WATER RESOURCES MANAGEMENT IN INDIA

By

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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 WATER RESOURCES OF INDIA

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. Fig. 1 shows the river basins of India.

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 km^3. 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 km^3) 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).

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 km^3 (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 km^3 (Table 2).

Table 1 Basinwise average flow and utilizable water (km^3/ year) (after NCIWRD, 1999).

Sl. 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 Meghna (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	21.36	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 rivers of Kachchh and Saurashtra including Luni	15.1	14.98
15	West flowing rivers south of Tapi	200.94	36.21
16	East flowing rivers between Mahanadi and Pennar	22.52	13.11
19	East flowing rivers Between Pennar and Cauvery and rivers south of Cauvery	16.46	16.46
21	Rivers draining into Bangladesh	8.57	NA
22	Rivers draining into Myanmar	22.43	NA
	Total (Rounded)	1953	690

Ground water resources

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

Table 2: State-wise estimates of dynamic ground water resource (source: CGWB)

	State/Union Territories	Annual replenishable GW resource	Natural Discharge during non-monsoon season	Net Annual GW Availability	Annual Ground Water Draft	Projected demand for domestic and ind. uses up to 2025	GW availability for future irrigation	Stage of GW development (%)
1	Andhra Pradesh	36.5	3.55	32.95	14.9	2.67	17.65	45
2	Arunachal Pradesh	2.56	0.26	2.3	0.0008	0.009	2.29	0.04
3	Assam	27.23	2.34	24.89	5.44	0.98	19.06	22
4	Bihar	29.19	1.77	27.42	10.77	2.14	15.89	39
5	Chattisgarh	14.93	1.25	13.68	2.8	0.7	10.67	20
6	Delhi	0.3	0.02	0.28	0.48	0.57	0	170
7	Goa	0.28	0.02	0.27	0.07	0.04	0.18	27
8	Gujarat	15.81	0.79	15.02	11.49	1.48	3.05	76
9	Haryana	9.31	0.68	8.63	9.45	0.6	-1.07	109
10	Himachal Pradesh	0.43	0.04	0.39	0.12	0.04	0.25	30
11	Jammu & Kashmir	2.7	0.27	2.43	0.33	0.42	1.92	14
12	Jharkhand	5.58	0.33	5.25	1.09	0.56	3.99	21
13	Karnataka	15.93	0.63	15.3	10.71	1.41	6.48	70
14	Kerala	6.84	0.61	6.23	2.92	1.4	3.07	47
15	Madhya Pradesh	37.19	1.86	35.33	17.12	1.74	17.51	48
16	Maharashtra	32.96	1.75	31.21	15.09	1.52	16.1	48
17	Manipur	0.38	0.04	0.34	0.002	0.02	0.31	0.65
18	Meghalaya	1.15	0.12	1.04	0.002	0.1	0.94	0.18
19	Mizoram	0.04	0.004	0.04	0.0004	0.0008	0.04	0.9
20	Nagaland	0.36	0.04	0.32	0.009	0.03	0.3	3
21	Orissa	23.09	2.08	21.01	3.85	1.22	16.78	18
22	Punjab	23.78	2.33	21.44	31.16	1	-9.89	145
23	Rajasthan	11.56	1.18	10.38	12.99	2.72	-3.94	125
24	Sikkim	0.08	0	0.08	0.01	0.02	0.05	16
25	Tamil Nadu	23.07	2.31	20.76	17.65	0.91	3.08	85
26	Tripura	2.19	0.22	1.97	0.17	0.2	1.69	9
27	Uttar Pradesh	76.35	6.17	70.18	48.78	5.3	19.52	70
28	Uttarakhand	2.27	0.17	2.1	1.39	0.08	0.68	66
29	West Bengal	30.36	2.9	27.46	11.65	1.24	15.32	42
	Total States	432.42	33.73	398.7	230.44	29.12	161.92	58

	Total Union Territories	0.597	0.036	0.556	0.181	0.05	0.365	33
	Grand Total	433.02	33.77	399.25	230.62	29.17	162.29	58

Total Water Resources

On the whole, the total utilizable water is = 690 (surface) + 433 (ground) = 1123 km^3.

As per the latest National Census data (provisional figures for 2011 census), India's current population is 1.21 billion. India accounts for world's 17.5 per cent population. India also has an estimated livestock population of 500 million which is about 20% of the world's total livestock population.

Table 3 provides details of the population of India and per capita water availability. Since the availability of water has wide spatial and temporal variations (including inter annual variations), the general availability situation is more alarming than that depicted by averages.

Table 3. Per capita per year availability and utilizable surface water in India (in m^3)

Year	Population (in million)	Per-capita surface water availability	Per-capita utilizable surface water
1951	361	5410	1911
2001	1027	1902	672
2011	1210	1614	570
2050 (Projected)	1346 (Low growth) 1581 (High growth)	1451 1235	421

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 (km^3) for different uses.

Uses	Year	Year 2025			Year 2050		
	1997-98	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

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 non-agricultural 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:

i. Highly uneven availability of water, both in space and time, often leading to floods and droughts.
ii. Rampant pollution of freshwater resources mainly by the agricultural, industrial and municipal sources.
iii. Highly unreliable municipal water supply with poor quality.
iv. 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.
v. Inadequate attention to water conservation, efficiency in use, water re-use, groundwater recharge, and eco-system sustainability.
vi. 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.

4.1 Dealing with Variabilities

Water availability in India has a large variation – both spatial and temporal. Basin wise per-capita water availability varies between 13,393 m^3/year for Brahmaputra-Barak basin to about 300 m^3/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 m^3 per capita/year then the country is categorized as water stressed and if it is > 1,000 m^3 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.

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:

1. Basinwise master plan for flood management in each flood prone basin should be prepared;
2. To the extent feasible, flood control schemes should fit in with other water related plans;
3. Future multi-purpose projects should simultaneously consider flood control aspects;
4. 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 5.

Table 5: Drought Prone Area of India.

Drought Prone Area	51.1 mha
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.

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:

- Water-supply measures: increase available water supply during drought and develop new supplies,
- Water-demand measures: reduce the water demand during drought,
- 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.

4.2 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 sseverely 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).

Table 6 Increasing urbanisation in India.

	1951	1991	2001	2021 (projected)
No. of Urban Agglomerations/ towns	2795	3768	4378	-
Urban population (in million)	62.0	217.0	285.0	550.0

Source: Subramanian (2002), Ministry of urban Development (www.urbanindianic.in)

Agricultural, industrial and domestic sources of water pollution are described below.

Agriculture: In India, agriculture is the biggest user and polluter of water. If pollution by agriculture is reduced, it would improve water quality. This would entail learning how to use less chemicals while boosting yields, and switching to organic farming so that fewer chemicals are introduced on farms. Like all other inputs, there is an optimal quantity of fertilizer for given conditions and excess application does not improve the crop yield. Pricing of fertilizers and pesticides as well as appropriate legislation to regulate their use will also go a long way in stopping indiscriminate use.

Industry: Contribution by the industrial sector to water pollution, particularly in urban areas, is significant. Wastewater generation from industrial sector has been estimated at 17,395 mld. Of the total pollution load, 40%-45% is contributed by the processing of industrial chemicals, while nearly 40% of the total organic pollution, expressed as BOD, arises from the food industries followed by industrial chemicals and the pulp and paper industry.

Industries need to carefully treat their waste discharges. Industrial symbiosis, in which the unusable wastes from one product/firm become the input for another, is an attractive solution. Also, there is a need to encourage reductions or replacement of toxic chemicals. Pollution taxes in the Netherlands, for example, have helped the country slash discharges of heavy metals into waterways. Many countries discourage use of equipment that contains harmful chemicals (such as thermometers with mercury). A high level of fertilizer use has also been associated with increased eutrophication in many inland water bodies. Some of the chemicals in fertilizers and pesticides, which enter water bodies through runoff and leaching, have been declared as hazardous by the World Health Organization (WHO) and should be banned.

Domestic: The domestic sector is responsible for majority of the wastewater generation. About 38000 mld of wastewater is generated each day. BOD generated is 7600 tons/day and discharged in water bodies is 5400 tons/day. The class 1 cities in the country produce over 35568 mld of wastewater and only about 11554 mld is treated.

Inadequate treatment of human and animal wastes adds to the high incidence of water-related diseases. Nearly 34 million people are affected by water borne diseases and 1.5 million children are estimated to die of diarrhea alone. Each year about 180 million working days are lost due to water borne diseases. Effective treatment of wastewater strict regulatory measures for wastewater management are needed.

4.3 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.

By the year 2004, about 58% of the annual utilizable groundwater potential was However, in states like Punjab, Rajasthan and Tamil Nadu, large areas fall under the dark category. In coastal regions, e.g., in Tamil Nadu and Gujarat, regional declines in water table have resulted in saltwater encroachment in aquifers.

Large-scale extraction of groundwater has led to overdraft and a drastic fall in water table in some basins. The adverse effects of over-utilization of ground water are lowering of the ground water table, depletion of the resource, wells going dry, need for more power to pump out water, and water quality problems (such Arsenic contamination, etc.). This poses serious financial and health burden on farmers.

The exploitation of groundwater resources should be regulated so that the withdrawals do not exceed recharge. Integrated and coordinated development of surface and groundwater resources and their conjunctive use should be envisaged right from the project planning stage Over-exploitation of groundwater should be avoided, especially near the coasts to prevent ingress of seawater. The role of government will have to switch from that of a controller of groundwater development to that of a facilitator of equitable and sustainable development. Measures such as well spacing norms, controlled drilling of new wells, regulation of water intensive crops, and pricing of electricity for lifting groundwater should be implemented. In overexploited areas, bore-well drilling should be regulated till the water table attains the desired position. Artificial recharge measures need to be urgently implemented.

4.4 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 two 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 of specify 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 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 wee not covered by any drinking water schemes while 133,305 habitations were partially covered. Thus, about 1,273,561 (89.5%) habitations were fully covered by the drinking water supply schemes in the country. 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).

Note that only about 6% of the available water is required for drinking and domestic use. A big challenge is to provided good quality water with high reliability to urban areas. Since the cost of transporting water from distant sources is high, measures to reduce demand, rainwater harvesting, recycle and reuse water are important. Water distribution network needs to be maintained and monitored so that the "unaccounted for" water (leakages, thefts) are minimized. It is said that Delhi has more water per capita than Paris. Yet residents of Paris get water 24*7 whereas most Delhi residents get it only for a few hours.

In urban water supply, almost 30% of the water is wasted due to leakages, carelessness, etc. Prices of water for all uses should be fixed based on its economic value, the ability of users to pay, and to control wastage. Of course, poor people can be provided a certain quantity of water at subsidized rates. For rural areas, it is important to provide water near the households so that the burden of fetching water which usually falls on women is removed.

4.5 Environment Protection and Restoration

Implementation of water pollution prevention strategies and restoration of ecological systems should be integral components of all development plans. To preserve our water and environment, we need to make systematic changes in the way we grow our food, manufacture the goods, and dispose off the waste (Lazaroff, 2000). For this purpose, society and individuals should have a greater knowledge and ability to bring about the required changes.

An environmental flow (EF) is the water regime provided within a river, wetland or coastal zone to maintain ecosystem and their benefits where there are competing water uses and where flows are regulated. Environmental flows provide critical contributions to river health, economic development and poverty alleviation. They ensure the continued availability of many benefits that healthy river and groundwater systems bring to society. Environmental flows normally include the flow requirements in rivers and estuaries for maintenance of riverine ecology. Some people view EF as wastage of water but clearly this is a narrow view. EFR for Indian rivers is to be assessed at different locations by developing methodologies which appropriately take into account the Indian scenarios (including the respect and religious values of rivers). A proper balance between development and conservation is to be established by noting that healthy ecosystems are necessary for the survival of the civilization.

4.6 Threat to Biodiversity and Wetlands

About 6.5% and 12.5% of the world's animal and plant species, respectively, are found in India. Out of these almost 7,000 are endemic to the subcontinent. Unfortunately, habitat destruction in both freshwater and coastal areas has endangered many endemic species. Most vulnerable are the freshwater fish, since they are more susceptible to water pollution, river fragmentation, and environmental change. Other endangered species include freshwater aquatic animals like the Gangetic dolphin and several species of aquatic birds, amphibians, reptiles and insects.

Wetlands in India cover a land area of about 4.1 M-ha. Most of these have become degraded due to pollution, development and conversion pressures. This is threatening not only the local fauna but also the livelihood of the residents dependent on the wetland ecosystem. In coastal areas, industrial and domestic pollution has severely degraded estuarine and coastal environments.

5.0 INITIATIVES NEEDED IN WATER SECTOR

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

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 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.

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.

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 km^3 per year, respectively. The storages available in these basins, including projects under construction, are 16.28, 54, 3.5, and 30.16 km^3. 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.

Interbasin Water Transfer (IBWT)

Transfer of water from surplus areas to deficit areas is an old concept. IBWT is an option to partly overcome the spatial and temporal imbalance of availability and demand. Many such schemes have been implemented all over the world and in India too.

A National Perspective Plan (NPP) for water resources development was formulated by the Government of India in 1980s. NPP comprises of two components: (a) Himalayan Rivers Development, and (b) Peninsular Rivers Development. Fig. 7 shows the proposed layout of canals for the interlinking scheme. Major benefits expected from NPP are: a) Irrigation potential can increase from 140 to 175 million ha, b) Drinking water availability will increase by about 12 km^3, c) Generation of 34000 MW of electricity, and d) Flood control, inland navigation, recreation, etc.

As of now (2017), most of the clearances for the Ken-Betwa Link project have been obtained and work on this project is likely to begin soon. The next projects in pipeline are the Damanganga-Pinjal link and Par-Tapi-Narmada projects. Work on many intra-state links is under progress. For providing water to South India, Manas-Sankosh-Teesta-Ganga link and the Mahanadi-Godavari links will be crucial.

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, desalinization 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. The Forum identified seven challenges to achieve water security: Meeting basic needs, Securing the food supply, Protecting ecosystems, Sharing water resources, Managing risks, Valuing water, and Governing water wisely.

Note that the Goal 7 of the Millennium Development Goals (MDGs) calls for halving by 2015 the proportion of people without sustainable access to safe drinking water and sanitation. True attainment of all the goals of the MDGs is necessary environmental sustainability and improving the quality of life.

6.0 TOWARDS A BETTER FUTURE

The growing population and increasing water use are making the freshwater scarce and polluted and posing a major threat to water resources in India. Interstate disputes are a threat to peace as well use of water. A new water revolution is needed to preserve, harness, develop and manage water resources keeping in view both their quantity and quality. For sustainable development of freshwater resources, it would be important to enable individuals and communities to appreciate their options, evaluate them and then choose the one that is the most appropriate.

Water is a major factor in each of the three pillars of sustainable development – economic, social, and environmental. India has to initiate a series of measures to ensure that her people have access to clean water and sanitation, there is food security, and there are no water related conflicts. Water must meet the needs of the present population and those of future generations.

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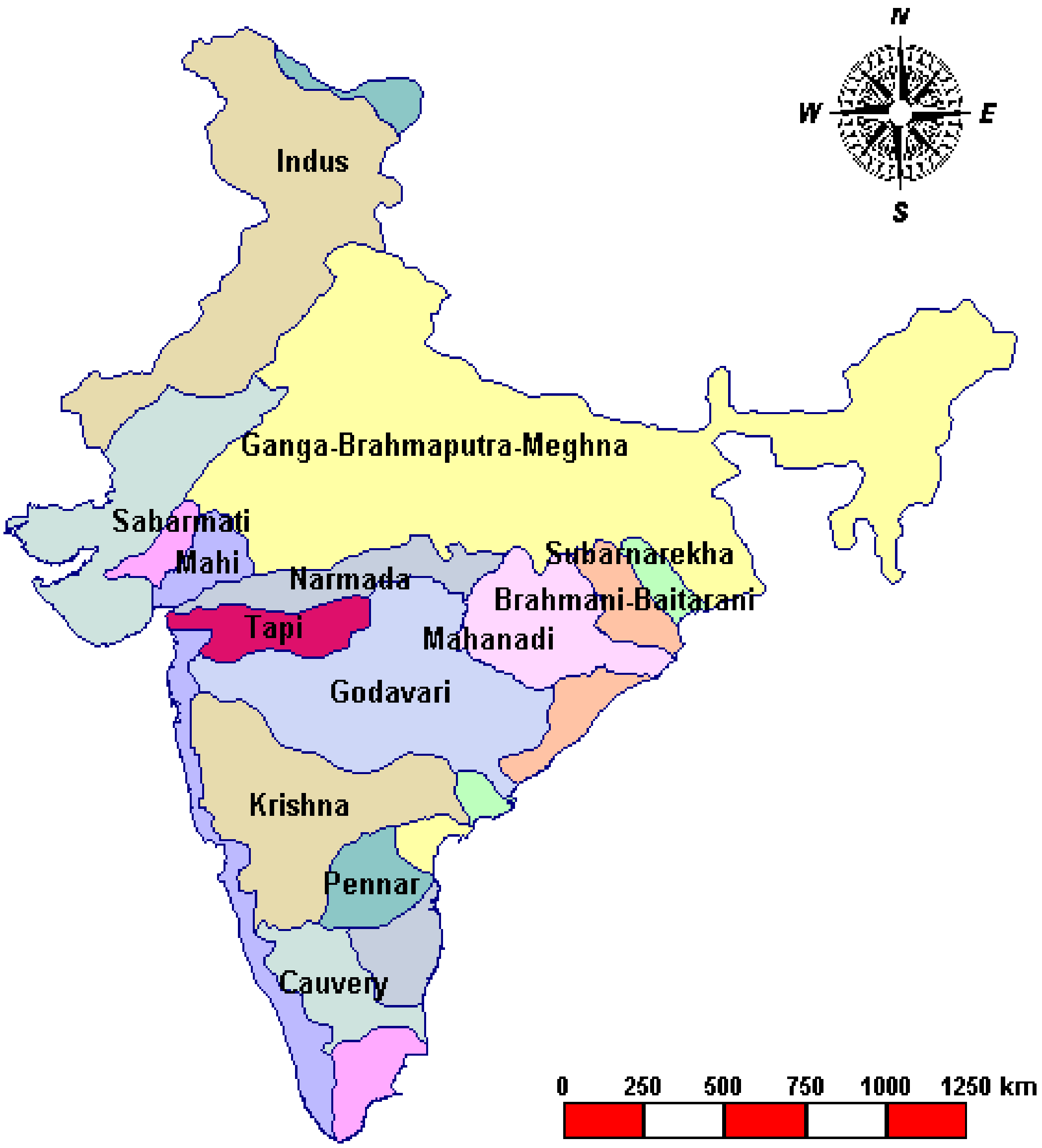

Figure 1 Major river basins of India.

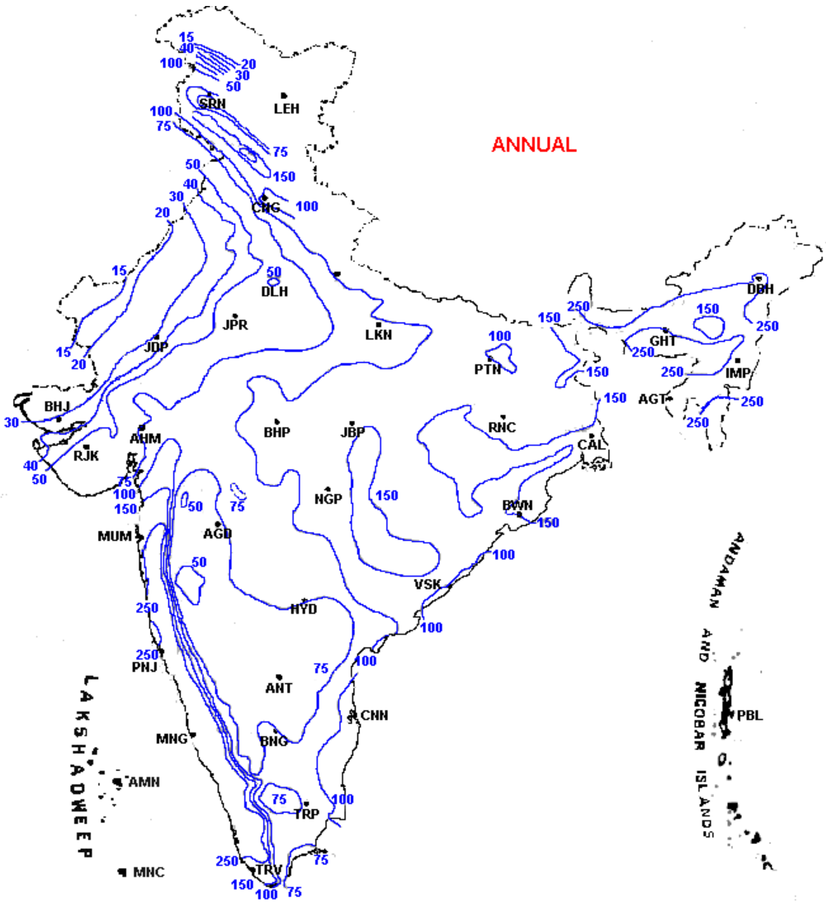

Fig. 2: Distribution of normal annual rainfall in India (Source: IMD, 2004).

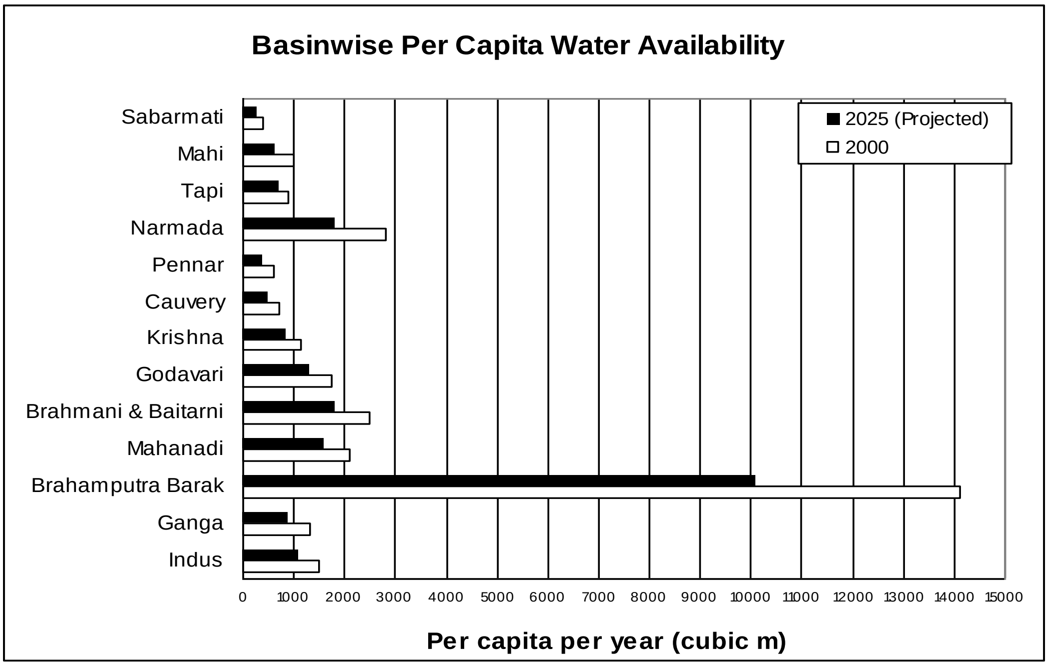

Figure. 3 Basin-wise per-capita water availability.

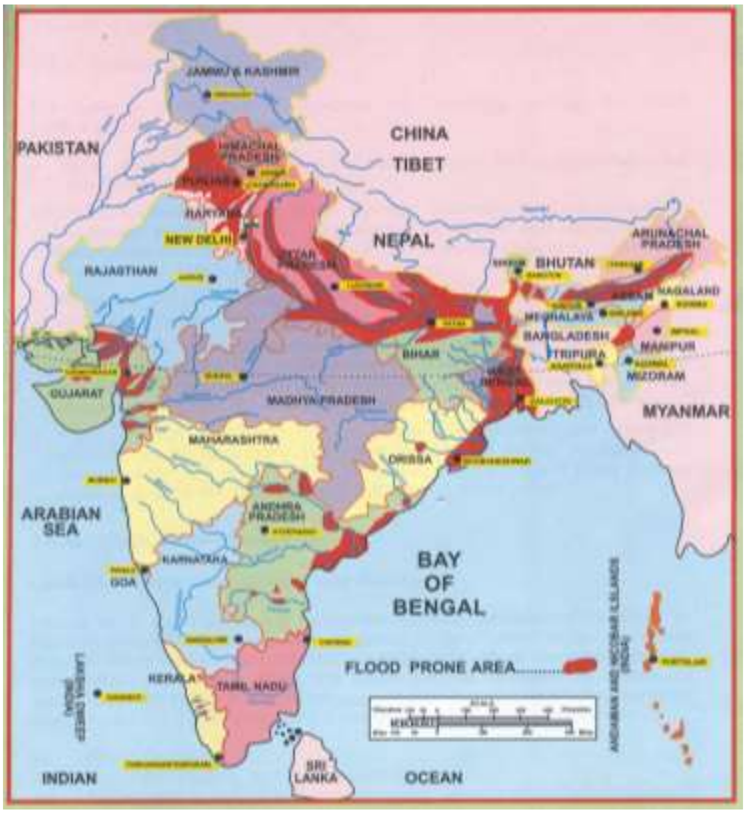

Fig. 4 Flood prone areas of India.

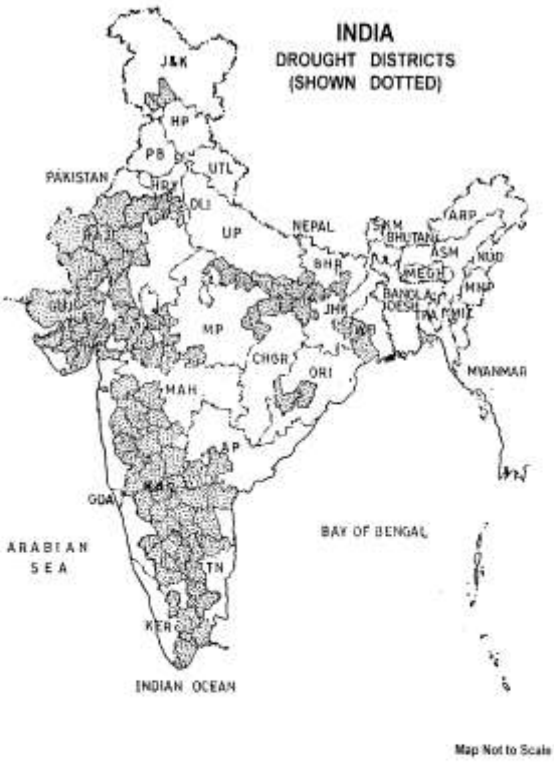

Fig. 5 Drought prone districts of India.

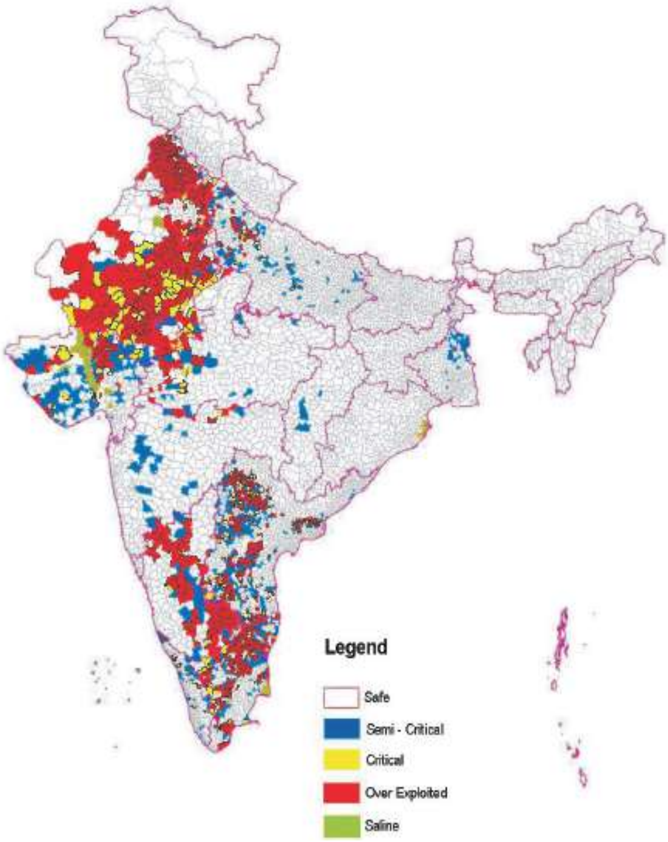

Fig. 6: Categorization of ground water blocks in safe, semi-critical, critical, over exploited, and saline. Source: CGWB (2006).

Fig. 7 National Perspective Plan of Interlinking of Rivers, prepared by National Water Development Agency.