 75% of the normal. Prolonged meteorological drought triggers hydrological drought. Drought is classified as “severe” if percent departure is more than 50% and moderate if it is 25-50%. Drought is a 'creeping disaster, whose onset and end are difficult to determine. The effects of drought accumulate slowly over considerable period of time and may prolong for major events.

Droughts are characterized by their intensity, duration, frequency, and severity. These characteristics form a basis in the planning of management strategies to cope with droughts. Drought indices (for example, the Palmer Drought Severity Index) are used to describe features of drought and are used in management. To reduce the impact of droughts, it is necessary understand their characteristics: how long will it last? How severe can it be? How often will it recur?

About one-sixth of the geographical area of India area with 12% of the population is drought prone; the areas that receive an annual rainfall up to 60 cm are the most prone. Details of the drought prone areas are given in Table

Table 5: Drought Prone Area of India

Drought Prone Area	51.1mha
Affected Districts	74
Affected States	13

Since the year 1800, there have been around 40 droughts in the country. The drought of 1987 was one of the severest in the recent past and it had affected about half of the country. Jain et al. (2007) list the droughts that have occurred in India over the last 200 years. 8 Most of the drought-prone areas are in arid, semi-arid, and sub-humid regions (see fig. 5). Chronic drought affected areas are confined to West Rajasthan and Kutch in Gujarat. Nearly 57 % of Rajasthan and 32 % of Gujarat falls in arid zone. Nearly 61 % of Maharashtra is semi- arid. Natural Disasters are huge economic burdens on India. A scheme called Calamity Relief Fund (CRF) has been constituted for each state to undertake relief and rehabilitation measures. Impacts of drought can be reduced through mitigation and preparedness which includes forecast and warnings, drought insurance, and disaster aid programs. Drought preparedness should be an integral part of water resources management in drought prone areas. Drought mitigation measures can be classified into three groups: o Water-supply measures: increase available water supply during drought and develop new supplies, o Water-demand measures: reduce the water demand during drought, o Impact-minimization measures: intended to minimize adverse drought impacts. Irrigation is the most effective drought proofing strategy and is the single biggest factor in bringing stability in agricultural production. Actions have been initiated by the Government of India from time-to-time to minimize the adverse impacts of droughts. Important of these are: watershed development, dryland farming, soil moisture conservation, use of sprinkler and drip irrigation systems, etc. The Government of India operates the command area development programme (CADP) to strengthen water management capabilities. The Drought Prone Areas

Programme and the Desert Development Programme have been devised to combat droughts.

4.1 Water and Environment Pollution

Water pollution is acquiring serious dimensions in India. Almost 70% of surface waters and a large proportion of groundwater reserves are already contaminated by biological, toxic organic and inorganic pollutants. In many cases, the available water has been rendered unsafe for domestic consumption, irrigation, and industrial needs. Sources of water pollution are diverse: untreated sewage, industrial discharges, leaching from municipal waste, and drainage from the residues of agricultural fertilizers and pesticides. With burgeoning cities (Tables 6) and increasing industrialization, the quantum of waste dumped into rivers has also increased. Water pollution varies in severity from one region to the other depending on the density of urban development, agricultural and industrial practices, and the systems for collecting and treating wastewater. Estimates (data provided by Dr RC Trivedi) show that 6750 km of river length is severely polluted [BOD (biochemical oxygen demand) is more than 6 mg/l], a length of 8550 km is moderately polluted (BOD is between 3-6 mg/l) and 29700 km length is relatively clean (BOD less than 3 mg/l).

4.2 Excessive Groundwater Exploitation

Groundwater has contributed vastly to agricultural development in India, particularly during the last four decades. It has helped attain food security through green revolution. However, its exploitation, which has grown exponentially over the years and is a matter of concern, is largely in the hands of private individuals. In 1950, there were 3.86 million dug-wells and 3000 deep tube-wells. Estimates show that nearly 19.8 million wells were operational in 2002 creating a cumulative irrigation potential of 50M ha (Chadha 2006). Groundwater sources have been classified in three categories depending upon the state of exploitation. In the 1st category (termed 'safe'), the level of exploitation is below 70% of the annual utilizable potential. The 2nd category (termed 'semi-critical') includes areas in the range of 70% to 90% exploitation levels and the third category (termed 'critical') has the level of exploitation exceeding 90%. When the stage of groundwater development exceeds 100% the unit is termed as over-exploited. Out of 5723 assessed units by CGWB (2006), 893 were over-exploited, 226 critical, 550 semi critical and 4078 safe in 2004. Figure 6 shows the categorization of ground water blocks in various categories.

4.3 Drinking Water Problems

There is an acute shortage of drinking water in various parts of the country due to different reasons. Over the past few decades, the expansion of the water supply and sanitation infrastructure in Indian cities has not kept pace with growing population. Consequently, running water is available for only a few hours each day. During summers or droughts, running water may be available for only a few hours every week and that too at very low pressure. Municipal supply is only a small fraction of the demand in many major cities. Another area of concern is the falling quality of drinking water in many areas. National norm specifies 40 lpcd (litres per capita per day) of water for rural areas and 150 lpcd for urban areas. Even with these norms, 233,000 habitations did not have clean drinking water as of March 2008. Due to various reasons, the habitations that are provided water slip back to uncovered habitations. At the beginning of 10th plan (April 2002), out of 1,422,664 habitations in the country, 15,798 habitations were not covered by any drinking water schemes while 133,305 habitations were partially covered. Only in 10 states and Union Territories all habitations had been covered partially or fully under the drinking water supply schemes. By March 2004, 75,607 habitations remained to be covered including 5,759 in the non-covered category (Planning Commission 2006).

5.0 INITIATIVES NEEDED IN WATER SECTOR

This section briefly discusses some initiatives that will provide essential support to sustainable water management in India.

5.1 Data Monitoring Program

A comprehensive, reliable, and easily accessible Hydrological Information System (HIS) is a pre-requisite for optimally utilising the water resources. In India, the availability of meteorological data is very good, that of surface water satisfactory (although the quality of data is doubtful at many locations) and data on groundwater good. But the data on water quality is limited. Although groundwater availability maps have been prepared for certain locations, extraction rates are often not available. To achieve these objectives, there is a need to strengthen the existing monitoring network; proper coordination amongst the different agencies is essential. To improve the existing HIS in India, many steps have been taken including the Hydrology Project phase 1 and 2. HP aims at developing and improving the existing HIS of 12 various government agencies in (mainly) peninsular states of India. Besides this, many other government organizations are putting in efforts towards collection and distribution of hydrologic and allied data. However, researchers and practitioners have to still spend considerable time and efforts to obtain the data needed. Although much computerization has been carried out recently, tedious bureaucratic bottlenecks remain.

5.2 Construction of New Projects

In recent times, new issues have emerged that have to be dealt with before taking up a new water development project. This has caused considerable delay into some projects leading to time and cost overruns. The issue of rehabilitation and resettlement (R & R) is of critical importance which affects all major projects. Displacement of population is one of the main criticisms against major dams. It is true that adequate care of the displaced population was not taken in past. This defect needs to be rectified to ensure that the displaced population is rehabilitated such that they enjoy a better standard of living than in the pre-dam conditions. The issue of displacement and compensation should be sorted out through satisfactory and negotiated agreements. Lessons from many projects show that if the water potential of the Indian rivers has to be optimally utilized, effective economic instruments to adequately compensate and rehabilitate the displaced people should be developed. Poor coordination among various agencies, lengthy procedures, corruption, thin spread of resources, and poor monitoring and some other causes of delays in completion of projects.

5.3 Water Conservation

Water conservation implies improving the availability of water by storing it in surface reservoirs, tanks, soil, and groundwater zone. If one looks at utilizable water resources in major river basins, these resources in Indus, Ganga, Brahmaputra, and Godavari basins are 73.31, 525.02, 629.05 and 110.54 km³ per year, respectively. The storages available in these basins, including projects under construction, are 16.28, 54, 3.5, and 30.16 km³. Thus, only a small fraction of available water is being regulated at present. No matter how water is used—whether for agriculture, industry, or domestic purposes—there is a great potential for better conservation and management. On the demand side, a variety of economic, administrative and community-based measures can help conserve water. Since agriculture accounts for about 82% of all water withdrawn, it has the greatest potential for conservation. Just a 10% improvement in irrigation efficiency could conserve enough water to double the availability for drinking. The use of drip and sprinkler irrigation saves large quantity of water. Thus, there is an urgent need for large-scale adoption of sprinkler and drip irrigation in various parts of the country. Rainwater harvesting is the process to capture and store rainfall for its efficient utilization. It increases water availability (locally), helps in checking the decline of water table, and may also control soil erosion and flooding. People were familiar with this concept and it is being vigorously promoted as a water conservation method.

Recycle and Reuse of Water Another way to improve freshwater availability is by recycle and reuse of water. Use of water of lesser quality, such as reclaimed wastewater, for cooling, cleaning, watering lawns, and fire fighting is an attractive option. This conserves better quality waters for potable uses. Currently, recycling of water is not practiced on a large scale in India and there is considerable scope and incentive to use this alternative. **Desalination of Water** There has been significant development in the past few decades in desalination technologies, including distillation, and reverse osmosis. Desalination is suitable in areas where freshwater is scarce but saline water is available and energy is cheap. Compared to water recycling technologies, desalination presents fewer health risks. As currently practiced, desalination mostly uses fossil fuels. As the costs come down, desalination will become commercially more attractive. **Dealing with Climate Change** Water resources assessment and planning assumes that the past records of variability are reflections of what will happen in the future. Climate change is likely to result in hydrologic conditions and extremes of a nature that will be different from those for which the existing projects were designed. The approaches for effectively dealing with climate change will have to be different than those that have been employed to manage variability in the past. It will not be advisable to be complacent about climate change which may ultimately put the planners and managers in a condition for which they may not be ready. Some recommendations to cope up with the problems in a systematic and a planned manner are: i) A nationwide climate monitoring program should be developed; ii) While formulating new projects that influence climate, it should be ensured that no action is taken which causes irreversible harmful climatic impact; iii) Improved methods for accounting of climate related uncertainty should be developed and made part of decision making; iv) Existing systems should be examined to determine how they will perform under the future climate situations; v) Water availability and demands in all regions should be reassessed in the future scenario; vi) Operating rules should be re-examined and updated as necessary. **The National Action Plan of the Govt. of India (2008)** is a right step which should be vigorously pursued. **Water Governance** We frequently hear that the world is in the grip of a “water crisis”. But a closer look shows that it is more a water governance crisis which has arisen due to mis-management of water and unscientific policies. The Ministerial Declaration of the 2nd World Water Forum, held in 2000 defined the main goal of water governance “to provide water security in the 21st century”. This requires that freshwater, coastal and related ecosystems are protected and improved and every person has access to enough safe water at an affordable cost. Further, the vulnerable people are to be protected from the risks of water-related hazards.

6.0 CONCLUSION

In conclusion, effective Water Resource Management requires a paradigm shift towards integrated, sustainable practices, moving beyond fragmented approaches to embrace holistic strategies like watershed development, demand management, and advanced reuse technologies, underpinned by robust governance and community engagement to overcome current challenges and build resilient water systems for a water-secure future.

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