CHAPTER 2

REVIEW OF LITERATURE

2.1 GENERAL

The world is now facing a great challenge—the tremendous growth of population and its increasing consumption of water. Water is a basic requirement of human beings in order to maintain daily life and activities. Without sufficient water, the very survival of human species is in question. The water supply systems are quite different from country to country, and even within the country. In other words, water supply is not uniform throughout. The following literatures examine the water supply and demand conditions across the world, the water crisis prevailing and the various views and approaches adopted to manage the crisis.

An urban water management plan shall describe and evaluate sources of supply, reasonable and practical efficient uses of water and shall carry out reclamation and demand management activities. The components of the plan may vary according to an individual community or area’s characteristics and its capabilities to efficiently use and conserve water. The plan shall address measures for residential, commercial and industrial water demand management. In addition, a strategy and time schedule for implementation shall be included in the plan. Every urban water supplier shall include, as part of its urban water management plan, an assessment of the reliability of its water service to its customers during normal, dry and multiple dry water years. This water supply and demand assessment shall compare the
total water supply sources available to the water supplier with the total projected water use over the next 20 years, in five-year increments, for a normal water year, a single dry water year, and multiple dry water years (California Water Code 1983).

Muyibi (1992) assessed that developing countries are still faced with inadequate water supply and poor sanitation in rural and peri urban areas. This problem may be attributed to the issue of equity in the provision of water supply and sanitation. In most developing countries, government still provides water supply and sanitation mostly to urban areas whilst the rural and urban fringes are poorly served. There are case histories of project failures in rural areas due to many factors including choice of inappropriate technology, lack of effective backup support, non involvement of user community in the planning and implementation process and implementation of projects for political gains. In order to solve these problems, the issue of equity should be vigorously pursued in the development of water supply and sanitation projects.

Sanitary sewage is mostly the spent water of the community draining into the sewer system with some ground water and a fraction of storm water from the area draining into it. Domestic sewage is the wastewater from kitchen, bathroom, lavatory, toilet and laundries. The water supply to the communities already contains mineral organic matters to which human excreta, papers, dirt, other fluid wastes and other substances are added. Industrial wastewaters vary in composition with industrial operations. Some are relatively clean rinse waters, others are heavily laden with organic or mineral matter, or with corrosive, poisonous, flammable, or explosive substances. Some are so objectionable that they should not be admitted to the public sewerage system. Others contain so little and such unobjectionable
waste matters that it is safe to discharge them into storm drains or directly to natural bodies of water (Manual on Sewerage and Sewage Treatment 1993).

A sequential procedure for total involvement of the user community in the planning, construction, operation and maintenance is to be made to provide equity. Jinno (1995) examines the feasibility of using risk analysis for the planning and operation of a water supply system where limited water resources have to be shared when drought occurs.

Asano (1999) reviewed the role of wastewater reclamation and reuse in the context of efficient water use in urban areas. Over the past few decades, the use of water increased rapidly and significantly. Frequent droughts, increasing water development costs, institutional and environmental concerns and a growing conservation philosophy are the key factors accounting for current surge of interest in wastewater reclamation and reuse throughout the world. Reclaimed water, after all, is a water resource existing right at the doorstep of the urban environment where water resources are needed most and priced the highest. Furthermore, reclaimed water provides a reliable source of water even in drought years because the generation of urban wastewater is affected little by drought. The fundamental concepts of wastewater reclamation and reuse are thoroughly reviewed which include applicable wastewater treatment processes and operations, categories of water reuse, emphasizing the role of water reclamation and reuse in the context of more sustainable water resources development.

Raising demand for water in urban communities due to population increase, commercial and industrial development and improvement in living standards is putting enormous stress on easily and economically exploitable water resources. Not only the quantity of extractable fresh water resources is being depleted but also the quality is deteriorating. It has therefore become essential to initiate measures for effective and integrated approach for water
conservation. Water conservation may be possible through optimal use of available water resources; prevention and control of wastage of water and effective demand management. The measures required to increase the water availability involve augmentation of water resources by storing rainwater on the surface or below the surface. Surface storage is usually contemplated either in natural ponds, reservoirs and lakes or artificially created depressions, ponds, impounding reservoirs or tanks. Water supply management aims at improving the supply by minimizing losses and wastage. Water demand management involves measures which aim at reducing water demand by optimal utilization of water supplies for all essential and desirable needs. Practices like reuse and recycling of treated wastewater may be promoted (Manual on water supply and treatment 1999).

Consumer oriented technological advancement and economic development is exerting a new kind of stress on the quality and availability of air and water in particular. As a result of this, the management of these natural resources has become absolutely necessary (Desai 2000). In this paper, various strategies for better water management are discussed. Time-tested and decentralized practices of conserving water resources on a small scale as well as modern and centralized planning for big water resources projects undertaken in various parts of the world are also described. In the light of this, a few feasible short, medium as well as long-term strategies are suggested to improve the quality and availability of water resources for the entire human population. Through these strategies, wherein the small will complement the big, the old will complement the new; an improved water management scenario is presented over an extended space as well as time.

The growing populations of most developed countries occur disproportionally in urban areas. Water supply problems in urban areas are three fold. First, the source of water may be limited; second, increasing cost
of delivery networks and treatment facilities may be infeasible because of limited capital; and third, inefficient delivery systems may waste up to 50% of the water being supplied. Limited water can be managed using programs such as water laws to support sustainable yield policies, to control the permitting of new wells, to regulate the extraction of existing wells and implementing aquifer storage and recovery. Increasing cost may be alleviated by optimization methods and advances in water supply designs. Improving system operation in water supply will manage the inefficient delivery system. There is a problem in importing technology from a developed country to a developing country that does not have the trained personnel. Engineers and technical staff in developing countries need to receive more training in managing scarce resources and newer technical solutions as stated by Helweg (2000).

Rapid urbanization in China causes serious conflicts between urban water demand and supply. Firstly, in the process of urbanization, water demands for residential uses inevitably increase with rapid population growth. On the other hand, people living in cities require persistent improvement of their living quality. They are highly water-consumed compared to traditional living surroundings. On the other hand, with the improvement of living quality, the people living in cities desire more public water-related recreational facilities. It lead to rapid construction of water-related municipal infrastructures such as swimming pools, water amusement parks, water landscapes, green land irrigation and municipal sanitation. Secondly, rapid industrialization in urbanized and urbanizing areas inevitably caused rapid increase in industrial water demand. The speed of building urban water supply capacity has not yet kept pace with the increasing water demand due to relatively long construction periods of water projects, inadequate investments allocated to the projects and some social, economic, political and legislative reasons. The imbalance between the water demand and supply lead to water
deficit in urban water resources systems. Integrated regional water resources systems with multiple water sources are recognized to be an essential solution to unitary water source induced urban water scarcity (Feng and Yuzhen Feng 2001).

Sustainable development must first consider the environment upon which economic and social factors ultimately depend and sustainable management of the environment requires an integrated approach. It recognizes that the basin or catchment is the best unit for management and emphasizes the interdependence of the urban and the rural parts of each catchment. Powell and Leslie Jones (2001) recommend that management is best done using the ecosystem approach which includes restoring and rehabilitating the functionality of ecosystems which is the key to a sustainable future.

Water stress and water scarcity are defined as the measures of medium and high unmet water needs. Both conditions exist in many parts of the world. They will become more pronounced as the world population reaches 9.4 billion by 2050 (Schmandt 2001). The water stress and scarcity are not a threat globally, at least not in the foreseeable future. Water deficiencies occur at the regional scale. They result from a combination of physical and social factors like climate, population growth and level of development. Many water-stressed regions are located in developing countries that have limited capacity for improving their water infrastructure. The water stress and scarcity greatly enhance the vulnerability of regions and have severe impacts on economic, social and political stability. Several policy options exist for managing water stress and scarcity. If implemented, they will greatly reduce regional vulnerability.

The poor and deteriorating state of tanks was a matter of concern for the colonial government of Tamil Nadu mainly because they were an
important source of irrigation and contributed substantially to land revenue. The efforts to improve tank irrigation was partly by undertaking repairs to existing tanks which were in a poor condition, partly by construction of new tanks. Tanks vary not only in size and source of supply, but also in terms of water storage relative to command, the duration of supplies, and its reliability (Vaidyanathan 2001).

For formulating a complete water resources management system, thorough assessment of demand is to be performed. Cai and Rosegrant (2002) presents a modeling approach for projections of water demand and supply for domestic, industrial, livestock and irrigation at the basin or country level in a global scope. Water supply is determined taking account of water demands, total renewable water availability, water supply infrastructure and economic and environmental policies related to water development and management at the basin, country or regional level. This modeling exercise integrates pieces of relationships and information in water resources, agronomy and economics into a consistent analytical framework. It also integrates numerous national and international efforts in national and global water resource assessments.

Integrated Urban Water Management means that in the planning and operation of urban water management, consideration should be given to the interaction and collective impact of all water-related urban processes such as human health, environmental protection, quality of receiving waters, water demand, affordability, land and water-based recreation and stakeholder satisfaction. In addition, Integrated Urban Water Management requires involvement by stakeholders such as those responsible for water supply and sanitation services, storm water and solid waste management, regulating authorities, householders, industrialists, labour unions, environmentalists, downstream users and recreation groups. While local authorities are well placed to initiate and oversee these programmes, planning and
implementation should be driven by a combination of top-down regulatory responsibility and bottom-up user needs or obligations. Top-heavy governmental approaches are to be discouraged because they become bureaucratic and unresponsive to the concerns of water users (Industry Sector Report by International Water Association 2002).

Urbanization has become inevitable in developing countries like India for various reasons including employment opportunities and infrastructure facilities and the towns grow into cities and cities into mega cities. The problem has become more complicated when such cities grow in water deficit areas and the rate of growth of population shows spurts and steep rise. Investigation and the identification of new sources to augment the water supply and innovation of new methods to enlarge and expand without disturbing the existing supply, which has to be live all the time, become necessary. Having fixed the projected population to be served, the planner looks for the sources of water and examines its adequacy, quality and reliability. More than one source is helpful for more dependability, to tide over critical situations (Mohanakrishnan 2002).

Water demand forecasting has become an essential ingredient in effective water resources planning and management. Water forecasts, together with an evaluation of existing supplies, provide valuable triggers in determining when, or if, new sources of water must be developed. This study emphasis on importance of accurate water forecasting. There is an increased need for water demand forecasts as water rights conflicts continue, the area’s population grows, the need for in stream flows is more accurately quantified and additional uses and needs of water are identified (Ennui 2003).

Introducing source separation concepts in municipal wastewater management allows adequate treatment of the different flows according to their characteristics. This is the key to technical solutions for the efficient
reuse of water, energy and fertilizer. As applied in industrial wastewater management low dilution and collection at the source is necessary to achieve economic systems. Separate collection and treatment of toilet waste in households, which contain almost all pathogens and nutrients, are the first and major step. Innovative sanitation systems have been introduced in several projects and have proven feasibility. Fresh water consumption can be reduced by 80% while nutrients can be recovered to a large extent. Source control can be advantageous also for hygienic reasons as low volumes are far easier to sanitize. There are experiences with urine-sorting systems, vacuum-biogas systems and many more available. New ideas as the black and grey water cycle system are presently researched at the Technical University Hamburg. Such modular integrated systems do have the potential to be installed in densely populated urban areas without the need for central water and wastewater infrastructure. Only recent advances in membrane technologies allow this development (Otterpohl et al 2003).

New directives for the management of urban stormwater prioritize infiltration and direct discharge into receiving waters. This requires innovative new stormwater facilities in urban areas. Boler (2004) suggested that the structures for stormwater handling are integrated into local landscaping in the surroundings of buildings in the form of ponds, reed-beds, ditches, etc. creating attractive blue-green environments.

The various aspects have to be thoroughly studied to go for the holistic approach. Increased impervious surface area is a consequence of urbanization, with correspondent and significant effects on the hydrologic cycle. It is intuitive that an increased proportion of impervious surface brings with it shorter lag times between onset of precipitation and subsequently higher runoff peaks and total volume of runoff in receiving waters (Shuster et al 2005). This water is wasted if there are no conservation measures.
2.2  CASE STUDIES FROM ABROAD

Abdulrazzak (1995) examined the water supply and demand problems for each country of the Arabian Peninsula. Projections for water supply and future demands are made. Suggestions for comprehensive water planning are made that emphasis conservation measures and optimum allocation both within and between countries. The suggested measures given are withdrawing water from shallow alluvial aquifers and fossil groundwater aquifers, desalination and reclaimed waste water process.

Mohorjy and Grigg (1995) compared and improved the Water Resource Management System for Saudi Arabia with United States. To summarize, the purpose of this research were to review and add background knowledge on water management in Saudi Arabia, to compare water management challenges in Saudi Arabia with similar challenges in United States with emphasis on State Government, to suggest policy elements that need attention in Saudi Arabian institutions and developing a comprehensive water policy for the future. Saudi Arabia leads the world in desalination and pumping of fossil waters. Supply is mainly from non renewable resources supplemented by desalted water and still the demand continues to increase. The eight categories of management elements to make a comparison are water law, planning, management, coordination process, organizational structure, water system infrastructure development, water quality management and water conservation programmes. Conclusions were made which denotes that water law and regulations are needed in Saudi Arabia especially for conservation, groundwater management and water quality management. The intergovernmental issues are less daunting in Saudi Arabia and the kingdom needs an efficient water policy.

Ada and Canyon counties of southwestern Idaho incurred a significant population growth between 1988 and 2000, an increase of 44
percent. This rapid growth has led to concerns that the continued growth will cause an increasing demand for water resources in the valley. A major concern is the ability of the water resources, especially potable water supplies from groundwater sources, to meet the increasing demand. Due to uncertainty about the availability of groundwater supplies in some parts of the valley, municipal providers must consider alternative sources. Surface water sources will be needed in order to supply the valley’s growing needs for domestic, commercial, municipal and industrial (DCMI) uses. DCMI water demand estimates were calculated for the entire populations of Ada and Canyon counties. The study used an end-use, sector-based approach in which water demand coefficients were calculated for all major categories of DCMI water demand for the years 2000 to 2025 in five-year increments using data from 1997 and 1998 as the baseline. Using the term residential to describe domestic water demand, sectors reflecting an end-use approach are residential single-family, residential multi-family, municipal, commercial and industrial. In conclusion, this study represents the first attempt to measure baseline and future water demand in the valley as a whole. It is predicted that there will be a significant increase in water demand during the next 25 years and that between 76 and 96 additional acre-feet of water will be needed to accommodate the additional demand (Cook et al 1999).

Dillon (1999) suggested an underground water banking technique known as Aquifer Storage and Recovery (ASR) that has emerged as a means of expanding urban water resources by harvesting waters, where peri-urban areas are endowed with saline groundwater aquifers. Injecting stormwater or treated effluent may restore saline aquifers so that they become underground reservoirs. With appropriate pretreatment these supplies can even be made potable. In South Australia, five years of experience with stormwater recycling has led to the development of an ASR trial for reclaimed municipal effluent for recovery in the dry season. Injection of potable water to aquifers
in years of plenty could add even more value to our natural urban water infrastructure below ground. This paper briefly describes the motivations for the development such as aquifer storage and recovery involving injecting water into a well and later recovering it from the same well, injection and recovery from different wells having got the advantage of filtration provided by passage through the aquifer. The paper also deals with the types of artificial recharge methods available, experiences with stormwater ASR and the research being performed to address the risks identified in ASR with recycled water. Legal, social and economic aspects of implementing ASR with reclaimed waters are also mentioned.

The paper by Phillips (2000) outlines the Australia’s water resources and how to use the water. It is increasingly being recognised that new development will not be sustainable with respect to water unless integrated strategies to manage the water cycle are implemented. The paper supports the adoption and implementation of such integrated strategies and promotes the conservation of the drinking water, suggested the more efficient and effective re-use of the stormwater and wastewater resources and recommended to reduce the use of high quality drinkable water for other purposes which only require a lower quality of water.

Castelan (2001) analyses the main water supply projects which have been developed in the Mexico City Metropolitan Area and their social, economic and environmental consequences. The emerging conclusion from the analysis is that technological and financial aspects play an important role, but cannot alone solve water supply problems. New vision for water management is needed that emphasizes aspects such as maintenance, efficient water allocation, elimination of subsidies, capacity building and access to information. This will improve water availability in terms of quantity and
quality, with less cost, as options instead of construction of water supply infrastructure.

Chen (2001) presented the experience and challenges in developing water supplies and managing water resources in Hong Kong. Urban water supply in a densely populated city cannot be sufficiently and securely provided without importing water from external sources. Availability of local water resources is evaluated in the context of territory’s geographical setting. The approaches adopted for developing urban water supply by making use of water imported from the Dongjiang are reviewed. The inter basin water transfer system called the Dong-Shen Water Supply Scheme was adopted to manage the water crisis. Chen suggested that further development, better management, and faithful coordination will be the key to tackle the water issues in the future. Apart from water quantity, water quality protection is a more pressing and important task which requires tightening of environmental enforcement, construction of wastewater treatment plants and integrated watershed management and initiatives for non-point source pollution control.

Istanbul has been a major urban center since the Hellenic period. Istanbul’s population is approximately 12 million people, with an annual increase of 400,000. Daily domestic water requirements average 2.6 Mm³ in 2000, while industrial demand is also increasing. Thus Istanbul faces several major issues in servicing the water needs of the city in years to come. To meet the urban water needs of the Istanbul, today it is forced to cast a wider net, proposing diversion from lakes across the Marmara Sea and from the Black Sea region. On-going urbanization and development continues to dominate the local landscape, requiring water resources and supply systems to keep apace for both domestic and industrial use. In this paper, the historical development of water sources for Istanbul, from the Roman Empire to proposed plans designed to meet the urban water crisis, in relationship to
Istanbul’s growing population is examined. It needs to adequately safeguard existing resources from pollution, through controlled growth, as well as construction and maintenance of infrastructure. In a city with high population growth rates and a country attempting to rapidly industrialize, these challenges are formidable. Water supply, and its disposal, will become an increasingly critical issue for Istanbul. Water diversion schemes can also partially solve the problem, but engineering solutions will not be the only answer. Water prices will need to be re-evaluated to incorporate a marginal water scarcity rent. Without such pricing and education, the true value of water will not be appreciated by Istanbul’s residents until too late (Demirci and Anya Butt 2001).

Water crisis has appeared in Iran as a serious problem. The two main reasons for the water crisis are lack of proper water management and occurrence of drought. In fact water crisis can be defined as the improper balance between water resources and rate of consumption. Attempts have been made to identify factors influencing water crisis in Iran. Solutions are also put forward to control and reduce this for future. The solutions suggested are construction of new water projects, quantifying unaccounted water, separation of urban water network and training and modification of water consumption culture (Motiee et al 2001).

In South-Central Kansas, the groundwater quality is threatened by natural salt intrusion that is being enhanced and expanded by groundwater pumping. Municipal water supplies face an uncertain long-term future. A regional water management structure is proposed that would make effective use of treated municipal wastewater to modify groundwater flow patterns, mitigate salt intrusion and meet presently unsatisfied demands for water. Implementation of a regional water management system designed to address the problems of all users over hydrologically-appropriate scales of time and
space would have additional benefits, such as increasing the feasibility of using advanced waste treatment or desalination techniques to augment the regional water supply (Robert et al 2001).

Alhumoud (2002) studied the water consumption of households in metropolitan Kuwait. The problem of gaining and securing reliable water supplies has been an issue of great importance to the people of Kuwait. This problem continues today and promises to become more acute as the population continues to grow and development of additional water supplies proves more difficult. The water consumption and other related data were collected randomly from different households from the five different governorates of metropolitan Kuwait. The results of the analysis indicated that there is considerable waste of fresh water by the average Kuwait household.

Dube and Pieter van der Zaag (2002) analyzed water use patterns in the City of Masvingo in Zimbabwe with a population of 70,000 and located a drought prone region of average annual rainfall of 600 mm. Water consumption has reached the limits of the water supply capacity. The paper analyses the patterns of water use of rich and poor households in the city and attempts to assess the possibilities of influencing these by means of an appropriate tariff structure that balances access to urban water by the city’s population. In projecting future demand, the paper then considers a number of interventions that could influence demand which include leakage control, pressure management, awareness campaigns, free technical advice to water users and a new tariff structure. It also discusses when new supply infrastructure should be available depending on the various demand management measures taken.

Hussain et al (2002) provided an economic analysis of urban water use with a view to enhance the understanding of the factors influencing urban
water demand and to estimate price elasticities of residential, commercial and industrial water demands in Sri Lanka. Separate water demand functions for each of the major sectors were estimated using monthly time series for 60 months. The results indicated that price can play an important role in urban water management. The price is found to have a significant effect on water demand and this is much higher for the industrial sector than for the residential and commercial sectors. In addition, real income, number of connections (population) and weather variables are important determinants of urban water demand. Public education and awareness will be necessary to achieve desired reduction in water consumption, especially in the less responsive residential and commercial sectors.

Wastewater in most countries of the Near East Region (NER) is being more and more recognized as of vital importance to be treated and made safe for reuse. It contributes considerably to the water budget in several countries, particularly those suffering from water scarcity. Treated wastewater is used directly in irrigation of farms or landscape green areas. Limited indirect use includes recharge of groundwater aquifers to control over-draft and salt intrusion in coastal areas. A large share of wastewater is still not treated and part of it is used in an uncontrolled manner, including the production of uncooked food crops the consumption of which poses health risks. This paper gives an overview of the existing practices of wastewater reuse in the NER and of the constraints facing it. It concludes with recommendations and policy options that are likely to reduce these constraints and to make a better use of the wastewater potential (Bazza 2003).

Mylopoulos et al (2003) evaluated and discussed the present situation and the perspectives of a new demand-oriented urban water management in an effort to shift the urban water policy in Greece towards sustainability. Present water resource management practices have proven
insufficient to integrate both socio-economic development and environmental ecosystem integrity. The results of the survey are high water consumption rates, a wide variety of water pricing policies, lack of public participation, sectoral and fragmented rather than integrated water management and the fact that water is considered as social commodity. The conclusions made are that the water supply management should be replaced by demand management policy. In addition to the non structural measures the use of dual networks with low water quality systems for secondary uses can also be an effective tool for water conservation.

In the study conducted in a small watershed in Cincinnati, Ohio, it is found that a tradable runoff allowance system carries promise as a low-cost method for attaining reductions in storm-water runoff (Thurston et al 2003). Stormwater flow from an impervious surface can lead to stream degradation, habitat alteration, low base flows and increased toxic loadings from non point sources, a problem that has resisted traditional command and control regulatory approaches. A well-designed, tradable runoff allowance system can create economic incentives for landowners to employ low-cost runoff management practices to reduce excess stormwater flow to more ecologically sound levels. Attributes such as percent impervious surface, soil type etc., determine a given land parcel’s runoff potential and management alternatives and its allowance requirements.

Water shortage and water environmental pollution have promoted the development of wastewater reclamation and reuse in China in recent years. Different treatment processes are employed for this purpose, such as pond-farmland systems using solar radiation as initial energy source, treating wastewater at low cost, low energy consumption to realize wastewater reclamation and reuse for irrigation on farmland to provide both water and nutrients. Some full-scale projects on municipal wastewater reclamation
mainly based on activated sludge and submerged bio-film processes followed by some advanced treatment processes such as filtration and disinfecting, from which the effluent is reused in agriculture, industry and domestic uses except for drinking purpose have been put into operation in some water shortage cities, are described in this paper. In some water scarce cities the domestic wastewater reclamation and reuse (dual water system) is employed for a building, a group of buildings or a sub-residential district, whose treatment system consists of submerged bio-film process, dual-media filter and disinfection (Wang et al 2003).

Palestine is one among the countries with the limited water resources due to both natural and artificial constraints, amounting to only 100 cubic meters per capita per annum (Jayyousi et al 2004). This amount is far below the available water in other countries in the Middle East and the World. At present, the water demand exceeds the available water supply. The available supply is constrained mainly due to artificial non-economic factors. The gap between the water supply and water demand is growing due to the population growth, improving standard of living conditions and the need to expand irrigated agriculture and industrialization.

A study investigates the water supply improvement measures used by the rural people of Ebonyi and Enugu State, Nigeria. Survey of six study communities was picked through systematic random sampling. Three hundred households in the six rural areas of Ebony and Enugu State were randomly selected and served with questionnaires. Tanker drivers, community heads and government officials were also served with questionnaires. Findings indicate that most government aided improvement measures existing in the various study communities are inefficient. Best applicable alternative improvement measures are then suggested. Among several high-value and low-value alternative improvement measures, massive rain water harvesting,
community participation and training of manpower and educating the masses are the ones most recommended for all the study communities (Onyenechere 2004).

Alkhaddar (2005) forecasted and indicated that Jordan is facing water shortages and the shortfall will exist significantly. The problem is not only that there is not enough water but this is compounded by the high population growth rate of the country. The increasing population, industrial requirements and the need for irrigation water puts increased pressure on water industries. Added to that, the living standards have increased raising the per capita use of water. Various sources of non-conventional supply have been considered to meet this shortfall and a review of the current literature revealed one option to consider: Water importation, which presents a justifiable mechanism for alleviating this need. The study reviews the available water resources in Jordan. Then it covers the water demands within the country and where the deficit can be addressed. Scenarios of additional volumes of water supply to Jordan are also detailed and then the possibilities of water import are discussed.

Cantin et al (2005) declared that there is limited concrete evidence of the efficacy or cost effectiveness of economic instruments used for water demand management. A number of policy research avenues are proposed to better assess the advantages and limitations. These include fostering multidisciplinary efforts, particularly in social sciences, to understand how our institutional arrangements affect water use, increasing Canada’s ability to monitor water supply and use and documenting strengths and weaknesses of economic instruments in well defined comparative case studies as well as in new projects. Some of the management strategies the author suggested are pricing strategies and demand side management methods. Generally they are
a less expensive means to provide additional water than building new infrastructure such as reservoirs.

Kharabsheh and Taany (2005) presented the challenges of water demand management in Jordan. Water scarcity is considered one of the most important challenges faced by Jordan because of the need to satisfy the municipal, industrial and agricultural needs. The climate in Jordan reveals that more than 80 percent of its area receives less than 200 mm rainfall. The water resources are divided into two parts as conventional (surface and groundwater) and non-conventional (treated wastewater, cloud seeding and desalination of sea water) resources. The major problems facing conventional water resources development are quality deterioration and resource depletion. The non-conventional resources could increase water supply enough to overcome the shortage and to satisfy the different water needs of the country. Desalination of sea water and brackish groundwater could reduce the need for additional water supply to cover the country’s water needs. The uses of water are divided among municipal, industrial, irrigation and livestock uses. The irrigation sector consumes most of the water resources in the country, and there is a gradual decrease in the water resources for all uses. Sharing water resources is considered very important to water supplies in the present and future. The annual safe yield of ground water is 275 Mm³ per year while water is pumped more than 450 Mm³. This increase the stress on groundwater and gives the priority to water harvesting projects in different areas to accumulate the runoff water either in pools or in desert dams for irrigation, livestock or artificial groundwater recharge. There are more than 25 dams located in the different parts of the country. To avoid the water shortage in Jordan, it is recommended to increase water harvesting projects and reuse wastewater for irrigation purposes.
The literature survey shows that there exist severe water crisis throughout the world and there is no unique solution to solve this. The nations adopt their own ways and means to manage the situation at times of crisis. In addition to the studies done abroad, an attempt has been made to look into the various aspects of management measures of water sector in India.

2.3 CASE STUDIES IN INDIA

Ravindra (1997) dealt with a water supply project executed in Bangalore, a leading metropolitan city in India. With the growth and expansion of the city, urban planners began looking at possible new sources of water and new methods of mobilizing resources to augment water supply. The unprecedented growth in population during the 1970’s necessitated further augmentation of the water supply to the city. The board, therefore, contemplated a third-stage scheme to supply water from the Cauvery River. Water supplied from the project is used for drinking, industrial, commercial and other non-potable purposes. The special feature of this project is that water must be transmitted over a distance of approximately 100 km from the water source. The steps involved are production, conveyance and distribution. The distribution network is connected to three sources. The first is directly tapped from the transmission main, the second is fed by ground level reservoirs and overhead tanks and the third is directly pumped from trunk mains into the distribution system using booster pumps. To facilitate the equitable distribution of water, the city is divided into twelve zones. The project also made provisions for re-modeling the distribution system through the construction of new ground level reservoirs and adequate overhead tanks.

Srinivasan (1999) suggested some measures to manage and conserve the precious water in Chennai during drought. Some of them are water has to be declared as an essential commodity just as items like rice, wheat etc., awareness should be created to minimize the misuse of water,
cloud seeding operations should be practiced in reservoir areas, inferior quality water should be used for gardening and washing purposes, blending good quality with inferior quality, rationing of water supplies etc.

In India, supply of drinking water, treatment and disposal of domestic wastewater are managed by local bodies. The existing status of water supply, characteristics of domestic wastewater, modes of collection, treatment and disposal system for sewage and faecal matter in 82 municipalities and 4 municipal corporations were assessed in the states of Bihar and West Bengal in India. Domestic wastewater in the municipal areas is collected and discharged through open kachha (earthen), pucca (cement-concrete) and natural drains and discharged into water course or disposed on to the land. The existing method of collection, treatment and disposal of sewage impairs the water quality of different water sources. Techno-economically viable remedial measures for providing basic amenities, namely safe drinking water supply and proper sanitation to the communities of these two states of India are suggested and discussed (Pandey and Kaul 2000).

Slum Networking is an innovative concept, which exploits the linkage between the slums and the natural drainage paths that influence the urban infrastructure and environment of the city. Using the concept, over a period of six years, the environment and infrastructure of the slum matrix of Indore city was improved to cover the lives of 450,000 slum dwellers. As a byproduct of Slum Networking between the slum locations, Indore now has 90 km of piped sewer mains serving the non-slum areas and a small stretch of polluted river running through the city centre was cleaned up and landscaped as a consequence. Based on the lessons learnt in Indore, the concept was evolved and replicated in demonstration projects in the cities of Baroda, Ahmedabad and Mumbai, each time bringing greater community interaction and self-sufficiency of resources (Parikh 2001).
The Central Ground Water Board (2002) had taken up a project of artificial recharge of groundwater in the Jawaharlal Nehru University (JNU), Delhi and in the Indian Institute of Technology (IIT), Delhi. A watershed of about 10 sq. km. area comprising of JNU, IIT, Sanjayvan and its surrounding area was selected. The JNU campus has a weathered quartzite formation while in IIT the formation is alluvium. Around 0.46 MCM water was going as surface runoff from the area. To harness the available runoff, three check-dams were constructed in JNU and one check-dam in the IIT campus. A study during the 1998 monsoon revealed that about 76,000 m$^3$ of water was recharged to groundwater. The rise in water level was in the range of 0.97 m to 13.7m benefiting an area of about 74 hectares. The results indicate that these structures are suitable in the Delhi ridge areas as well as alluvial areas if sufficient space is available for the creation of reservoirs.

To increase the coverage and accessibility of safe water supply in the Kerala state, the best alternative is to rehabilitate the traditional water system such as the wells, springs and ponds. The possibility of extending the supply of safe water through pipes has many constraints. The major constraints are cost, lack of vision and institutional framework. Therefore, it is of prime importance that cost effective and appropriate technologies are to be developed and popularized for providing safe water supply. A combination of traditional and modern water supply technologies responding to specific local circumstances are required. The first step in spring development is to regenerate the springs. Protecting them from sources of contamination is another important consideration. The advantages are: the cost of source development is significantly low, easy to construct and maintain by the local communities, the maintenance cost is negligible and traditionally used system and local community has good knowledge about protecting, developing and using the spring sources (Kurup 2003).
Thirunavukkarasu (2003) suggests an ecologically sound method to manage the drinking water supply of rejuvenating the de-functioning infiltration galleries. The study deals with the problem of availability of groundwater for drinking from alluvial river beds. Due to the over exploitation of groundwater for irrigation on both banks of the rivers, the aquifer level had been lowering year by year. This has resulted in a short supply to many towns and cities. To improve this, ecological approach is made. This method involves the formation of a subsurface dyke which will be of clay across the river just downstream of the infiltration wells and galleries. This method will go a long way in improving the water availability for the people and thereby improving the health and sanitation of the people.

Temple tanks have long been serving as water harvesting structures. The water from the tank was used for drinking, other domestic purposes and also for irrigation. But in recent times these tanks have fallen into disrepair. Due to widespread urbanization and construction activities around the tanks, the inlet and outlet channels of several tanks have become clogged. The dumping of waste, construction material and garbage around the tanks has also brought about degradation. Consequently, the quantity and quality of water has greatly reduced due to eutrophication and growth of micro-organisms. These tanks can still be desilted and used for harvesting the rainwater. The obstructions to the inlet and outlet channels can be identified and cleared. If maintained properly, these already existing large tanks can recharge the aquifers and solve the water problem of at least the people in and around the area of the temple tanks (Amirthalingam 2004).

The population of India is expected to stabilize around 1640 million by the year 2050 (Gupta and Deshpande 2004) and India as a whole will be on the verge of becoming water-scarce. Various options have been considered in quantitative terms as possible sources to augment the
anticipated deficit. These include conservation of water through rain water harvesting and groundwater recharge, recycling and reuse of municipal and industrial wastewater, utilizing increased return flow from irrigation and adopting inter basin water transfer.

Bangalore, one of the fast growing, most happening city, called as Garden-city of South Asia is feeling the heat presently due to the lack of adequate water. The economy of the city has increased from last decade by emergence of software and biotech industries, renowned academic and research institutes and high-rise commercial buildings. As a result, there is water scarcity in one hand and increase in wastewater generation on the other hand. The paper indicates the potential of reuse of wastewater for meeting the supply-demand gap. For Bangalore city (i) 64% of the supply is through groundwater (ii) of 864 MLD surface supply, 38% goes as unaccounted (iii) 800 MLD of wastewater is generated, of which 500 MLD goes unused. The study found out that reused water can meet 66% of the present demand (Latha et al 2004).

The recent developments in agricultural sector have led to the increasing use of groundwater for irrigation resulting in a tendency towards drilling deep wells. The annual extractions of groundwater are far in access of net average recharge from natural sources. The declining groundwater levels results in crop failures, adverse salt balances and sea water intrusion in coastal aquifers and land subsidence in sedimentary horizons. The artificial recharge can facilitate augmenting natural infiltration of precipitation and surface water (Patel 2004).

India is endowed with many river basins. The rich civilizations have overgrown and receive high concentration of population. Urbanization has emerged as one of the major factors responsible for polluting the water bodies as these generate too much wastewater and large amount of which is
untreated. This untreated wastewater is disposed in the river water. Some of the remedial measures are planned urban development programme, efficient management of wastewater and solid waste to combat the environmental problem as well as water stress problem. To make necessary steps for settlements connecting to the sewerage system and proper sanitation system, it requires proper maintenance and uninterrupted operation of the sewage treatment plant by municipalities as well as concerning authority, adoption of the scientific technology for removal of pollution from lakes and reservoirs and ban on activities responsible for polluting the water bodies, ensuring about the proper solid waste disposal in the landfill areas under guidelines provided by the concerning bodies, identification of groundwater vulnerable zones by preparing vulnerability maps for physical, chemical and biological contaminants for the whole country, all landfills and disposal sites of industrial effluents and sewerage, which are hazardous to groundwater aquifer systems should come under jurisdictions and strict to laws, enhancing the environment for the Research and Development studies for corrective action techniques on polluted aquifers as well as polluted rivers (Sharma 2004).

The availability and the demand for water resources in India show substantial spatial and temporal variations. Analyses of water supply and demand across river basins indicate that some basins are physically water scarce due to inadequate availability of water in the basin, while others are physically water scarce due to excessive development in the basin. Because of India’s large population, significant shifts in deficits in water scarce basin would have serious consequences. The factors that could influence India’s future water supply and demand includes spatial variation and future growth of population, urbanization, changes in income and associated changes in dietary preferences, future growth in other factors such as domestic, industrial and environmental water demand. These factors need to be carefully assessed in projecting future water supply and demand (Amarasinghe et al 2005).
Chennai is one of the four metropolitan cities in India and is ranked within the top 35 largest populated cities in the world. The study carried out by Anu et al (2005) deals with the effects of the increase in population on to the groundwater table, especially, in the city due to its urbanization. The increase in the settlement areas has considerably changed the land use of the entire city. Thus the quantum of recharge to the groundwater table is reduced. The extraction of groundwater has been increased due to the increase in public water supply demand. Taking all these factors into account the variations in the groundwater table is analyzed by considering its long-term variation as well as its short-term variation. The variation in the land use is obtained by the interpretation of the satellite imageries and master plans of the city and its influence on the groundwater table is analyzed with the increase in population statistics. The effects of the population increase onto the groundwater table are found alarming. The paper recommends the need to control the migrant population in to the city and also the need for increasing the recharge areas for groundwater table in the city. Restoration of temple tanks and development of mass recharge areas must be implemented to increase the level of water table in future.

Dutta et al (2005) assessed the unplanned sector of India’s capital city has an enormous backlog in the provision of reliable water supplies to its population which is further exacerbated by the growing number of informal urban settlements. The findings in the study have important policy implications for gauging public support for water supply improvements in infrastructural disadvantaged households.

For the present study, a thorough literature review is done regarding the various management strategies adopted in India and abroad to solve the water crisis. It reveals that there exists no unique solution to meet the water problems. Each city has to adopt their own measures to solve the water needs.