IMMINENT CRISIS OF WATER AND WATER CRISIS IS IMMINENT

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ABSTRACT

Water is a universal solvent. Its dissolving capacity is immense. As such purification of water is a very difficult task. Water serves human needs. It satisfies human demands. It solves human problems since time immemorial. Easy availability of water is a hindrance to realise its importance. Many parts of this planet do not get water sufficiently or regularly and India is no exception. Only those who are deprived from this natural blessings can feel its real cost. Climate is changing. Its controlling parameters are also changing. Double changes have rendered the whole situation quite unpredictable. Global climate change causes change of global hydrological cycle. This changed hydrology offers either untimely precipitation or huge precipitation causing flood or no precipitation at all resulting to severe drought and death. Due to this peculiar behaviour of Indian Summer Monsoon sectors viz., production of rain fed crops, fisheries, livestock production and forestry, etc are severely affected leading to huge economic loss of society thereby nation at large. With the growth of population the demand thereby production of crops has been increased. Agricultural land is limited. In this limited land unlimited manure and pesticides have been used to get the desired quantity of crop. This type of chemical dependent cultivation needs huge water. Water is lifted causing water level down thereby increasing arsenic limit higher. Though rainfall is irregular but its quantum is more or less unchanged as is evident from analysis of hundred year's rainfall data. Main problem lies in the conservation of water or no conservation infrastructure at all. Major quantum of precipitation is wasted quite unused simply due to runoff. Unplanned and ill planned management both of private and public have rendered the situation quite critical. Further, rapid industrialisation and urbanization have raised demand of water much, instead lowered water level more and polluted the environment and river water most. In future pure water will be like luxury goods. If proper care is not taken then pure water will be a dream in near future. Water dissolves all and solves all problems. But at present it cannot solve its own problem.

Keywords: Climate Change, Hydrological Cycle, Water, Crisis, Imminent.

1). Introduction and Conceptual Background:

Water is needed in all aspects of life. Difficult to purify, expensive to transport and impossible to substitute, water is an indispensable element of life. Renewable fresh water is an increasingly scarce commodity and the amount of fresh water actually available to people is finite. The general objective is to make certain, that adequate supplies of water of good quality are maintained, for the entire population of this planet, while preserving the hydrologic, biological, and chemical functions of the ecosystems, adapting human activities within the capacity limits of nature and combating vectors of water related diseases. Without sufficient water, economic development becomes virtually impossible and conflict over scarce resources virtually inevitable. Regional and local water shortages have always existed because of the inequalities of the hydrological cycle, but a global view also indicates that the entire hydrologic cycle is nearing the limits of use and therefore, even the water surplus countries will very soon start experiencing water shortages.

United Nation Organization has given top priority to the problem of water scarcity and sanitation. This is because:

· The subsurface water table level is shrinking in all the continents of the world.

· Agricultural lands are becoming saline.

· Increasing pollution of surface and sub-surface waters.

· Nearly 45 crores of people in 29 countries are staying in water-deficit regions.

· More than 100 crores of people are not getting safe drinking water.

· Nearly half of the world's population is lacking water purification plants.

· In the Third World countries nearly 50 % of its diseases are due to the use of contaminated water.

· Nearly 70 % of the fresh water is used for irrigating the agricultural fields which has raised water conflict between the urban and rural areas.

If all this continues, then very soon i.e. by 2032, nearly half of the world's population will be facing water shortage problem. It is predicted that in the 21st century there will be water wars. Water being unevenly distributed over the land, influences inter-state and international relations and so is the cause of hydro politics. The earth's growing population with its multifaceted activities demanding fresh water is now putting this vital resource under increasing pressure. The United Nations estimates that by 2025, nearly 1/ 3rd of the World's population, will suffer from chronic water shortage, if current rate of consumption continues.

Human concerns regarding water can be divided into two categories: *quantitative* and *qualitative*. **Quantitative** refers to issues such as whether we will have enough water to meet our needs and what will be the impacts of diverting the water from one point of cycle to another. **Qualitative** refers to issues, such as whether the water will be of sufficient purity so as not to harm human or environmental health.

Water and conflict

Resource scarcity can exacerbate preexisting tensions or invite new ones, and water is no exception. Renewable fresh water is an increasingly scarce commodity and the amount of fresh water actually available to people is finite. As population grows, the average amount of renewable fresh water available to each person declines. Thus water stress and outright scarcity are all but inevitable. Tensions over water resources permeate in every region of the world, ranging form urban and agricultural water uses in the Western U.S. to outright warfare in the Middle-East. With over 200 river and lake basins bordered by two or more countries and aquifers crossing International borders, the potential for increased regional tensions over shared resources, as population increases, is substantial particularly in arid and semi-arid regions, where water is already a scarce resource. Within a decade water could overshadow oil as a precious resource commodity at the center of conflict and peacemaking. Freshwater ecosystems are disappearing as rivers sand coastlands are developed around the world. Dams block the return of Salmon fish to spawning areas; toxic pollution and acid precipitation kill fish; leaching of fertilizers promotes algal blooms (eutrophication) in surface waters; heavy metals drained by industries in water accumulate in fish and shell-fish that enter into the higher food-chain. Throughout the World urban areas lose staggering amounts of water through leaks and breaks in water supply systems, and much of this water will have to be saved through targeted efficiency and conservation efforts. With 90% of future population growth expected to occur in urban areas the demand for fresh water for domestic and industrial use and waste treatment will soar worldwide. Agriculture is the single largest user of water with 70 % followed by industry and energy withdrawing 23 % of water, while household use is just 8 %. However these patterns vary greatly from country to country depending upon the levels of development, climate and population size. In many of the developing countries river pollution from untreated sewage has crossed the limits of the recommended safe limits for drinking and bathing, for example; in India, cremated corpses and millions of tons of sewage is all found in the holy waters of the Ganges. This gives rise to spread of infectious diseases through water related diseases. Such diseases form single largest killers of infants in the third world countries. **Gross mismanagement in preserving rainwater is much to blame for the present water crisis in the country of India.** There are enormous amounts of recoverable water that go wastes every year. Although many parts of India receive up to 38 inches of rainfall annually, only 10 % to 20 % of it is actually captured. This is because we lack in well-established practices and water development projects. Besides, much of the water is lost through leakages due to poor maintenance of thousands of tanks, wells, pipes and their fittings, and water reservoirs. Hence, while formulating any strategies for the country, the first priority has to be assigned to the issue of raising of water resources and its management. Established in 1998, the World Commission on Water for the 21st century was given the responsibility for developing a long-term vision for water for that century. The U.N.O proposed to organize an international conference on water resources in the year 2005. To face this problem and avoid water conflicts and water wars the timely steps are incorporated with the concepts of River-Basin Partnership, Hydro-solidarity. For the development of this concept the International Organizations such as Global Water Partnership, World Water Council and World Water Forum are working actively. Hence **22nd March is celebrated as 'Global Water Day'**. To be used sustainably, water cannot be withdrawn from reservoirs and other sources faster than it is replenished through the natural hydrologic cycle. Water must be drawn at a rate that permits water-table level to remain stable over time. The essence of 'Sustainable Development' is that natural resources must be used in ways that will not limit their availability to future generations (Water Scenario 2025, Shinde).

Water is one of the fundamental resources and indispensable element of life on the earth, as rightly stated by GOETHE that 'everything originated in the water and everything is sustained by water'. The earth appears as a water planet from the space, yet water is a scarce resource, because, of the planets total water**,** accessible fresh water accounts for less than 1%.

Fresh water that is continually renewed through the Global water cycle is a finite natural resource in each country. The precipitation on the earth is also highly unevenly distributed as it is governed by natural factors that are favourable to some areas resulting in water surplus regions and unfavorable in other, causing water-deficit regions in the world.

India shares only 5 % of the total world's water and supports approximately 15 % of the total World's population. China & India and other countries together constitute 86 % of World's population but receive only 47 % of water, whereas 14 % of the world's population receives 53 % of water. This scarce potable water has long been over-exploited, polluted and fought over. The earth's growing population along with its multifaceted activities demanding fresh water, is now putting this vital resource under increasing pressure. Since the 1992 International Conference on Water and the Environment in Dublin, there has been a great deal of intensive and serious thought about the limited water availability and possibilities of exploiting and managing the earth's fresh water resources. According to World Bank estimates, by the year 2025, one person in three will live in conditions of water shortage. Water is becoming as increasingly scarce and extremely valuable resource; without which sustainable development is impossible. The guaranteed sustainable supply of water, the quality of which is also good enough to meet the requirements of people, is an enormous challenge to the governments of many countries, especially the developing world. Water being unevenly distributed over the land, influences inter-state and international relations and so is the cause of 'Hydro politics'. Already its footprints are noticed with conflicts increasing at local, regional, national and international levels. The United Nations estimates that, by 2025 nearly one third of the world's population will suffer from severe water shortage if current rates of consumption continues. The United Nations therefore declared 2003 as the International Year of Fresh water. A recent World Water Development Report ranked India 133rd among 180 countries in terms of water availability and 120th among 122 countries in terms of water quality. Water tankers supplying drinking water in many parts of the country by rail and road is a common sight. Women in villages suffer most as they have to walk more than 2 kms to fetch drinking water needs. Millions of households in urban areas wake up in the pre-dawn to fill water as the municipal supply is only for few minutes/hour in a day. Water situation in the country is indeed critical as noticed with water riots and acrimonious conflicts over water becoming the norm. Skirmishes among stated over sharing of water are becoming too common, for example; for decades the two states from south India namely, Tamilnadu and Karnataka have been bitterly squabbling over sharing of the waters. Rapid population growth, industrial expansion and migration of people from rural to urban areas, especially to the metro cities of the country, are threatening India's water resources. The supply of water for human use is related with its quantity and quality. All human activities impair the natural quality of water which beyond a certain degree or pollution becomes unusable. This results in the reduction of supply of usable water. Reports of acute water shortage of drinking water are pouring in from different parts of the country. According to World Watch Institute, Washington, India will be a highly water-stressed country from 2020 onwards. Hence there is a need to evolve simple solutions that can be replicated on a large scale. Therefore identifying the water potentials of the country is utmost essential.

Rainfall and Potential of Flow

The climatic condition influences to a great extent the water resource availability in the country, as it ranges from continental to maritime, resulting in extreme aridity in some areas to torrential rains in the other areas of the country. Rainfall in India is dependent upon the influence of south-west monsoon between June to September and north-east monsoon during October to November. The annual average rainfall over India based on the daily collected data by Indian Meteorological Department from more than 3000 rainfall-recording stations for a period of 50 years (1901-1950) is computed as 105 centimetres. It is largest anywhere in the world for a country of a comparable size. A good part of it is lost through the process of evaporation and plant transpiration, leaving only a half of it on the land for us to use. However distribution of rainfall in India shows great variations with unequal seasonal and geographical distributions and its frequent departure from the normal. Because of this spatial and temporal variation in precipitation, the potential usable water supply is very small. The entire western coast and Western Ghats, most of the Assam and the Sub-Himalayan West Bengal receive more than 250 cm. rainfall, but it decreases rapidly from 50 cm. in Delhi to less than 15 cm. in Rajasthan to the extreme west. Peninsular India receives less than 60 cm. to 50 cm of rains. The resources potential of the country, which occurs as natural run off in the rivers, is about 1869 km3 as per the latest estimates of Central Water Commission Ministry of Water Resource Govt. of India, considering both surface and ground water as one system. Ganga-Brahmaputra-Meghana system is the major contributor to total resources potential of the country with 60 % of its share to total water resources potential of the rivers. Of total potential surface water resources, 40 % of utilizable surface water resources are in the Ganga-Brahmaputra-Meghana system. In majority of river basins, present utilization is significantly high and is in the range of 50 % to 95 % of utilizable surface resources. However, in the rivers, such as Narmada and Mahanadi percentage of utilization is quite low.

The distribution of water resources potential in the country shows that as against the national per capita annual availability of water of 19054 m3, the average availability in Brahmaputra and Barak is as high as 16589 m3, while it is as low as 360 m3 in Sabarmati basin. Brahmaputra and Barak basin with 7.3 % of geographical area and 4.2 % of population of the country has 31 % of the annual water resources. Per capita annual availability for rest of the country excluding Brahmaputra and Barak basin works out to about 1583 m3. Water shortage is a regionally, locally and seasonally specific problem.

Catchment Area of River Basins

There are fourteen major river basins in the country which occupy 83 % of the total drainage basins, contribute 85 % of the total surface flow and house 80 % of the country's population. These are Brahmaputra, Ganga, Indus, Godavari, Krishna, Mahanadi, Narmada, Cauvery, Brahmini, Tapi, Mahi, Subernrekha, Pennar and Sabarmati. A glance at the river basins map of India reveals some interesting features. The Brahmaputra, Ganga, Indus basins along with that of Godavari cover more than half of the country.

Classification of Rivers

All the major river basins are not perennial. Only four of the fourteen major basin posses areas of high rainfall, i.e. Brahmaputra, Ganga, Mahanadi and Brahmini are perennial having annual average discharge of a minimum of 0.47 million cubic meter per km2. Six basins i.e. Krishna, Indus, Godavari, Narmada, Tapi and Subernrekha area in the medium rainfall zone and have annual average discharge of a minimum of 0.26 million cubic meter per km2, and the remaining four i.e. Cauvery, Mahi, Sabarmati and Pennar occupy the area of low rainfall and have annual average discharge between 0.06 to 0.24 million cubic meter per km2. Thus many of the major rivers basins also go dry during summer leaving no available water for dilution of waste water discharged in them. The water resources of the country as natural runoff in rivers (surface & sub-surface water) is about 1869 km3 as per the latest estimates of Central Water Commission Ministry of Water Resources, Government of India. The Northern Rivers are always subjected to floods during monsoons and during early summers due to melting of snow in Himalayas. **This water therefore needs to be carried to the drought stricken areas of Central and South India.** All this water needs to be collected and stored so that it can be used during 'dry spell'. The National Water Grid Policy such as interlinking of rivers for eg. Ganga-cauvery link, Brahmaputra-Ganga link, a link canal from Narmada to Rajasthan and other links needs due consideration for sustaining development in the country.

Ground Water Potential: Total replenishable ground water potential of the country has been estimated by Ministry of Water Resources as 431 cu.km. per year. After making provision for drinking, industrial and other purposes (other than irrigation), which is about 16 % of the total potential, the potential available for irrigation is 360 km3 per year. Thus substantial portion i.e. about 68 % of ground water is still remaining untapped. Analysis of basin wise potential of ground water by the Ministry of Water Resources indicated that the Ganga Basin has the maximum potential which is 171 km3 i.e. 40 % of total potential in the country. The potential of Uttar Pradesh is in about 84 km3/year and Goa with the lowest of 0.22 km3/year. Development of ground water in Punjab in percentage is highest where about 94 % of the resources appear to have been tapped Haryana with 84 %; Tamil Nadu with 60 % Water Resource; and Rajasthan with 51 %. Percentages of development in the states of J&K, Assam, Goa and Orissa are very low.

Water resources regions: It can be planned on the basis of river basins, which are the natural unit. A river basin has a defined watershed boundary and also has relationship with ground water resources in most of the cases. The development of a balanced plan for water resources utilization requires full knowledge of the quantity, quality and distribution of water resources utilization and also the changing patterns of land use in the entire water shed and its influence of the river flows. India has been divided into six river basins for the purpose of assessment of the available water resources. Ganga-Brahmaputra Meghana system is the major Contributor (60 % to total water resources potential of the country. The rest of the river systems are with less potential.

Population and Water Stress: Malin Falkenmark, a Swedish hydrologist, pioneered the concept of a "Water Stress Index", based on an approximate level of water required per capita to maintain an adequate quality of life. According to her **100 litres of water per day** per capita is a minimum requirement to maintain good health. Based upon it Falkenmark suggests specific thresholds of water stress and water scarcity. The 1000 cubic meter benchmark has been accepted as a general indicator of water scarcity by World Bank and other analysts. Water engineers and planners consider a country to have reached a point of water scarcity when it has fewer than 1000 cubic meter of renewable fresh water availability annually per person in the country. Cauvery, Pennar, Sabarmati, East Flowing rivers and west Flowing rivers are some of the basins that fall into this category. Since renewable fresh water resources are essentially constant in each nation per capita availability falls as population increases pushing some countries over time into water stress and water scarcity. Falkenmarks higher stress benchmark of about 1700 cubic meter per capita per year is a "Warning Light' to nations whose populations continue to grow.

Regional Water Scarcity in India: Water shortage is a regionally, locally and seasonally specific problem. Based on per capita renewable water availability, India has enough water to meet its people needs. But despite an estimated 2,462 cu.m. per person per year, many of its nearly 900 million people suffer from severe water shortages in part as a result of uneven availability of water. India's vulnerability of regional water scarcity is well illustrated by the case of Rajasthan with per capita water use in 1990 at 562 cu.m., a level of absolute scarcity. The state houses about 8 % of India's population but claims only 1 % of the country's water resources in the form of ground water, limited rainfall and a restricted share of water that straddle state boundaries. With increasing population in the coming decades acute shortages are imminent. Even the regions receiving high rainfall in India often face drought because landscapes have been denuded, soil is compacted and most of the rainfall run's off before sinking into subsurface leading to flooding for 3 to 4 months and then dry for the rest of the year, for eg. Cheerapunji of Meghalaya with rapidly growing population, clearing of forests for agricultural and housing, water shortages and desertification will likely worsen the situation. Hence combating floods, checking growth rate of the population, providing other survival measures, restoring the forests and preserving forests lands would go a long way in preserving water resources (Water Resource of India, Chawan, S.V).

Rapid industrialization and urbanization in India are responsible for the huge increase in the demand for water. The inefficient management of the resource has led to deterioration in water quality, posing new challenges for water management and conservation. Today, the hydrological cycle has altered in most of India's river basins due to land use change, inter–basin transfers, irrigation and drainage. Sustainable management of water has therefore gained considerable importance in recent years. An assessment of the availability of water resources, taking account of the multiplying demands and likely impacts of climate change and variability is critical for planning and sustainable development as a basis for economic and social development.

Water is vital to all forms of life on earth, from the simplest of living organisms to the most complex of human systems. Lack of fresh water for drinking, for use in industry and agriculture, and for several other essential needs is a limiting factor — perhaps the most important factor — hindering development in many parts of the globe. In south Asia, increasing water shortage and declining water quality from pollution during the past few decades have drawn attention to the inherent scarcity of water and have led to concern about water availability to meet the requirements of the twenty–first century. Because of increasing population and changing patterns of water use in south Asia, additional demand is likely to be accompanied by a sharp decline in per capita water availability. **While consumption of 1000m3 of water per year and per capita is considered a standard for 'well–being'** in the developed world, annual water availability per capita by the year 2025 for south Asia is projected to be a mere 730 m3, and is on a declining trend in all parts of the world, including those that are considered to have ample water resources. With the growing recognition of such issues as the possibility of global climate change, an increasing emphasis on the assessment of future availability of water on various spatial and temporal scales is needed. A warmer climate will enhance the hydrological cycle, which implies higher rates of evaporation, and a greater proportion of liquid precipitation compared with solid precipitation; these physical mechanisms, associated with potential changes in precipitation amount and seasonality, will affect soil moisture, groundwater reserves and the frequency of floods or droughts. The supply of water is limited and governed by the renewal processes associated with the global hydrological cycle.

2). Literature Review: Survey of literature reveals that water crisis is imminent if the nations do not take immediate precautionary measure as suggested by scientists and sociologists with utmost care as is evident from the following discussions.

Water resources will come under increasing pressure in south Asia due to the changing climate. Changes in climatic conditions will affect demand, supply and water quality. In regions that are currently sensitive to water stress (arid and semi–arid regions of India), any shortfall in water supply will enhance competition for water use for a wide range of economic, social and environmental applications. The growing population will heighten demand for irrigation and perhaps industrialization at the expense of drinking water. Disputes over water resources may well be a significant social consequence in an environment degraded by pollution and stressed by climate change.

India is home to a billion people, a figure that is projected to increase to 1.7 billion by 2050, assuming a fertility rate of 2.1per cent. The surface water and groundwater resources in India play vital roles in agriculture, fisheries, livestock production, forestry and industrial activity. Water and agriculture sectors in India are largely dependent on monsoon rainfall. There have been considerable spatial and temporal variations in rainwater availability in recent years as a result of an observed swing in the onset, continuity and withdrawal patterns of the monsoon.

Agricultural output is primarily governed by availability of water, making the country's agrarian economy sensitive to the status of water resources and the monsoon. The monsoons serve not only as a sole provider of water to large areas of rainfed cultivation but also remain the primary source of water to recharge the groundwater resources of the country. The demands on the water resources in the country by the several sectors are, not surprisingly, dominated by the agriculture sector. In 1999, agriculture consumed 85.3 per cent of the water, industry 1.2 per cent, energy sector 0.3 per cent, and other sectors 6.4 per cent, whereas domestic consumption was 6.6 per cent (GOI 2000). Besides being a source of irrigation supplies, large water reservoirs are also required to generate hydropower. But unlike irrigation the consumptive use of water in this sector is mainly limited to evaporative losses. Many of the large reservoirs like Bhakra, Hirakud, Nagarjunasagar, Koyna, Pong, Rihand, Srisailam and Idduki are excellent examples of providing hydropower to the nation and have brought economic growth and prosperity to the region.

The two key sources of fresh water are groundwater and surface water; of these the river basins represent the main source of fresh water in the Indian subcontinent. Groundwater acts as a regulating mechanism for storing water in the wet season and thus complements surface storage, which being location specific, may not be available.

Interestingly, almost 80 per cent of domestic water requirement in India today is met from groundwater sources. However, the groundwater resources in several states of India are fast getting depleted primarily due to over–extraction and poor recharging facility.

Despite the presence of substantial reserves of water in India, the actual utilizable quantity is limited and a water crisis is seen as inevitable in the future. The per capita availability of fresh water is currently estimated at about 2,000 m3 i.e., 2x109 litres per person per year, and a further drop to 1480 m3 is expected in the next decade due to increase in the population coupled with no further augmentation of water resources and also its consequent decrease over the same time due to consumption. **India will reach a state of water stress before 2025 when the availability falls below 1000 m3.** This clearly indicates the 'two–sided' effect on water resources — the rise in population will increase the demand for water, leading to its faster withdrawal, which in turn would reduce the recharging time of the water tables. As a result, availability of water is bound to reach critical levels. This makes it imperative to draw up appropriate plans and strategies to conserve our water resources and optimize utilization of water from the various water sources.

In India, the two monsoon seasons (the southwest monsoon from June to September and the northeast monsoon in November–December) bring rains — many a time in intensities and amounts that can cause serious floods, creating hazardous (and often disastrous) situations. Moreover, cyclonic storms in the pre–monsoon months (April–May) and the post–monsoon months (October–November) cause large–scale inundation, destruction and deaths. In fact, floods and cyclones are the two major natural disasters that visit India quite often.

The long–term average annual rainfall for the country as a whole is 116 cm, the highest for a land of comparable size in the world. But this rainfall is highly variable both in time and space.

An annual mean global warming of 0.4–0.8°C has been reported since the late nineteenth century (IPCC 1998). The global warming threat is real and the consequences of the climate change phenomena are many and alarming. The impact of future climatic change may be felt more severely in developing countries such as India whose economy is largely dependent on agriculture and is already under stress due to the current population increase and associated demands for energy, fresh water and food. In spite of the uncertainties about the precise magnitude of climate change and its possible impacts, particularly on regional scales, measures must be taken to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects.

Groundwater is the principal source of drinking water in the rural habitations and almost 85 per cent of the rural water supply in India is dependent on groundwater. India, on the whole, has a potential of 45.22 Mha metre/yr of replenishable groundwater. Unfortunately, due to rampant drawing of the subsurface water, the water table in many regions of the country has dropped significantly in recent years, threatening groundwater sustainability.

The water quality of subsurface water is interlinked with quantity. Overexploitation of groundwater has resulted in a drop in its level, leading to ingress of sea water in coastal areas, making the subsurface water saline. India is especially susceptible to increasing salinity of its groundwater as well as its surface water resources, especially along the coast, due to the rise in sea level. Increase in the sea level leads to intrusion of saline water far into the land mass through rivers draining into the sea, and also increases groundwater contamination by making water saline. Saline water cannot be used for either agriculture or fishery development. Lower levels of water due to excess withdrawing have also led to deterioration in water quality. Several problems of arsenic and fluoride contamination in water have surfaced in certain parts of the country. High levels of fluoride in water have led to cases of acute flourosis in many villages of Andhra Pradesh, Ajmer in Rajasthan, Gurgaon district in Haryana, Salem in Tamil Nadu, and some villages in Agra, Uttar Pradesh. The problem of arsenic is rampant in West Bengal and has given rise to acute health problems in the State. More than 7,000 wells in several districts in West Bengal have high dissolved arsenic, usually more than 50 mg/l today.

Future Demand for Water

According to statistics on water demand, the agriculture sector is the largest consumer of water. About 85 per cent of the available water is used for agriculture alone. The quantity of water required for agriculture has increased progressively through the years with expansion of the area brought under irrigation. In 1950, a total area of 25 x 106 hectares was under irrigation and this has more than trebled in five decades. The contribution of surface and groundwater resources for irrigation has played a significant role in India's attainment of self–sufficiency in food production during the past three decades, and is likely to become more critical in future in the context of national food security. According to available estimates, the demand on water in this sector is projected to decrease to about 74 per cent by the year 2050 though agriculture will still remain the largest consumer. In order to meet this demand, augmentation of existing water resources by development of additional sources of water or conservation of the existing resources through impounding of more water in the existing water bodies and its conjunctive use will be needed.

Demand for water in the other sectors is also expected to increase significantly. In the energy sector it is likely to increase dramatically, almost 70 times by the year 2050. This may be associated with rapid growth in industry and urbanization. The projected share of demand by the energy sector would most likely be about 8.9 per cent in the year 2050 as against the present share of 0.3 per cent. The demand for water in the industry sector could increase eightfold during the same period. It can be expected to increase to 4.3 per cent in the year 2050 as against 1.2 per cent for this sector, which is poised for rapid expansion in the decades to come.

With the increase in population, there will be a corresponding increase in the demand for water in the domestic sector. The demand for domestic water is likely to increase from the 6.6 per cent at present to 7 per cent in 2050. Even at present, at least a part of the urban populations in many states have no access to drinking water. In certain states like Assam, the percentage of urban population with access to drinking water is only 10 per cent, and in Tamil Nadu it is 50 per cent. The other states experiencing shortage of drinking water include Kerala, Andhra Pradesh, Bihar, Goa, Orissa, West Bengal, Punjab, and the northeastern states of Meghalaya, Mizoram, Manipur, Tripura and Sikkim. The fall in per capita water availability in the future will not be uniform throughout the country. For instance, based on the data on per capita availability of water for the last fifty years, projections have been made for the next fifty years. The national average in the year 2000 has been projected at 2.5 x 103 m3/yr/person. The corresponding availability of water for the Northeastern region was reported to be 18.4 x 103 m3/yr/person, which is much higher than the national average. The per capita availability in the southern part of the country, Tamil Nadu, in particular, is lower than the national average at about 0.4 x 106 m3/yr/person.

In order to fulfil such demands in the future, we will need to rationalize the various means of capturing and storing water. The interannual variability of the monsoons is expected to increase, making the monsoons a less reliable source of water. Therefore, efforts are needed for more efficient groundwater recharge and harvesting of rainwater through identification, adoption and adaptation of technological options. Some of the structural activities such as nalla bunds, contour bunds, contour trenches, gully plugs, check dams, pits and shafts, basin percolation tanks, surface channels, groundwater dams, injection wells, connector wells, storage tanks, dug well recharge, bore hole flooding, ditch and furrow, stream augmentation, de–silting of existing tanks and inter–watershed transfer should be tried depending on local conditions. Restoration, revival, revitalization and upgrading of existing / traditional rainwater harvesting structures would ensure sustainability of water resources.

Much of the future demand will need to be met from the groundwater resources, which may have immense potential. The water potential of the Ganga valley can irrigate an additional 200 Mha of land, which can sustain rice productivity of about 4 tonnes per hectare and produce another 80 million tonnes of rice that can sustain another 350–400 million people. The excess water requirement in the future can, however, only be made through properly planned and precise management. Studies carried out for the Ganga basin need to be conducted for all major river basins in the country in order to discover additional potential sources of water such as deep artesian aquifers. The increasing demand for water and its reduced availability is a growing national concern. Projections of water stress in the near future are rapidly turning into stark reality. Major initiatives need to be taken by the government to plan and implement water conservation programmes. Keeping in mind the plausible impacts of global warming on our water resources, the government has to frame appropriate guidelines and action plans for water conservation for the future.

Coping with Climate Change and Adaptation

Climate change is just one of several factors influencing the hydrological system and water resources. Population growth, changes in land use, restructuring of the industrial sector, and demands for ecosystem protection and restoration are all occurring simultaneously. Current policies affecting water use, management, and development are often contradictory, inefficient, or unresponsive to changing conditions. A change in drought or flood risks is one of the potential effects of climate change with the greatest implications for human well–being. In the absence of explicit efforts to address these issues, the societal impacts of water scarcity in India are likely to rise as competition for water use grows and supply and demand conditions change.

There are many opportunities to reduce the risks of climate variability and change for India's water resources. Past efforts have focused on minimizing the risks of natural variability. Many of the approaches for dealing effectively with climate change are different from the approaches already available to manage risks associated with existing variability. Tools for reducing these risks have traditionally included supply–side options such as new dams, reservoirs, and improving efficiency. This is largely independent of the issue of climate change, which will have important implications for the ultimate severity of future water stresses.

Sole reliance on traditional management responses should be avoided. First, climate change is likely to produce, in some places and at some times, hydrologic conditions and extremes of a different nature than current systems were designed to manage; second, climate change may produce similar kinds of variability but outside of the range for which current infrastructure was designed and built; third, relying solely on traditional methods assumes that sufficient time and information will be available before the onset of large or irreversible climate impacts to permit managers to respond appropriately; and fourth, this approach assumes that no special efforts or plans are required to protect against surprises or uncertainties.

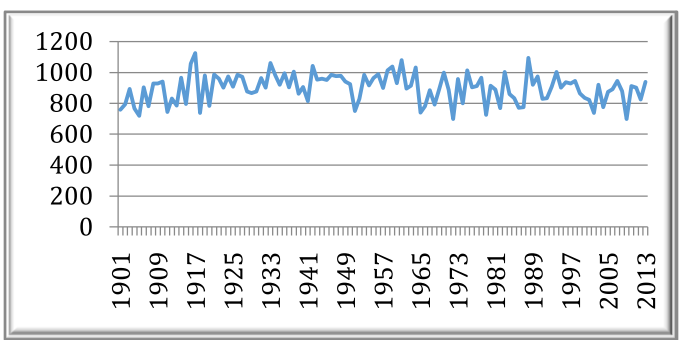
The first situation could require that completely new approaches or technologies be developed. The second could require that efforts above and beyond those currently planned or anticipated be taken. Complacency on the part of water managers, represented by the third and fourth assumptions, may lead to severe impacts that could have been prevented by cost–effective actions taken now.

Recommendations and observations on how to cope with the climate change issue in terms of future water resources in India are as follows: (i) Prudent planning requires that a strong national climate and water monitoring and research programme should be developed, that decisions about future water planning and management be flexible, and that expensive and irreversible actions be avoided in climate–sensitive areas; (ii) Better methods of planning under climate uncertainty should be developed and applied; (iii) Decision makers at all levels should re–evaluate technical and economic approaches for managing water resources in view of potential climate changes. The government should ask all states managing national water systems to begin assessing both climate impacts and the effectiveness of different operation and management options; (iv) Improvements in the efficiency of end uses and the management of water demands must now be considered major tools for meeting future water needs, particularly in water–scarce regions. Water demand management and institutional adaptation are the primary components for increasing system flexibility to meet uncertainties of climate change; (v) Water managers should begin a systematic re–examination of engineering designs, operating rules, contingency plans, and water allocation policies under a wider range of climate conditions and extremes than have been used traditionally.

For example, the standard engineering practice of designing for the worst case in the historical observational record may no longer be adequate; (vi) Cooperation between water agencies and leading scientific organizations can facilitate the exchange of information on the state–of–the–art thinking about climate change and impacts on water resources; (vii) Timely flows of information among the climate change scientists and the water–management community are valuable. Such lines of communication need to be developed; (viii) Traditional and alternative forms of water supply can play a role in addressing changes in both demands and supplies caused by climate changes and variability. Options to be considered include waste water reclamation and reuse, rainwater harvesting and even limited desalination where less costly alternatives are not available. None of these alternatives, however, is likely to alter the trend toward higher water demand in the future; and (ix) Prices and markets are increasingly important for balancing supply and demand. Because new construction and projects can be expensive, environmentally damaging, and politically controversial, the proper application of economics and water management can provide incentives to use less and produce more. Among the new tools that need to be explored are water banking and conjunctive use of groundwater.

3). Methods of Study: The study is based on available secondary data pertinent to the field as follows.

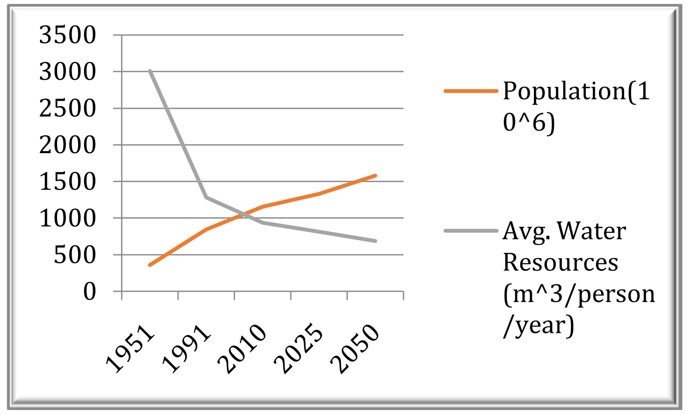
Rainfall Data (1901-2013) in mm



Source: http://www.tropmet.res.in/~kolli/mol/Monsoon/Historical/air.html

Per Capita Availability of Water

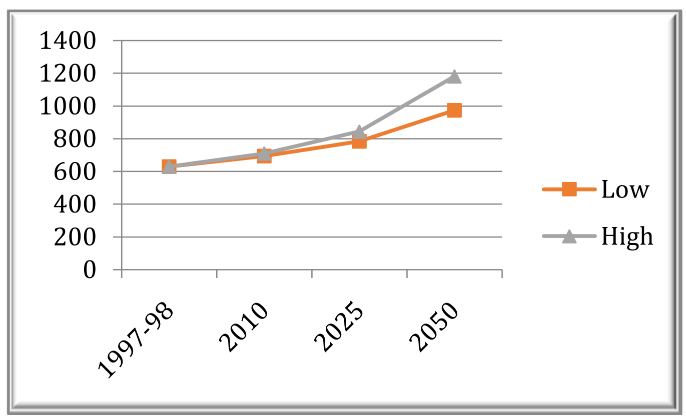
Year	Population(10^6)	Avg. Water Resources (m^3/person/year)
1951	361	3008
1991	846.3	1283
2010	1157	938
2025	1333	814
2050	1581	687



Source: http://nihroorkee.gov.in/rbis/India_Information/Water%C2%A0Budget.htm

Annual Water requirement for different uses (in km³)

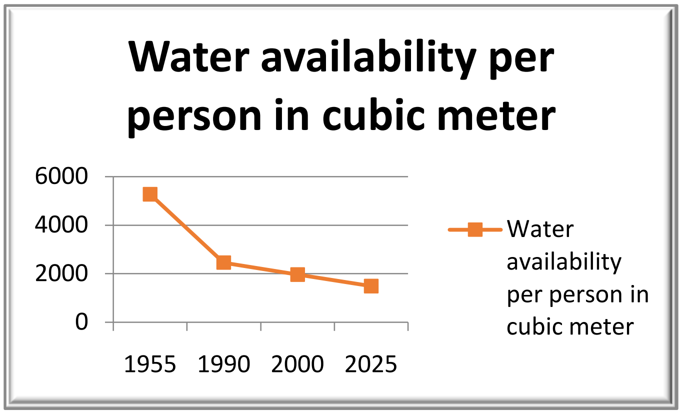
Year	Low	High
1997-98	629	629
2010	694	710
2025	784	843
2050	973	1180



Source: http://nihroorkee.gov.in/rbis/india_information/AnnualWaterRequirements.htm

India's Annual Renewable Fresh Water availability per person

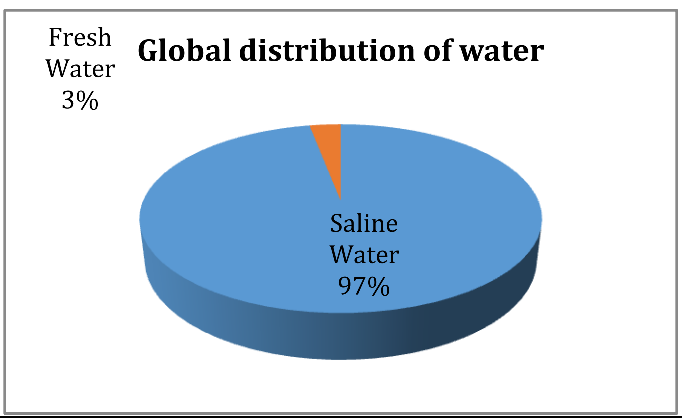
Year	Water availability per person in cubic meter
1955	5277
1990	2464
2000	1970
2025	1496

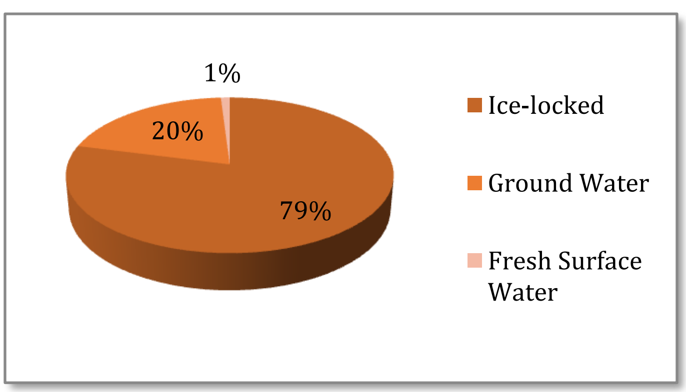


Source: S, V, Chawan. Water Resource of India, National Level Conference on Water Management Scenario 2025 Problems, Issues and Challenges.

Global distribution of water

Saline Water	97%
Fresh Water	3%
Ice-locked	79% of 3%
Ground Water	20% of 3%
Fresh Surface Water	1% of 3%

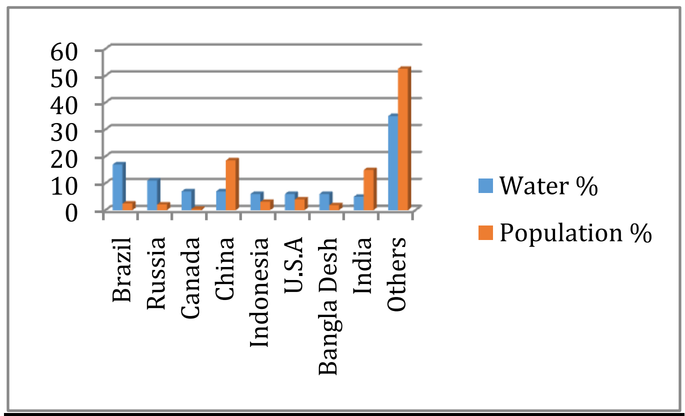




Source:S, V, Chawan. Water Resource of India, National Level Conference on Water Management Scenario 2025 Problems, Issues and Challenges.

Distribution of World's Water and Percentage Share of Population to total World's Population of few selected countries

Country	Wate %	Population %
Brazil	17	2.46
Russia	11	2.12
Canada	7	0.45
China	7	18.52
Indonesia	6	3.09
U.S.A	6	3.99
Bangla Desh	6	1.86
India	5	14.91
Others	35	52.6



Source: S, V, Chawan. Water Resource of India, National Level Conference on Water Management Scenario 2025 Problems, Issues and Challenges.

Water Scarcity Index

Annual per capita availability in cubic meters

1700 Occasional shortage

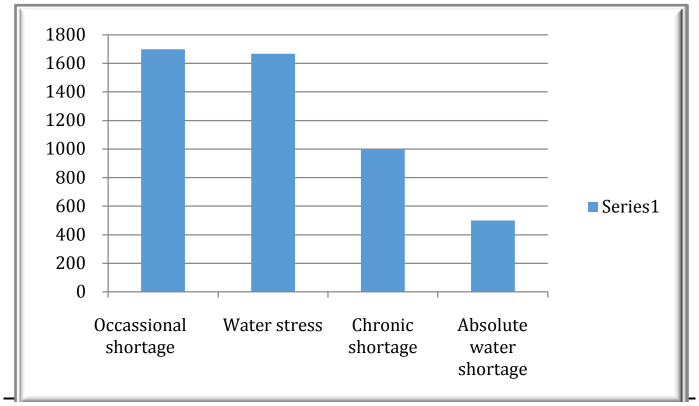
1000 – 1667 Water stress

< 1000 Chronic shortage

< 500 Absolute water shortage.

1000 Cubic meter as bench mark

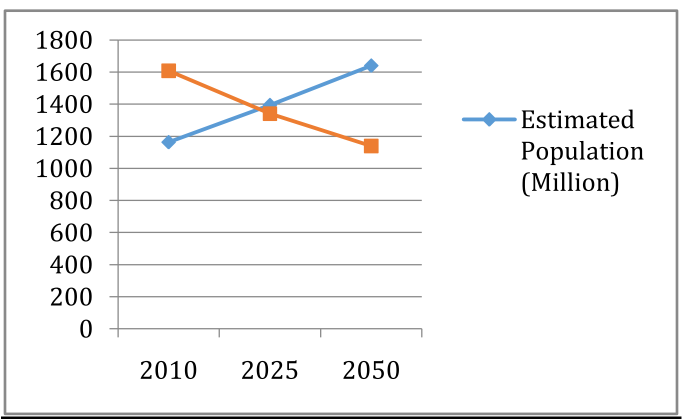
1700 Cubic meter as Warning Light



Source: S, V, Chawan. Water Resource of India, National Level Conference on Water Management Scenario 2025 Problems, Issues and Challenges.

Per Capita Average Annual Availability of Water in India during 2010, 2025 & 2050

Year	Estimated Population (Million)	Estimated per capita Average Annual Water Availability (m^3)
2010	1162.31	1608.26
2025	1394.02	1340.94
2050	1640	1139.82



Source: Water and Related Statistics April 2015, Central Water Commission, Govt. of India

4). Empirical results and discussion is as follows:

Water Budget of India

The average annual precipitation received in India is 4,000 km3, out of which 700 km3 is immediately lost to the atmosphere, 2,150 km3 soaks into the ground and 1,150 km3 flows as surface runoff. The total water resources in the country have been estimated as 1,953 km3. Nearly 62% or 1,202 km3 of the total water resources is available in the Ganga-Brahmaputra-Meghna basin. The remaining 23 basins have 751 km3 of the total water resources.

The annual water availability in terms of utilizable water resources in India is 1,122 km3. Besides this, the quantity of 123 km3 to 169 km3 additional return flow will also be available from increased use from irrigation, domestic and industrial purposes by the year 2050. The per capita availability of utilizable water, which was about 3,000 m3 in the year 1951, has been reduced to 1,100 m3 in 1998 and is expected to be 687 m3 by the year 2050.

5). Conclusion and Policy Implications / Concluding Remarks

Water Scarcity in India is largely man-made. It is the result of a short-sighted pricing policy for public water supply that encourages wasteful use of water and makes it difficult to raise resources for upkeep and expansion of the system. Reduced recharge mechanisms, unregulated exploitation of ground water due to highly subsidized electricity supply for pumping water, illegal tapping of water by slum-dwellers and illegal dwellings in the urban areas, theft of water from the major water supply pipelines by rural communities, as they are deprived of their own water resources, and enormous wastage of water at different points all along the pipeline is very common. Besides loss of water from runoff, conventional methods of water use are all responsible for water scarcity in India. The water crisis could spiral out of control if it is not handled in time. The challenge is to develop and apply water saving technology and management methods and through capacity building, enable communities to aadopt new approaches for both rain fed and irrigated agriculture. It is crucial to stop successive runoff by increasing the infiltration or by transferring it to regions of drought. It can be achieved only by massive afforestation, planning and implementing inter-basin transfer and sustainable development without harming the natural surroundings. It therefore calls for concerted efforts to make people aware of the magnitude of Water crisis and to settle the water disputes on fair and equitable sharing within the admissible limits. Thus India has to manage its water resources sensibly, optimally and equitably. It therefore calls for everything humanly possible to be done to guarantee sustainable use of fresh water (Chawan, S.V)

There are two distinct but complementary approaches to the problem of water resources in a holistic manner. They include (a) augmenting and enhancing the present reserves, and (b) taming the end demand. Sustainable use of water resource gets increasingly difficult as the demand for water far exceeds the availability, and the discounting rates for the future tend to increase under such circumstances. Therefore, in order to make our water utilization more sustainable both these approaches will have to be followed.

Though India is endowed with extensive sources of water, the utilizable quantity is less as the full potential of our rivers has not yet been assessed accurately (as is evident from the study of water potential of the Ganga Basin). Neither has there been a proper river management programme. The present water availability is further restricted due to water pollution as well as increasing salinity, which has rendered much of our river water as well as groundwater unfit for one or the other type of use.

In order to meet the future demand of water in a sustainable manner, emphasis has appropriately been laid in recent years on the implementation of rainwater harvesting as well as rooftop harvesting of rainwater. These options are limited in their capacity to meet the burgeoning national demand for water as they are subject to the variability of the monsoon, which is projected to increase due to global warming. These steps would be most effective at the grassroots level in meeting the demands of the rural population without having to depend on the government for the required infrastructure and would help in supplementing the main water supply.

In spite of the growing anti–dam sentiment in the country, it is considered irrational to rule out the hydrological projects completely as it would otherwise be impossible to ensure food security and supply of water for energy and industrial sectors. These projects would also increasingly reduce our dependence on the monsoons as the precipitation patterns over the country become more erratic due to climate change. So we will have to rationalize the options available to us and make the best use of our resources.

The other end of the water problem is to increase the efficiency of end use of water. The water policy of the country has been rightly oriented in this regard but implementation of the policy has been far from satisfactory. The water demand has to be tamed through an appropriate conjunction of economic and legislative mechanisms (Murari Lal).

6). Future Guidelines / Research Needs

Records of past climate and hydrological conditions are no longer considered to be reliable guides to the future. The design and management of both structural and non–structural water–resource systems should allow for the possible effects of climate change, but little professional guidance is available in this area. Further research by hydrologists, civil engineers, water planners, and water managers is needed to fill this gap, as is broader training of scientists in the universities.

The decision–making bodies on water policies in India must realize that climate is not static, and assumptions made about the future based on the climate in the past may be inappropriate. Assumptions about the probability, frequency, and severity of extreme events used for planning should be carefully re–evaluated. Climate change will be imposed on top of current and future non–climate stresses. In some cases, these changes will be larger than those expected from population growth, land–use changes, economic growth, and other non–climate factors. Certain threshold events may become more probable and non–linear changes and surprises should be anticipated, even if they cannot be predicted with a high degree of confidence. The time lags between identifying the nature of the problems, understanding them, prescribing remedies, and implementing them are long. Waiting for relative certainty about the nature of climate change before taking measures to reduce climate–change related risks might prove far more costly than taking certain pro–active management and planning steps now. Methods must be used that explicitly incorporate uncertainty into the decision process. Expensive and long–lived new infrastructures should consider a wider range of climate variability than provided by the historical record into infrastructure designs.

Areas for further research include the means of improving the ability of global and regional climate models to provide information on water–resources availability, to evaluate overall hydrologic impacts, and to identify regional impacts. Substantial improvements in methods to downscale climate information are also needed to improve our understanding of small–scale processes that affect water resources and water systems. Information about how our summer monsoon will be affected due to climate change is vital for determining impacts on water and water systems; yet such information is still not reliably available. More research on how the severity of cyclones and other extreme hydrologic events might change is necessary.

In addition, increased and widespread hydrologic monitoring systems are needed across the country. There should also be a systematic re–examination of engineering design criteria and operating rules of existing dams and reservoirs under conditions of climate change. Information on economic sectors most susceptible to climate change is extremely weak, as is information on the socioeconomic costs of both impacts and responses in the water sector. More work is needed to evaluate the relative costs and benefits of non–structural management options, such as demand management and water–use efficiency in the context of a changing climate. A detailed analysis of the implications of climate change for international water treaties and agreements with Pakistan, Nepal and Bangladesh is also required. Moreover, no information is available on how climate change might affect our groundwater aquifers, including quality, recharge rates and flow dynamics. Studies on these issues would be useful (Murari Lal).

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