CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Recent emergence of formal and informal groundwater market for meeting irrigation, domestic and industrial demands worldwide necessitates the present research. In this chapter, a review of literature is presented including the concepts and methods used in the earlier studies, which can provide the link for the present approaches. The literature reviewed is grouped under different categories dealing with water supply management, interdependence of groundwater and urbanization, different type of groundwater market and groundwater management strategies such as land use analysis, assessment of quantity and quality, and mapping of groundwater potential. The methods and techniques adopted in different places and for different purposes have been dealt in order to investigate the present research issue effectively.

2.2 WATER SUPPLY MANAGEMENT

As the world's population continues to grow up, water resources are under siege. With increasing demand and finite resources, improved management of water resources is urgent in order to avoid an even more severe national crisis. Mega cities with rapid growth are confronted by two main problems pertaining to water supply and sanitation. One is water scarcity because local demand exceeds local supply. The other is that the infrastructure for water supply and sanitation cannot keep up with the rapid growth of the mega cities (Tortajada 2008).

The argument on water resource management in the international arena most often focuses on integrated water resources management, river basin management, good governance and public participation. In spite of this oratory, priority in megacities is the prerequisite for clean water even at increasing social, economic and environmental costs.

2.2.1 International Scenario

Rapid growth of the mega cities of the developing world has caused major water planning, development and management changes. Investments for water supply and sanitation in the developing world, including mega cities, has escalated noticeably. At this point, many scholars and water activists have pointed out the breakdown of achieving the development goals at the international level; cities afford water that is not always potable and collection of sewage has been conveniently considered as sanitation even when it is not treated (Tortajada 2008).

Like wise, the mega city of Dhaka, Bangladesh, depends heavily on groundwater since surface water is heavily polluted. Authorities face the challenge of providing services to a population increasing at approximately 6% per year. Singapore is an excellent example for planning and management of water with a long-term vision. Singapore, being a water-scarce country due to a restricted amount of land where rain water can be stored, has developed and implemented modern solutions that have included both demand and supply management strategies.

In Africa, 12 countries are considered to be in a water stress situation. Further 10 countries will be stressed by 2025. A total of 1.1 Billion people or two thirds of Africa’s population will be affected (Dzikus 2001). The threat to water resources has brought into focus the urgent need for planned action to deal with water resources effectively as it is widely recognized that water is a major limiting factor in the socio-economic development. The United Nations (UN) in their Millennium Declaration gives consideration to the importance of water and water related activities in supporting development and eradicating poverty (UN 2003). The existing water stress in many developing countries is not only due to source constraint but other factors such as poor distribution efficiency through city networks and inequalities in service provision between the rich and the poor (UN-HABITAT 1999). The available water sources throughout the world are becoming depleted and this problem is further aggravated by the rate at which populations are increasing, especially in developing countries.

Currently, some 30 countries are considered to be water stressed, of which 20 are absolutely water scarce. It is stated that by 2020, the number of water scarce countries will likely to approach 35 (Rosegrant et al 2002). Hadipuro and Indiriyandi (2009) researched the typical water supply provision in Indonesia and the major role of groundwater supply by the private water supply providers. The main objective of this article is that the analysis of water provision and its changes will give a policy changes in coastal clean water supply and thus to better conditions for the vulnerable people living along the coast. The study indicated that the lack of access, especially to the poor, is a business opportunity for small-scale water supply providers. The problem with these providers is that all of them utilize groundwater as sources. The worse the service of the public water supply the more necessary it is to regulate groundwater extraction. The poor will become very dependent on groundwater while also becoming victims of environmental degradation due to extreme groundwater extractions. Varis et al (2006) explained that when accelerating water scarcities and pollution in and around urban centres are superimposed on issues like financial constraints for constructing and maintaining water infrastructures, inadequate management capacities, poor governance, and inadequate legal and regulatory regimes, water management in the mega cities may all pose challenging tasks in the future.

2.2.2 National Scenario

In India, 85% of urban population has access to drinking water but only 20% of the available drinking water meets the health and quality standards set by the World Health Organisation (Singh 2000). Basu and Main (2001) concentrate on the increasing environmental issues associated with Calcutta's water supply and on their links with the inefficiency and inequity of supply and distribution. Healing these source environments is integral to efficiency and equity improvements. Supply sources have been contaminated, the utility supply fails to reach millions of city's population and even those who are served cannot rely on it, while those who draw their drinking water informally directly from natural sources put their health at risk. In order to manage with its complex problems, an integrated water supply policy designed to improve the degraded environment is an urgent need. Overdrawing of water for ever rising population caused depletion of groundwater sources and ingress of saline water intrusion in Mumbai though water supply in Mumbai kept rising with newer schemes to meet the demand of growing population. However, the reason for water scarcity is distribution losses, wasteful use etc., causing about 40-60% loss of water (www.bcpt.org).

2.2.3 Interdependence of Groundwater and Urbanization

Intensive use of groundwater can continue to play a key role in the growth and development of cities. However, understanding the influence of urbanisation on groundwater quality and quantity is essential. If future resources are to be adequately confined from potential depletion and water quality degradation, this understanding alone does not guarantee the sustainability of the groundwater resource. Of the 23 mega cities with a population of over 10 Million by 2000, 12 cities are heavily dependent on groundwater and 11 out of the 12 are in developing countries (Burke and Moench 2000). As the surface and groundwater resources are under threat of vulnerability in terms of quality and quantity, the usage of treated/processed water for drinking is growing in recent years.

Figure 2.1 as depicted by Howard and Gelo (2002) enlightens the linkages between the dependence of peri-urban aquifers in the water supply provision and urbanization effects. It has been accepted that urban areas evolve through a series of distinct stages as they gradually mature. The early stages begin with the small settlement that gradually grows into a semi urban/town. Successive stages comprise rapid industrialisation and urbanisation, which is followed by suburbanisation as the population becomes decentralised.

During early stages of development, water is normally supplied by shallow open wells in a generally central location. On-site sanitation is the prime method of disposal for human waste. As growth accelerates, the settlement commonly experiences degradation of shallow groundwater and the slow decline of water levels, which is observed in many emerging cities nowadays. Deeper wells initially provide a temporary solution but inevitably there is a shift towards new pumping wells in the adjacent peri-urban areas. Finally, increasing demand is met by transporting water from distant sources and the city becomes a major net importer of water.

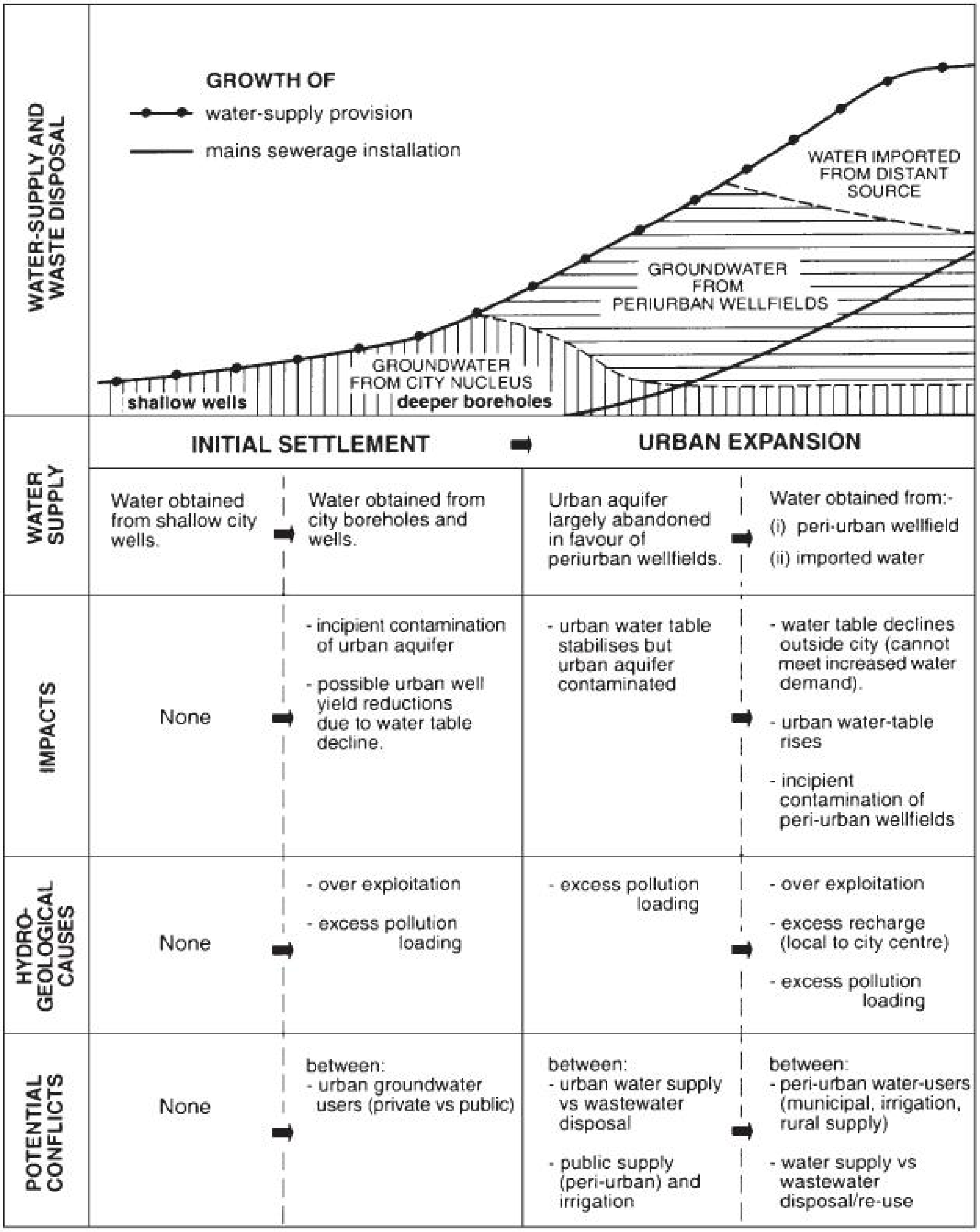

Figure 2.1 Role of groundwater in evolution of a city

2.3 GROUNDWATER MARKET

Globally, the last two decades have seen an increased focus on the role of markets as a mechanism for allocating water and communicating its value to users. Water markets are considered as an important and essential tool in many water management circles for reallocation of water away from agriculture by the largest uses to meet growing urban and industrial demands (Moench 2002).

Easter et al (1999) analysed different experiences from India, Pakistan, United States and also from other parts of the world to find whether water market, either formal or informal, be an efficient method for allocating scarce water sources. They found that informal water market works fairly well for groundwater situation where there is an adequate recharge and sufficient sellers. Informal markets may be good for local level allocation (traditional irrigation system) but formal markets will be required for transaction between different region and sectors. To prevent monopoly and overexploitation, organizational and institutional measures are needed.

Moench and Janakarajan (2002) studied the existing water market in South Asia and Western U.S. Water markets. The study about the informal water market represents a highly adaptive resource for meeting many local water needs. They also explained the services water markets currently provide, the impact both positive and negative and their role in meeting the water needs.

2.3.1 Rural - rural Water Market

In the Rural-rural water market, water extracted from rural areas is sold to the users in the same or nearby rural areas. Usually this type of transaction takes place in agricultural sector. Rural-rural water market is very much useful to improve food production and access equity. According to Prasad (2002), the emergence of rural water markets, both ground and surface water, has helped in increasing agricultural production. The studies conducted by Shah (1993), Janakarajan(1999), Moench (1991), Palanisamy (1995), Shah and Ballah (1997) and Nayak (2007) have all investigated the impacts of groundwater market in various locations. Pant (2005) highlighted that marginal farmers are the biggest beneficiaries of groundwater market. Nearly 60% of the marginal farmers purchased water from well owners making groundwater accessible to economically deprived sections of the society. Electrical power for groundwater pumping is, in many Indian states, provided either at a flat annual rate based on pump horsepower or free of charge. In this situation, the presence of water markets provides a strong incentive to extract as much water as possible in order to maximize the returns and minimize the fixed costs though the overall impact of water market is highly beneficial (Moench and Janakarajan 2003). However, in certain cases the rural-rural water market affects the social status and expands the gap between the marginal and small farmers.

2.3.2 Rural - urban Water Market

This type of market is commonly increasing adjacent to both large urban areas and intermediate sized towns. The transfers here typically involve sale of water by well owners (generally farmers) either directly to industries or to tanker companies who then supply to the end users (smaller industries, commercial establishments and households). The Palar and Noyyal river basins in Tamil Nadu are the typical cases for domestic and industrial uses. Its implications on the local agriculture and the ecology are quite disastrous (Moench and Janakarajan 2003).

2.3.3 Industrial Water Market

Nelliyat (2007) studied the functioning of industrial water market in Tiruppur industrial areas. It was highlighted that 85% of demand was met through private water supply. The continuous pumping of water from villages to Tiruppur has led to depletion of groundwater in many villages and the reduction in agricultural and allied activities altogether has led to frequent violence and conflicts in the villages. The estimated annual loss in agriculture by marginal farmers is Rs. 11.70 lakhs (Palanisamy 1995).

2.3.4 Groundwater Market by Packaged Water Industries

The shortage of protected water supply by the urban authorities has led to a boom in bottled water across the world in the name of 'mineral/packaged water' (Thakker 1997). For example, the sale of bottled water in all urban centres of the developing world has increased significantly during the past decade. This explosion in demand for bottled water is now a general phenomenon in all developing countries. It stems from only one factor, which is the intense fear of the consumers that the water supplied by the public utilities is not of good quality. Thus, drinking it may involve significant health risks.

Ironically, even though consumers have taken to drinking bottled water the quality of water bottled is also uncertain. Absence of legal standards and/or lack of mechanisms for enforcing whatever legal standards that exist mean that quality control is left almost exclusively to the bottlers. In many developing countries, quality standards do exist for bottled drinking water but adherence to the standards is purely voluntary. Meanwhile, there are no precise regulatory requirements for establishing a bottled water plant. Anyone who wishes to construct one can do so without indicating the source of water, technology used to purify it and the final quality of water bottled. Accordingly, the quality of bottled water is basically unknown in most developing countries (Biswas 2006).

2.3.5 Peri-Urban Groundwater Market

Indian demography is being marked by a dramatic shift from its rural dominance to urbanization and 50% of total population will be living in the urban areas by the year 2025 (Londhe et al 2004). With rapid industrial growth and vast urban expansion, cities experience severe stresses due to factors such as scarcity of land for urban use, pollution, lack of adequate drinking water and sanitation and sea water intrusion etc. In most of the situations, the pressure developed by these activities is transferred to natural resources on the peri urban fringe, particularly water.

Chennai (formerly Madras) is a rapidly growing metropolis of over 6.5 Million people, whose infrastructure has not kept pace with its growing demand for water. In the year 2003-2004, Chennai experienced a severe water crisis. Piped supply for the entire city was virtually shut down for a 12-month period. Consumers became dependent on private tanker suppliers trucking in untreated groundwater from peri-urban areas. A good deal of groundwater was pumped from the agricultural wells in the peri urban areas and transported in to the city. Most prominent such well fields exist in the Araniar – Kosasthalaiyar basin in Thiruvallur district, north of Chennai city. Moreover, due to proximity to the sea, sea water intrusion has already reduced the quality of groundwater in these areas. In several places, farmers and local people have agitated over round the clock pumping of groundwater from the agricultural wells to the city needs (Janakarajan 2004).

The process of transportation of groundwater is inevitable but at what extent and at what way is debatable. The solution to water crisis is quite closely associated with integrated view of water governance, which encompasses issues such as long term perspective and planning a broad based partnership through dialogue among all key stakeholders. Janakarajan et al (2007) suggest an alternative solution to Chennai water problem and simplification of the institutional frame work by redefining responsibilities in order to better coordinate at various decision levels and avoid the overlapping of tasks.

Over-drafting or over mining of groundwater at a rate higher than the recharge increases pumping lifts and cost of extraction because of lowering the water table. This affects the ecology and environment, sometimes irreversibly damaging the aquifer. It induces the possibility of saline water intrusion and degradation of water quality in the aquifer due to its proximity to the coastal aquifer (Easter et al 1999 and Ruet et al 2007). Rajesh (2000) pointed out that dependence of tube well have grown over the years and groundwater levels have fallen to dangerous levels in many areas sucking the wells and ponds dry.

Declining trend of agriculture and the depletion of water table force the people to move out in search of employment opportunities and vice versa. An identical impact has been analyzed by Diwakara and Nagaraj (2003) in adjacent areas of Karnataka. They argued that informal groundwater market has severe negative impacts on local food security and related employment opportunities.

Janakarajan et al (2006) analyzed Chennai's ground water market and multi stakeholder approach to provide long term sustainable solutions for growing problems of mega cities such as Chennai. The study explained the water conflicts developed in two peri-urban villages of Chennai. They carried out stakeholder analysis and conflict analysis to understand and characterize multi stakeholder groups and their conflict interest. It concludes that stakeholder participation in multi stakeholder dialogue is a gradual process that requires research and ongoing stakeholder analysis.

According to Vaidyanathan (2007) two thirds of the Chennai city's domestic demand is met by groundwater. He conducted a detailed survey among 1510 households in 151 streets located in 31 wards to estimate the overall levels and patterns of water use in the city. In this study, a rough estimate of cost incurred by an average household per month for water in a city is reported to be as Rs.455. Public supply from groundwater source was increased by 35% and private extraction by 18% when compared to 1995 status. Moreover, low income group people rely on public systems. Only middle and high end people depend on the tanker waters.

A study on analysis of water supply strategies in Chennai conducted by Srinivasan (2008) argued that water supplied by public authorities highly varies significantly across periods due to a combination of physical factors (limited reservoir capacity, monsoon variations) and management factors (low tariff and high leakage). Faced with intermittent and unreliable supply, it is rational for consumers to invest in private coping mechanisms like tanker water and packaged water.

The surveyed literatures on water supply provisions in global and national contexts and different type of groundwater market shed lights on how far the prevailing market mechanisms could be able to managing the supplies for increased demand for irrigation, domestic and industrial sectors. The following literature survey explains the scientific approach on various aspects such as land use analysis, quantity, quality, and mapping groundwater potential for the management of groundwater resources in order to protect the aquifer as the source of groundwater marketing.

2.4 LAND USE

Land use/land cover of areas, which are adjacent to urban centres, undergo unexpected changes due to various human activities, natural conditions and developmental activities. Coastal regions, the most important and thickly populated zone, have been under intense pressure. Changes are one of the important aspects of global changes (Li 1995 and Luo et al 2005).

Urbanization and unplanned development of land and water resources have resulted in adverse changes in the land use pattern and on the groundwater resources in the southern suburban of Chennai city. The increasing population pressure and induced urbanization on land use have contributed to the general degradation of the environment, warranting suitable land use planning and management (Minakshi et al 1999, Kangalawe 2010 Bisht and Kothyari 2001).

The land use system and related resources, particularly water resources, are highly dynamic. They undergo significant changes according to the changing socio-economic and natural environment. Groundwater sustainability is defined here as “the use and development of groundwater in such a way that result in no unacceptable damage in future to the quantity, quality and the dependent ecosystems” (Alley et al 1999, Pearce et al 1989). To understand the sustainability of natural resources such as water in general, one needs to understand the impact of future land use changes on the natural resources. Environmental conservation should be strengthened where the regions impacted due to severe land use changes and to guarantee their ecological security (Kangalawe 2010, Yongjun et al 2006, Genxu et al 2005, Twarakavi and Kaluarachchi 2006).

Santhiya et al (2010) analysed the land use/land cover changes for Chennai coastal zone using remote sensing and GIS to monitor the coastal land use dynamics. Due to increased population, the settlement and built up areas have increased considerably 16.82% (1976), 26.20% (1999) and 31.91% (2007). It has been observed that the industrial areas have gradually increased from 0.26% (1976) to 1.89% in 2007.The plantation areas have gradually decreased from 19.49% (1976) to11.19% (2007) due to urban growth. Hence, the study argued that proper coastal zone rules should be strictly implemented to protect the construction and other related activities near to the coast.

The process of rapid land transformation has not only brought about an ecological crisis in the region but also has threatened the agricultural economy of the watershed through accelerated soil erosion, deforestation and reduction in groundwater recharge. This creates the necessity for evolving a suitable land use planning to arrest further land use changes and land degradation. The studies about the land use/land cover changes show that settlement areas expanded by permanently depleting extensive forests and grasslands and thereby damaging the prevailing agro-climatic conditions favourable for the sustenance of agriculture. A similar finding is recorded by Bisht and Kothyari (2001), Raju and Anil Kumar (2006). They conducted a study on land use changes in Garur Ganga Watershed, Uttranchal and Idukki District, Kerala, respectively. Kangalawe and Lyimo (2010) conducted a study on the linkages between population growth and environmental degradation in Tanzania. Increasing population has in many rural areas contributed to changes in land use/cover patterns, land fragmentation and livelihood insecurity. They argued that increased reliance on natural resources, high urban demand and unplanned urbanization towards rural areas also have negative impacts on the environment and social well-being. It needs to undertake deliberate efforts to guide urban development towards having more sustainable centres.

The land and water resources in the sub urban areas are in high demand for non agricultural activities and the farmer's interest towards agriculture is also getting reduced. This is mainly due to the proximity to the city and associated employment opportunities. Most of the people in villages around Chennai are involved in groundwater marketing and their proximity to the city has induced severe changes on the land use pattern such as reduction of agricultural land and increased settlements due to urbanization activities (Veeralakshmi 2009). Hence, cautious developmental activities are needed to balance the relationship between the livelihood of poor farmers and environmental protection (Li et al 2007).

The satellite remote sensing data with their repetitive nature have proved to be quite useful in mapping land use/land cover patterns and changes with time. The remote sensing and GIS based land use study is very effective and high resolution satellite imageries are very reliable to provide information accurately (Sharma et al 2001).

2.5 GROUNDWATER ESTIMATION

For a sustainable development of groundwater resources, it is imperative to make a quantitative estimation of available water resources. It is necessary to maintain the groundwater reservoir in a state of dynamic equilibrium over a period of time. Further, water level fluctuation has to be kept within a particular range over the monsoon and non monsoon seasons (Silva 2004).

Groundwater balance principle is based upon the law of conservation of mass. Flows entering and leaving a distinct geohydrological unit in an unexploited steady state over a period of time can be described by the following water balance equation.

$$\text{Recharge} - \text{Discharge} = 0 \qquad (2.1)$$

The sum of abstractions and outflows should be less than average effective recharge. If the total groundwater use is greater than the effective aquifer recharge, it creates long-term deterioration of the resources base (Wright 2000).

The Government of India had constituted a Groundwater Expert Committee (GEC) for the estimation of groundwater resources. GEC has come with a methodology in 1984 (GEC, 1984) and subsequently effected modifications in 1997 (GEC 1997). On the basis of the experiments conducted all over the country, GEC has recommended norms for various parameters, if actual values are not available. The study, conducted by CGWB (2008), carried out a lumped model for groundwater flow components for the coastal aquifers in southern part of Chennai Metropolitan Area, Tamil Nadu.

Groundwater budget for the two layer aquifer system has been computed and an attempt on distributed modelling has provided a reasonable estimate on groundwater flow condition. In both the layers, the change in storage is negative thereby indicating the recharge components were not sufficiently compensating the discharge component.

Quantification of the rate of recharge is a pre requisite for efficient groundwater resource management. It is particularly important in a region with large demand for groundwater supplies where such resources are key to economic development. Kumar and Seethapathi (2002) estimated the quantity of natural groundwater recharge using groundwater balance approach for the Upper Ganga canal command area, U.P. Based upon the groundwater balance study an empirical relationship has been suggested for the estimation of recharge with a reasonable accuracy. Sekhar et al (2004) developed a groundwater modeling for assessing the groundwater balance and estimating the recharge in Gundal sub basin, which is located in a semi arid portion of the Kabini river basin, southwest of Karnataka state. The typical groundwater flow equation for two dimensional anisotropic, non homogeneous system is considered and the equation is modified to incorporate the site specific recharge components. The study suggests that there is a potential for application of such a method for assessing the groundwater balance with the available water level data along with data of remote sensing by using GIS tools.

Water table fluctuation method may be the most widely used technique for estimating the recharge and it requires a knowledge of specific yield and changes in water levels over time. The accuracy is highly dependent on estimating the specific yield. Recharge R, is calculated as

$$R = S_y \, dh/dt \qquad (2.2)$$

where S_y - Specific yield;

h - Water table height;

and t - time

The method, however does have its limitations such that (i) The method is suitable for shallow water tables and wells should be located such that monitored water levels are representative of the catchment as a whole;(ii) The method cannot account for steady rate of recharge; and (iii) The difficulties related to identifying the cause of water level fluctuation and calculating the value for specific yield (Healey and Cook 2002).

Bhuiyan et al (2009) suggest that water level fluctuation method is found to be capable of computing actual groundwater recharge. The authors adopted a GIS based water table fluctuation method for quantitative modeling of groundwater recharge for the Aravalli terrain, south central part of Rajasthan state. To generate the grid map of rainfall and water table fluctuation, GIS software Arcview 3.2a and spline interpolation technique were used. For places lacking site specific data on specific yield, norms recommended by CGWB is considered. Actual recharge was empirically computed through two different approaches of Water Level Fluctuation (WLF) and Rainfall Infiltration Factor method (RIF). The study demonstrates that even with limited data a GIS based modelling using WLF and RIF methods can determine the distributed infiltration coefficients of a region and can be used in demarcation of recharge potential zones. It concludes that differences in recharge computation by these methods are found to be small. The model is considered to be acceptable for natural recharge computation.

Computation of groundwater balance is based on the estimation of recharge and discharge components. Recharge components include rainfall recharge, lateral inflow, irrigation return flow and influent seepage from rivers. Discharge components include evaporation losses, lateral outflow, effluent seepage and groundwater draft. The average total annual discharge of the area exceeded the total average annual recharge implying that the system is in deficiency and an indication of unsustainable water withdrawal (Njamnsi and Mbue 2009)

Marchell et al (2003) developed a methodology based on the relationship between the water balance and water table fluctuation. The study found that the main positive term of the budget is the irrigation return flow from the paddy fields. Despite normal rainfall, the annual budget is little negative necessitating a decrease in the pumping rate and water harvesting/ recharges measures to reverse the deficit.

Chaulya (2003) conducted a study on water resources accounting for Thondamuthur block, Coimbatore district. The study found that out of the total rainfall, 33% is stored as groundwater through recharge. The total annual utilizable groundwater available in the study area is 79.22 Mm^3, whereas total groundwater demand is 68.92 Mm^3. Taking considerations of various hydro geological conditions, the recommendations have been suggested for effective implementation of recharge measures.

Rivera (2000) explains the limitations in the estimation of groundwater resources by the water balance approach. The horizontal groundwater flow is the main source of water and the basement depth is an important feature to be considered in the groundwater balance equation.

Varadaraj and Suresh (2010) developed a new methodology for groundwater estimation. The proposed methodology is mainly based on the aquifer saturation. It brings out the aquifer saturation at the end of the hydrological year in pre-monsoon period thereby indicating the balance potential of the aquifer for further development. The results also match with the GEC-97 methodology based on the water balance computation.

Based on the reviewed literature, the present study adopted the GEC-97 methodology with inclusion of site specific data such as value of specific yield, rainfall infiltration factor based on geologic characterization, irrigated area identified from land use analysis and number of irrigation wells from well census to assess the stage of groundwater development in a watershed scale.

2.6 GROUNDWATER QUALITY

Groundwater quality has become an important issue due to rapid increase of population, rapid industrialization, unplanned urbanization and too much use of fertilizers and pesticides in agriculture (Joarder et al 2008). In many parts of India, especially in the arid- and semi-arid regions, due to the failure of the monsoon and scarcity of surface water, dependence on groundwater has increased tremendously in recent years. India supports more than 16% of the world's population with only 4% of the world's fresh water resources (Singh 2003). In the last decades, the progressive increase of water requirements and the consequent scarcity of its availability together with its qualitative deterioration must certainly be included among the most serious environmental problems of developing countries.

Hydrochemistry is used to assess the quality of groundwater for determining its suitability for drinking and agricultural purposes. The competition for economic development associated with rapid growth in population and urbanization has brought in significant changes in land use, resulting in more demand for water for various purposes. The science of geochemistry has largely developed during the present century. Nevertheless, the concept of autonomous discipline dealing with chemistry of the earth is an old one, and the term "geochemistry" was introduced by the Swiss Chemist Schonbein in 1838 and Brian Mason in 1917. Degree of urbanization changes, functioning of natural ecosystems, ecological balance and specific micro climate condition in the cities all contribute to the changes in soils as an important component of urban environment. Groundwater quality depends not only on natural factors such as the lithology of the aquifer, quality of recharge water and the type of interaction between water and aquifer, but also on human activities, which can alter these groundwater systems either by polluting them or by changing the hydrological cycle (Helena et al 2000)

Spatial and temporal monitoring of groundwater quality, such as salinity, hardness and other parameters, and identifying their changes have become imperative for water management and regulation, especially in a rapidly urbanizing environment (Tirumalesh et al 2010, Pandey and Shweta 2009, Paramesha Naik et al 2007, Lu et al 2011). In view of the growing water scarcity and the adverse impact of global climate changes on water resources, it is essential that groundwater be used efficiently, equitably, and in an ecologically sound manner for both the present and future generations so as to ensure sustainable utilization of this vital resource (Jha et al 2010).

Hydrochemical analysis is one of the most important aspects in groundwater studies. Changes in groundwater quality are due to rock–water interaction and oxidation–reduction reactions during the percolation of water through the aquifers (Krishna Kumar et al 2009, Prasanna et al 2010, Aghazadeh and Mogaddam 2010). Undesirable and soluble constituents in the water cannot be controlled after it enters the ground (Johnson 1979, Sastri 1994). Sami (1992) has explained that leaching of surficial salts, ion-exchange processes and residential time of groundwater in the aquifer cause hydro geochemical variations in groundwater.

Hydrochemical studies may reveal the quality of water that is suitable for drinking, irrigation and industrial uses (Hossain et al 2010, Jalali 2007, Yesilnacar and Gulluoglu 2008). Dey et al (2012) calculated a risk index for Boden block area, Orissa as a function of fluoride level in groundwater and identified the high risk villages in Orissa.

Subramani et al (2005) have studied the groundwater quality and its suitability for drinking and agricultural use in the Chitar basin, Tamil Nadu. They have compared the analytical results with the recommended limits suggested by the World Health Organisation (WHO 1971 and 1983). High total hardness and TDS indicate the unsuitability for drinking and irrigation purposes.

Sadasivaiah et al (2008) evaluated the groundwater quality in Tumkur taluk, Karnataka. In this case, the methods proposed by Piper, Wilcox and USSL classification have all been used to study critically the hydro chemical characteristics of groundwater. Ramakrishnaiah et al (2009) developed a water quality index for Tumkur Taluk, Karnataka. The study indicates that 63.5% of water samples are poor in quality and this may improve due to inflow of freshwater of good quality during rainy season. Magnesium and chloride are significantly interrelated which show that the hardness of the water is permanent in nature. The findings suggest that the groundwater of the area requires some degree of treatment before consumption and it also needs to be protected from the threat of contamination.

To delineate spatial variation in physico-chemical characteristics of groundwater, Geographic Information System based water quality mapping in the form of contours are widely used in the present study. A Piper trilinear, Wilcox and US Salinity classifications are used to identify the suitability of water for drinking and irrigation purposes (Ravikumar et al 2010, Arumugam and Elangovan 2009, Srivastava and Ramanathan 2008, Chidambaram et al 2008, Jeevanandam et al 2012).

2.7 GROUNDWATER POTENTIAL ASSESSMENT

Successful development of groundwater requires a proper understanding of its hydrogeological characteristics of the aquifer. Lee et al (2005) stated that fluctuation behavior of groundwater levels in response to rainfall were very different depending on the thickness of a unsaturated zone and the location of monitoring well.

Singh et al (2010) developed quantitative modeling of groundwater in Sutlej river basin using remote sensing and GIS. The thematic layers such as soil, slope, lineament, geology and geomorphology are generated and overlay analysis has been carried out for deciphering groundwater potential zones. It has an added advantage over conventional techniques and can be applied on a broader prospect to identify potential zones for tapping of groundwater and suitability of identifying artificial recharge zones and its sustainable uses (Chasanatus et al 2010). Due to increased dependency, pumping exceeds the recharge rate. Hence, assessment of potential and scope for artificial recharge in the over developed watersheds is very crucial. Maggirwar and Bhavana (2009) developed a GIS based methodology for the possibility of artificial recharge for an over developed mini watershed. This is done by giving weightages to individual parameters of different thematic layers. This site suitability analysis is effectively used to increase the groundwater availability on a sustained basis in an over developed watersheds. Prasad et al (2008) developed a groundwater potential map by integrating geology, geomorphology, slope, drainage density and lineament maps. The study identified groundwater prospecting zones for proper planning and management.

The key to success of any geophysical investigation is the calibration of geophysical data with hydrogeological and geological ground truth information (Nejad 2009). The Vertical Electrical Sounding (VES) is commonly employed in geophysical investigations to delineate various geoelectric layers, aquifers and their characteristics. Based on the over burden thickness and resistivity values of different layers, the suitability of sites for groundwater development are established (Ariyo and Oguntade 2009). In order to reveal the potential, the identified layers with different resistivity values are used to investigate the aquifer properties (Batte et al 2010). Electrical resistivity method, of all the surface geophysical methods, has been applied most widely in groundwater exploration studies (Todd 1995). In general, Vertical Electrical Sounding (VES) with Schlumberger array assumes considerable importance in the field of groundwater exploration because of its ease of operation, low cost and its capability to distinguish between saturated and unsaturated layers (Nur and Kujir 2006).

Krishnamurthy et al (2003) conducted a comparative study on surface and subsurface geophysical investigation to delineate the fracture zones. The resistivity technique, particularly sounding, alone cannot identify the fractured aquifer because the layer gets masked on a sounding curve as its thickness becomes low compared to the depth of occurrence. Among the additional techniques that support Vertical Electrical Sounding (VES) interpretation, Self Potential (SP) method is one. They concluded that a thin fracture zone occurring at a greater depth is well interpreted by the SP method with VES interpretation than VES alone.

Srinivasa Gowd (2004) carried out electrical resistivity surveys to delineate groundwater potential aquifers in Pedavanka watershed, Anantapur district, Andhra Pradesh, India. Ninety nine Vertical Electrical Soundings were conducted using Schlumberger configuration as this method has practical, operational and interpretational advantages. The resistivity data were interpreted using master curves and auxiliary point charts. The study found that the resistivity values were in good correlation with existing litho logs. Groundwater potential map has been prepared based on the depth to bedrock, thickness of the saturated layer and the resistivity of the second layer. The study concludes that the electrical resistivity data provide reasonably accurate results to understand the subsurface layers and basement configuration in groundwater investigation.

Subbo Rao (2003) conducted an integrated study on groundwater prospecting and management in the crystalline terrain of Guntur district, Andhra Pradesh. The study comprised of geoelectrical surveys, remotely recorded data and pumping tests. Total Transverse Resistance (TTR) and Total Longitudinal Conductance (TLC) were computed from the interpretation of sounding data. By integrating the data such as resistivity, depth of aquifer zone, TTR, TLC and discharge, a criterion was generated to identify the possible potential zone. Finally, the study proposed a management plan for sustainable development of groundwater to eliminate the water scarcity and its related socio economic issues. In the present study, characterization of aquifer is studied using the geophysical data and the available borehole details.

2.8 SUMMARY OF LITERATURE SURVEY

With all diverse interrelated apprehensions of dwindling water resources, particularly groundwater, an interdisciplinary cross cutting research effort is required to attain a feasible solution. This study comprises of an integrated cluster of various sub-themes involving groundwater evaluation with special reference to prevailing informal peri-urban to urban groundwater market. Several studies carried out to analyze the social crisis of ground water market and issues of inequitable access to water etc., between rural-urban and peri-urban and urban areas. But the studies about evaluation of groundwater resources with its hydrogeological background considering socio economic implications are very limited. The findings indicate that there is a need to study the issue with hydrogeologic environment to eradicate the potential impacts. The literature survey presented here reveals that majority of the studies are about the water market issues, either surface/groundwater or rural-rural/rural-urban, conducted against the socio-economic background. They conclude with assessments of the social and economical impacts. Similarly, groundwater management studies in various arid and semi arid environments, which are under threat, investigate only the technical issues of the basin or watershed or administrative boundaries rather than looking at the social issues for the explanation or motivation of the causes. The proposed study tries to merge the gap between the analysis of the social aspects of water marketing qualitatively and quantitatively with the technical measures such as the hydrogeological condition, groundwater quality and potential of the watershed for the sustainable development of groundwater resources.