CHAPTER 2

REVIEW OF LITERATURE

2.1 INTRODUCTION

South India and Sri Lanka are known for hydraulic civilization. Traditionally tanks have been used for agriculture, domestic, livestock and fisheries. The current status of these tanks are investigated by many researchers and some of them have been reviewed in this chapter. Discharge of untreated wastewater from industries and households into water resources like river, tanks and ponds have deteriorated the quality of such water bodies and have affected the livelihoods of the community. Many studies have confirmed that institutions play important role in management of tanks. Various methods of investigation for water quality analysis, ecosystem services and wastewater treatment in natural wetland have been adopted from these literatures.

2.2 IRRIGATION TANKS AND THEIR PERFORMANCE

The tanks are the main source of water for agriculture for centuries and the neglect of tanks in the recent past has increased in the number of bore wells which depleted the groundwater table resulting in salinity in many parts of Tamil Nadu. The poor maintenance of tanks resulted in sedimentation and loss of storage which cannot hold the run-off water from the catchment and end up in drought like conditions during scarce rainfall period. Tanks are community assets that have to be taken care with complete responsibility and
good institutional mechanisms operating at the village level with enhanced
guidance and financial help from the government (Binayak Das 2009). The
threats that deteriorate the tanks are siltation in tank beds, weed infestation in
tank water spread area, implementation of social forestry, encroachments, use
of chemical fertilizers and free electricity (Sampath 2015).

The direct benefits from tank irrigation are food production,
employment and environmental benefits like rise in groundwater table. A
survey of 32 tanks from Tamil Nadu, Andhra Pradesh and Maharashtra states
was conducted by Von Oppen & Subba Rao (1987) to assess the economic
performance of irrigation tanks. In the above mentioned states, 60% of the
area are irrigated by tanks. The percentage of tank irrigated area to net
irrigated area had reduced from 17% in 1950-51 to 10% in 1978-79. The main
factors responsible for deterioration of tank irrigation include abolition of
ownership rights of private tanks after independence, increased well irrigation
with free electricity and poor tank water management, lack of administrative
authorities for tank maintenance and repair, provision of proper water control
structures and its maintenance. Remedial measures like proper water
distribution and management, regular repair and maintenance, de-siltation,
soil conservation measures to control erosion and farmers participation in the
maintenance of tank for efficient water management increase in water use
efficiency.

Andhra Pradesh based community tank management programme in
2007 reported that agricultural economy of the state faces serious threat due to
decline in tank irrigation. Annual economic return of about INR 37,500 per ha
of cultivated area is estimated under minor irrigation which amounts to a loss
of about INR 2250 crores per year for about 6, 00,000 ha of land lost under
tank irrigation. As the tanks provide domestic and drinking water to the poor,
the loss is further aggravated. The project restored the tanks by revitalizing
the irrigation potential in a decentralized manner by involving the community. The project carried out rehabilitation of 3000 tank systems in 22 districts of Andhra Pradesh with the four components like 1. Strengthening community based institutions to improve and manage tank systems. 2. Actual rehabilitation works in feeder channels, tank structures and water distribution systems. 3. Agricultural research and extension services, including fisheries and livestock products. 4. Monitoring and evaluating.

Overall tank performance was measured considering all the multiple uses like crop production, drinking, washing, bathing, fodder and water for live stocks, fish culture, duck rearing, brick making, social forestry and silt collection. The total revenue estimated in terms of taxes and fees from all users of tanks are nearly twice the amount that government allotted for tanks operation and maintenance and four times as much as the tanks actually received from operation and maintenance (Palanisamy et al 2001). The study emphasized a strong water users association at tank level, with sufficient rights for local management body to undertake the tank management activities. Performance of irrigation tanks became profitable in economic, environmental and social terms when the physical structures are modernized properly and maintained with farmer’s participation (Anbumozhi et al 1997)

Tank rehabilitation enhanced the agricultural productivity to a great extent. Economic analysis confirmed that rehabilitation resulted in increased tank storage, increased area of cultivation and increased cultivation of crops per year resulting in significant increase in income per m$^3$ of water per ha of land in the post-rehabilitation period. There were significant increase in income from other indirect uses like livestock, fish rearing, washing, rat trapping, fuel wood, duck rearing and brick making (Anuradha 2009).

Tank cascade system was the backbone of traditional economy and its main function was to irrigate the drylands for paddy cultivation. During the
colonial era, the tank cascade system were neglected and transformed into large scale reservoirs and feeder channels. Improper maintenance of hydraulic structures deteriorated the tank ecosystem and resulted in poor agro-ecological conditions due to which many ecosystem services were not able to sustain (Narayana et al 2014). Modern technology should strengthen the tank cascade system by understanding each component and considering the agriculture and the livelihood as a unit (Geekiyanage et al 2013).

Irrigation tanks which are source of water storage and supply for multiple uses declined after independence due to various factors like, the development of large-scale gravity irrigation systems, growth of tube well technology and decline in traditional way of tank management by the community. Other reasons for the decline in tank irrigated areas are silting of feeder channels, encroachments, interruption in the catchment, poor maintenance and the development of tube well irrigation in tank command area (Raj and Sunderasan 2005, Palanisamy and Easter 2000, Janakarajan 1996, Mukundan 1988). Shankari (1991) in her research has pointed out that poor management of the tanks is primary cause for their decline. Sekar and Palanisami (2000) reported that tank bed cultivation and the lack of an administrative structure to perform repair and maintenance contributed to the decline of tank irrigation. Negligence of the tank maintenance resulted in increased soil erosion, decreased bio-diversity, reduced soil moisture regime, diminished vegetative growth, decreased fodder and bio-mass production. As there was reduction in the availability of surface and ground water, both total area and number of seasons of crop cultivation in command area decreased. This resulted in decreased crop production due to which their livelihood got affected. In mid-1980’s, realising the importance of tanks, rehabilitation of the tanks was carried out (CWR 2000). Tank rehabilitation not only helped the farmers but also improved the livelihoods of landless poor, women and other vulnerable groups (Sakthivadivel 2005).
2.3 WATER QUALITY STUDIES

Continuous disposal of industrial effluents on land led to groundwater pollution which resulted in the increased salt content of soil. In some places deep bore wells that were used for drinking purposes have high salt concentrations. The environmental impacts of industrial effluent irrigation on soil and groundwater quality was done by analysing the soil and water samples. The less stringent effluent standards for land application has become direct threat to the soil quality and also affect human health, crop yield, product quality, aquatic ecosystems and finally socio-economic opportunities and sustainability. The volume of industrial effluent would increase with economic growth and the land disposal option could be serious environmental threat for agriculture. Environmental monitoring institutions with stakeholder’s participation would be a sort of solution (Mukerjee & Nelliyat 2006)

The wastewater from the common treatment plants are let into Amaravathi river. Both the river water and groundwater were polluted due this. The analyzed water samples from the outlet of common effluent treatment plants for the parameters like TDS, chlorides, BOD, COD, TSS and sulphate revealed that all the values exceeded the permissible inland surface water discharge standards (Rajamanickam & Nagan 2010). Tamil Nadu pollution control board directed all the dyeing units to setup RO (Reverse osmosis) plant with RMS (Reject management system) and recycle the entire treated effluent so as to achieve zero liquid discharge to protect the river and ground water. Similar study done by (Sarathi et al 2011) in Tiruppur indicated that disposal of untreated and partially treated effluent water on land resulted in high salt concentration in soil. The effluent discharged into the stream caused severe impact on fisheries, drinking water and agriculture. The fish mortality rate has become very high which compelled the fisheries department
to stop the fish culture. Though the reverse osmosis option is recommended by the Tamil Nadu Pollution Control Board (TNPCB), the large and medium size units are able to invest in it but the small units need more subsidies from the government.

The suitability of groundwater for domestic and agricultural use in Tondiar river basin of Tamil Nadu was assessed during pre-monsoon and post monsoon period. Groundwater samples were collected and analyzed for physical and chemical characteristics. The groundwater is evaluated for irrigation, based on the following indices like sodium percent, sodium absorption ratio, residual sodium carbonate, US Salinity diagram, Wilcox’s diagram, Kelly’s ratio and permeability index (Ramesh et al 2011). Around 31% of groundwater samples are suitable for drinking and 36% are suitable for irrigation. Study concluded that higher levels of hardness and electrical conductivity made the groundwater unsuitable for drinking and agricultural purposes. Ahamed et al (2015) computed water quality index to assess the suitability for drinking and irrigation purposes. The results were plotted in United States Salinity Laboratory (USSL) diagram and Piper tri-linear plot using Aquachem software. The Piper diagram illustrated that the groundwater was mixed Ca-Mg-Cl type followed by Na-Cl and Ca-Cl type. The water quality indices calculated revealed that the groundwater in the area is suitable for irrigation and unfit for drinking purposes.

Hyderabad city disposed huge quantities of untreated domestic sewage into Musi river which had a negative impact on farmers’ health and crop productivity. A research performed by (Ensink et al 2009) to remediate the Musi river in Hyderabad conducted water quality survey for 14 months (December 2003 – January 2005) to quantify spatial and temporal changes in the water quality parameters along a 40 kms stretch of the Musi river. The physico-chemical and biological parameters were analyzed and statistically
compared. The survey found that improved river water quality with distance from the city was due to different measures like irrigation weirs and waste stabilization ponds placed along the stretch of river. A hydro chemical analysis was performed by Ramakrishnaiah (2009) to evaluate the groundwater quality in Tumkur taluk, Karnataka. The suitability of water for irrigation is evaluated based on sodium absorption ratio, residual sodium carbonate, sodium percent, salinity hazard and USSL diagram.

Irrigation tanks in Bangalore were polluted due to both industrial and domestic wastes. Chandrasekar et al (2012), pointed out that that surface water quality exceeded the permissible limits of drinking standards. At certain places groundwater is also polluted. Suggestions given by the author are (i) reduce intensive farming and recommended bio fertilizers and organic fertilizer so as to reduce the groundwater pollution (ii) stop illegal disposal of industrial effluent and penalties be levied on industries violating the rules (iii) the lakes in the village should be protected by fencing to prevent illegal encroachment. The lake bed sediments were analyzed for heavy metals like Cd, Co, Cu Cr, Mn, Pb, Ni and Zn and compared with sediment quality guideline for 17 lakes in Bangalore city. Sediment geo-accumulation index and pollution load index were calculated for all the tanks. Jumbe et al (2009) concluded that (i) Cu and Ni are in higher levels of pollution followed by Pb and Cd. (ii) Cr failed a single sediment quality guideline while Zn, Mn, Co are in safety levels (iii) Certain tanks have very high concentration of heavy metals and if this is allowed to continue the food web complexes in the affected wetlands are at a very high risk.

Lalbagh garden, Bangalore is the country's famous tourist place and the tank inside the garden is a glory to the city. Presence of heavy metals in water hyacinth in Lalbagh tank, of heavy metal are very high due to discharge of untreated domestic sewage and idol immersion in the tank (Lokeshwari &
Chandrappa 2006). Surface water quality of river Ganga in Haridwar city was evaluated for drinking purposes for a period of one year from January 2009 to December 2009. Among the four sites, turbidity, COD, total alkalinity and total hardness were higher in two sites. Water quality index computed revealed that the values fall in the range of poor at all the four sites. The study concluded that water quality parameters compared with national and international standards at the above mentioned sites were poor and can be used for drinking only after conventional treatment and disinfection process are performed (Khanna et al 2013).

Fluoride content are at alarming state and water is not fit for drinking purpose in eastern part of Sikar city. The analytical results compared with World Health Organization (WHO) standards confirm the presence of excess salt in the water and if used for irrigation, increases the salinity of the soil. Shyam & Kalwania (2011) emphasized the need for treatment and management measures for controlling salinity. A research was performed by Dubey et al (2010) at Binjhole, Haryana to evaluate the water quality of pond, hand pumps and groundwater for domestic consumption and irrigation purpose. Samples from hand pumps, tube wells, and dye house effluent both raw and treated, drain carrying effluent from dye industry and pond water were collected. Analysis of the samples indicate that average COD, TDS and heavy metal concentration of dye house discharge, treated sewage, pond water and hand pumps exceeded the safe limits. The study concluded that seepage of effluents led to deterioration of groundwater quality for drinking purpose and the well water rendered unfit for irrigation purpose within a span of 2 years. The study recommended appropriate disposal measures for sewage and dye industry effluent in order to prevent deterioration of groundwater and health of human and animals.
Bagru region, printing cluster of Jaipur is known for textile industries. Untreated effluent that come out as a result of dyeing, printing and processing activities are at higher levels and affect human being, flora and fauna and entire ecosystem. The effluent samples and soil samples indicated that printing units discharge effluents with high levels of acids, chlorides, cations and anions which exceeded the standard permissible levels and has deteriorated the soil quality and fertility. Proper treatment of wastewater was suggested by Mehta et al 2013, Varsha & Seema 2013.

The untreated effluent from Bangladesh dyeing and finishing industries was found to be unsuitable as it contained coloured dyes. Trace element contents in untreated effluent are found to be double than that of the treated effluent. This have adverse effect on soil if it used for irrigation. A case study analysis was carried out in by Jolly et al (2009). The study analyzed untreated effluent and treated effluent for cations, anions, COD (Chemical oxygen demand), BOD (Biological oxygen demand) and trace elements. The average value of electrical conductivity (EC) and soluble sodium percentage (SSP) for treated and untreated samples were plotted in the Wilcox diagram. The untreated effluent corresponds to the class permissible to doubtful and treated effluent corresponds to the class good to permissible for irrigation purposes. The study concluded that the treated effluent can be used as an alternate means of irrigation but on the condition of monitoring the long term effect of the build-up of salinity and heavy metals that are harmful to the soil system.

2.4 ECOSYSTEM SERVICES AND ROLE OF PRA TOOLS

Ecosystem services framed by Millennium ecosystem assessment (MEA 2005) are listed under four groups viz. (a) Provisioning services like food and water, (b) Regulating services such as flood, drought, land degradation and diseases, (c) Supporting services such as formation of soil
and nutrient cycling and (d) Cultural services such as spiritual, recreational, aesthetic and educational benefits. Ecosystem services and water security must be viewed under one umbrella, the national development program which help in social welfare and economic growth. In achieving the millennium development goals the above consideration plays a major role (Steiner 2009). But the millennium ecosystem assessment illustrated that these linkages are not recognized and the sustainability is not ensured, as the human society throughout the world try to over exploit and pollute ecosystems. The ecosystem degradation resulted in poor economic development and human well-being.

A conceptual framework and a strategic sketch for delivering promissory ecosystem services was proposed by Daily et al (2009). The study explored the link between ecosystem services, values, institutions and decisions together in an integrated framework. The study emphasized stakeholders participation in the decision making process and design of institutions to manage, monitor and provide incentives which reflect social values of ecosystem services. The society should be well informed that nature is no longer a luxury instead an essential asset for sustaining and improving human well-being all over the world.

Burkhard et al 2014 reviewed the current state of the art of ecosystem service science regarding spatial localisation, indication and quantification of multiple ecosystem service supply and demand. Concepts and tables for regulating, provisioning and cultural ecosystem service definitions, related indicators for quantification were discussed. Ecosystem service matrices linking land cover types to ecosystem service potentials, flows, demands and budget estimates were studied. The matrices show that ecosystem service potentials of landscapes differ from flows, especially for
provisioning ecosystem services. Matrices with rankings are recorded and interpreted for long term planning and decision making.

Multiple uses of water in Kironaya basin of Sri Lanka was evaluated by Bakker (1999). The basin has multiple water services namely irrigation, domestic, livestock, fisheries and forest. Water quality studies done in the basin indicated that the drinking water quality exceeded the maximum desirable levels at certain locations. The study pointed out that the negative impact of water quality had reduced fish population, migration birds, waders, dabbling birds and also eutrophication of tanks. The study concluded that the multiple uses and users of water need to be accommodated in a single forum by involving all stakeholders.

Economic valuation of direct uses like agriculture, domestic, drinking water, livestock, industry, fishery, sedges, lotus flowers and roots and indirect services like groundwater recharge, water quality, biological diversity, nutrient and sediment retention were examined in Kala oya, tank cascade system to quantify the benefits associated with tank ecosystem goods and services (Vidanage et al 2005). The study analysed and linked the economic benefits and livelihoods of the local communities and concluded that (i) investment in tank rehabilitation generated high economic returns, (ii) its contribution to the community and ecosystem is large when indirect services are also considered and (iii) if tank management is not effective, money spent would become waste.

The PRA tools used in participatory research are resource mapping, problem tree, focused group discussion, priority ranking exercises, influence diagrams. These activities enable community members to express their concerns about livelihood, resource problems and potential solutions to solve problems. The benefit of PRA are that the community members fully participate in research regarding their own lives and region and share their
valuable local knowledge with researchers, (ii) activities and discussions can be changed, extended or dismissed, based on the needs of the community. Most of the PRA exercise requires, a facilitator to initiate constructive dialogue. Maintaining flexibility and a relaxed attitude allows PRA facilitators to encourage exploration of issues that are important to the community and to generate possible solutions to those problems identified (Chambers, 1994b).

PRA tools like transect walk, natural resource mapping, problem tree analysis and focus group discussion with key informants were used by to collect information about village and tank ecosystem. Ariza et al (2007) analysed the multiple use of a tank ecosystem in an integral social perspective at two locations namely Endiur and Athur using the above mentioned PRA tools. The study listed economic, socio-cultural and ecological functions of tank ecosystem.

PRA tools like resource mapping, web diagrams, flow diagram of wetland values, seasonal calendar, wealth ranking and relative ratings are used to collect the information about the importance of the wetland resources. Participatory research methods are key tool for economic assessment and planning the importance of wetland resources. Chong (2005) illustrated the application of participatory approaches to assess the importance of wetland resources from Veun Sean, Island located in Ramsar site of Mekong river. Participatory rural appraisal tools like focus group interviews, timeline, seasonal calendar are useful to understand livelihood resources, identify the social segregation and prevailing agricultural practice system. The participatory activities and the quantitative assessments reported that both rice cultivation and fisheries are essential for the sustainable livelihoods of Veun Sean village.
The Village resource map is a tool that helps us to learn about a community and its resource base. The primary concern is to get useful information about local perceptions of resources. The participants should develop the content of the map according to what is important to them. The Village Resource Map is a good tool to begin with, to learn the villagers' perception on natural resources found in their community and how they are useful. It is easy and fun for the villagers to do (Cavestro, 2003).

Problem tree analysis involves an initial brainstorm of all causes, direct and indirect or underlying the problem. The cards are then placed into cause and effect order using a right to left hand logic. In each box one or more factors leading to underlying cause are listed. Then causes and effects are sorted out. The working group exchange their views to validate and improve the problem tree. It involves an exchange between two working groups in which the facilitators stay behind to explain (Richards & Swan, 2014).

Primary data collection was done adopting rapid and participatory methods. Rapid case studies include secondary data related to capital assets from revenue office, primary health centers, primary veterinary centers, regional marketing centers, regional forests center, village panchayats, regional poverty initiative programme office and NGOs and development societies. Participatory approach consisted of focus groups discussions with 60 to 78 households in a village. Other PRA tools used in the study were collective mapping of the local area developing a timeline, ranking the importance of problems with a matrix, wealth ranking and observation walks producing seasonality calendar (Sreedevi 2005).

2.5 WASTEWATER TREATMENT AND THE ROLE OF MACROPHYTES IN WETLAND TREATMENT

In recent times there is a rising concern regarding the ability of the water bodies to assimilate the waste discharged into them and associated
risks. Ecosystem and human health face threats due to different variety and concentration of pollutants discharged by domestic and industrial wastes. Surface and groundwater resources face dual threats of increase in demand and deterioration of quality. In Canada and northern China, quality of water in most of the lakes and rivers are poor and in declining states. In both the countries constructed wetland have proven to be an efficient removal process. Wastewater treatment occurs due to variety of physical, chemical and biological processes like sedimentation, filtration, precipitation, sorption, plant uptake, microbial decomposition and nitrogen transformations (Kadlec & Wallace 2009; Wetzel 2000).

Due to high concentration of organic matter and dyes, the textile and dye industry wastewater causes significant environment pollution. As explained by Olejnik & Wojciechowski (2012) Constructed wetlands (CW) are man-made ecosystems engineered and designed to remove pollutants from wastewater that resemble hydraulic conditions and habitat same as those in natural wetlands. The different types of constructed wetlands are surface flow wetlands, sub-surface flow wetlands and hybrid systems which incorporate both surface and sub-surface flows. Wastewater treatment have been done using constructed wetlands for more than 60 years. Israel was probably the first nation to put its CWs in operation in 1950. Germany was the first country in Europe to initiate the experiment in wastewater treatment by wetland plants.

Studies investigated by Chazarenc et al. (2003); Kadlec & Wallace (2009) indicate that performance of treatment systems with vegetation are higher than without vegetation. Kvet et al. (1999) illustrated that the wetland vegetations, removed nutrients upto 20% and the plant uptake depends on climatic condition and type of vegetation. Tang et al. (2009) reported his experimental results conducted with Jinhe river water in Tianjing. The wetlands planted with vegetation showed higher removal percentage of
ammonium nitrogen, nitrate nitrogen, total nitrogen, soluble reactive phosphorus and total phosphorus than that of the unplanted wetlands. Significant increase in removal of ammonium nitrogen was 17.18%. The study reported that unplanted wetland system limited the removal of ammonium nitrogen whereas performance of wetland with *Typha latifolia* resulted in 21.78% removal of total nitrogen.

The treatment potential of Alfred municipal lagoon in Ontario was evaluated (Cameron et al 2003). The study reported that pilot scale surface flow constructed wetland was able to treat 5% to 15% of flow entering the lagoon. The treatment efficiency achieved for a flow of 57.3 m$^3$/d with hydraulic retention time of 15 days are BOD (34%), ammonia (52%), total phosphorus (90%) and *E.coli* (58%). The growth of nine aquatic plant species in the constructed wetland in Beijing region, northern china was studied in the context of pollutant removal. The removal percentage of the pollutants in the domestic sewage are found to be COD (95.1%), ammonium nitrogen (87.1%), total nitrogen (85.3%) and total phosphorus (73.6%) which is highly appreciable (Wang et al 2008).

Macrophytes in a CW treatment contributes for reducing organic matter and nitrogen (N). Twenty subsurface flow (SSF) basins with different combinations of plants (*Phragmites communis* or *Typha latifolia*) and substrates were fed with a reconstituted fish farm effluent in a greenhouse experiment in Montreal. The authors found out that removal of organic matter (BOD$_5$, COD) and N were superior under strong plant cover, because of a healthy microbial population (Naylor et al 2003).

Uptake of P by cattails at the end of the growing season had removed about 40% and 45% of the P mass input under primary and secondary effluent conditions respectively (Weng et al 2006). A laboratory-scale study at the University of Saskatchewan for P uptake by broad-leaf
plants (*Typha latifolia*) growing in gravel substrate was done. P concentrations of the synthetic wastewater at which cattails were fed were representative of primary and secondary municipal sewage effluent. The authors reported that adsorption of P to the gravel substrate and other fine sediments removed about 43% and 56% of the P mass under the primary and secondary effluent conditions, respectively.

2.5.1 Comparison of Subwet with other Predictive Models

Modelling the performance of the natural wetlands is a challenge and is constrained by the limited options that are available for the purpose. The natural wetlands as the name suggests, are naturally formed and hence the details regarding the engineering aspects of the wetlands like the depth, flow rate and the influential path of the flow are not easily available. The non-availability of these details makes it difficult to apply an engineering model to evaluate the performance of the wetlands. There are very few models which can be used for modelling the performance of the wetlands. One of the option that is available and that is simple to apply is the “Rule of Thumb” (Empirical model). This model is based on the observed data and is considered to be least precise with high degree of uncertainty. As it takes into account the observed data like type of the wastewater, climatic condition and other parameters to model the performance of the wetland, this model can be used only after extensive calculation and the designs that have been based on the anticipated results (Rousseau et al. 2004).

The other option that is available is the first order kinetic models or two dimensional or three dimensional models. This model consist of first order equations and is based on areal rate constant (k), flow rates and the concentration of the wastewater in the wetland. The parameters K, C* and θ aggregate many other characteristics representing the complex interactions in the target wetland and the external influencers like weather conditions. Using
the parameters this model predicts the exponential profile between the inlet and outlet for the given ideal plug-flow behavior and constant conditions (Kadlec & Wallace 2009). Most of the rate constants used in this model have been developed using the data from constructed wetlands in locations in warmer climate.

The other advanced models like HYDRUS, WASP, TABS-2, STELLA use parameters that are not commonly available in the natural wetlands are compared by Chouinard (2013). The default values that are considered in the model do not represent the realistic conditions of the natural wetland. Hence the resulting outcome from the model is not precise and not reliable for the natural wetlands. The majority of the wetland treatment method depend on relationship and regression between the input output data instead of the data that represents the dynamic processes in the wetland. In spite of this shortcoming, regression equations are very useful and effective in interpreting and applying the input output data. The models that depend on the regression, tend to aggregate the complex processes to two or three parameters to arrive at an outcome. Moreover these regression equations depend on the concentration of the wastewater that rely on both hydraulic loading rates and the concentration of the influent. Due to this limitation, for predicting the maximum hydraulic loading rates for the given influent concentration, only those regression equations which relates the hydraulic loading rate and the influent concentration can be used in the modelling (Rousseau et al. 2004).

The SubWet 2.0 model is a user friendly software package designed to simulate the treatment of wastewater within subsurface horizontal flow wetlands. This model was originally developed by the United Nations Environment Programme - Division of Technology, Industry and Economics-International Environmental Technology Centre (UNEP-DTIE-IETC). The
model is distributed as free-ware by the United-Nations and can be found on the home web page for UNEP-IETC. SubWet was developed for both cold and warm climate applications with both artificial and natural wetlands.

Compared to the first order equation models and the 2D / 3D models, the SubWet is a good compromise as it considers 16 rate constants and some of the rate constants can be calibrated to simulate the actual site condition. The calibration processes accommodates some of the processes of the wetland to derive the data that is not available for the wetland. The calibration of some of the rate constants is needed to predict the treatment of BOD, organic nitrogen, ammonium, nitrate and total phosphorous. The accuracy of the prediction from the SubWet model shall increase with the data availability.

Chouinard et al. (2014) presented cases studies on two natural treatment systems in Tundra. SubWet 2.0 wetland model was applied to predict and assess the results of management options on treatment potential of natural wetlands. The study analyzed different hypothetical scenarios like influence of pre-treatment, temperature changes, land development, wastewater strength and flow rates on the treatment potential. The study concluded that pre-treatment reduced BOD and ammonium significantly from 10.5 to 5 mg/l and 1.1 to 0.1 mg/l respectively. Inspite of increase in flow by 3 to 5 times, the BOD of effluent concentration remained below 25 mg/l. Decrease in temperature, resulted in poorer treatment of BOD. Reduction in wetland size by 35% increased effluent BOD while ammonium, nitrate and phosphorus remained acceptable.

2.6 ROLE OF INSTITUTIONS IN WATER RESOURCES MANAGEMENT

The sustainability of tank ecosystem rely on its multiple and diversified uses by interacting between human, land and water. Maintenance
of it is based on the integrated management of command area, tank area and network of channels. Involvement of local people in the form of farmer’s institutions in planning and implementation of development works along with panchayats would help sustaining multiple uses of the tanks. Such institutions will perform the advisory role in shaping the conservation movement of tanks. Awareness, education and research on tank ecosystems at all levels can be done to educate the institutions (Dhan foundation 2004)

The performance and characteristics of locally managed tank institutions were evaluated using six indicators namely institutional performance, tank contribution to livelihood, enabling conditions, agricultural performance, objective based impacts and institutional sustainability. The study concluded that the powerful, equitable and cost effective tool to alleviate the rural poverty is to rejuvenate and renovate the tank with people’s active participation. Further it emphasized the role and responsibility of government and the farmers in maintaining the tank by building institutions involving all the stakeholders and setting clear protocols for future rehabilitation and maintenance (Sakthivadivel et al 2004). The determinants of farmer’s participation on water management and its impact on tank performance were analyzed in two districts namely Madurai and Sivagangai. The study concluded that returns from tank irrigation can be increased if farmer’s participation in the form of water users association is significant. The study recommended that village panchayat and NGOs (Non-governmental organization) in the region should take adequate efforts in capacity building initiative and strengthening the social capital in the tanks (Nandhakumar & Palanisamy 2010)

The stakeholders involvement helps in achieving millennium development goals (like goals-7, target 9 and target 10). The government plans get diluted while implementing and monitoring them. Farming
community should be involved at all the stages from planning to implementation. On action, plans should be in such a way that farming should be made remunerative so that farmers could gain confidence in adopting the techniques and technologies recommended by the government with greater accountability attached to the government (Gurunathan 2012).

National water policy 2002 provided guidelines towards institution building and conserving water resources through participatory approach. A case study analysis was performed in Kondakarla Ava wetland, which is the economic backbone for 17 villages with various ecosystem services like irrigation, fishing, washing, cattle rearing and rich flora and fauna biodiversity. The study pointed out that there exist dispute between irrigation department and fisheries department. The participatory governance structures comprising of all the stakeholders of wetland users’ villages are formed and the coordination was restored (Narayanan & Chourey 2012).

Similarly Vembanad Kol, a wetland located in Kerala, is ecologically structured for its mangrove patches and a habitat for migratory water fowl. The major livelihood activities are agriculture, fishing, coir knitting, lime shell collection, shrimp and crab farming, tourism, inland navigations and sand mining. There was conflict of interest between the department of agriculture and fisheries. Though the regional agricultural research station is responsible for monitoring salinity intrusion in the lake and Kerala water authority is responsible for closing the gate, the political parties follow their own rules and thus there was a failure in coordination. Finally Vembanad Kol authority was established to promote education, public awareness, monitoring evaluation of activities. The study concluded that local NGOs like WWF India and ATREE have created awareness and helped in institution building to resolve the conflicts.
Chilika lake, situated in Orrisa, a largest lagoon in Asia is fed by the rivers Mahanadi, Rushikulya and Bhargavi. With rich bio diversity and ecological characteristics, livelihoods of 14 villages are sustained with capture fisheries. The practice of culture fisheries started with rise of shrimp culture that hampered the lease of fishing rights and triggered conflict. Chilika Development authority (CDA), was created by government of Orissa to protect the lagoon ecosystem and to coordinate multiple institutions for a sustainable resource management. Thus a new lagoon mouth was created which improved its hydrology, reduced silt loading from the catchments, increased fish captures, decreased weeds and improved bio diversity. The CDA lacked the mechanism for local people’s representation, though the local NGOs tried to take part the CDAs which is dominated by the politicians, sidelined them and hence needs solution.

Salient features of National water policy 2012, relevant for the present study can be summarized as follows “(i) local governing bodies like Panchayats, Municipalities, Corporations, etc., and Water Users Associations, wherever applicable, should be involved in planning water resources projects and the same should be managed with community participation, (ii) IWRM taking river basin / sub-basin as a unit should be the main principle for planning, development and management of water resources. The departments / organizations at Centre / State Governments levels should be restructured and made multi-disciplinary accordingly, (iii) appropriate institutional arrangements for each river basin should be developed for monitoring water quality in both surface and ground waters and (iv) states should be encouraged and incentivized to undertake reforms and progressive measures for innovations, conservation and efficient utilization of water resources”.

2.7 IWRM FOR SUSTAINABLE ECOSYSTEM

As per GWP (2000) IWRM is defined as “a methodology that promotes the coordinated development of land, water and related resources
in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Three main goals of IWRM are (i) maximizing economic efficiency of water use in response to increasing water demands, (ii) equity in basic access to water resources, (iii) Environmental and ecological sustainability in managing the water resources and utilizing the ecosystem services. The goals of IWRM can be achieved by (i) enabling a framework that comprises policies, legislations, regulations and information, (ii) framing the institutional roles and functions of all the stakeholders and administrators and (iii) finding the operational instruments for monitoring, regulating and enforcing the decisions.

IWRM considers water and ecosystem as an integral part of the management agenda (Steiner, 2009). Hence instead of creating separate frameworks and institutions, IWRM improves the management of water resources and in turn the multiple ecosystem services at the watershed scale. In order to integrate ecosystem services (ESS) with IWRM, it is important to understand and evaluate ESS by involving stakeholders. IWRM links human needs and the ecosystem services that are delivered.

The river basin planning need to be done with an ecosystem perspective. In achieving integrated water resource management, institutional support and capacity building are very important. The local governments called panchayats need to be empowered all over India such that the small watersheds be scientifically managed by these local level government (James 2010). The author also suggested that the larger projects can be managed by the elected groups, from the watershed committees of the panchayats which would ensure coordination and participation of stakeholders. A strong institutional support is indeed essential to achieve governance system supporting integrated resources management to ensure an environmentally and socially sustainable development (Falkenmark et al 2007).
Link between IWRM and water efficiency planning processes in achieving the millennium development goals like eradicating poverty, major diseases and to attain environmental sustainability in the developing countries was studied by Jønch - Clausen (2004). The study emphasized that poor management of water resources resulted in loss of health, environment and economy. The study listed that countries like Uganda, India, China, Nicaragua and others have already integrated IWRM in their water laws and policies. The role of United Nations Educational, Scientific and Cultural Organization (UNESCO) in sustainable water resources management in the Arab world was studied by Al - Wesbah (2002). Economic growth of many Arab countries are impeded due to increasing water scarcity. Institutional development was reinforced with capacity building, water education and training. To prevent and resolve conflicts the water users are educated with social and ethical views. Methodologies are framed and implemented to protect groundwater and surface water against deterioration of quality and over abstraction.

Integration of social science and eco-hydrology approach helps in water policy implementation. Lemos et al. (2007) emphasized that UNESCO’s eco-hydrology program needs to be integrated with the social science. The knowledge from households to public policy systems are essential for decision makers. The participatory planning process to understand the stakeholder’s participation are essential to obtain meaningful results for decision making and innovation in water management.

Water policy should be framed on a comprehensive understanding of how the water economy actually functions, with complete, numerous institutional arrangements that communities have devised to serve their own ends. Close monitoring should be done to understand what works on the ground and what does not; and devise indirect policy instruments to attract or
compel private institutional arrangements to serve public policy goals. It should also be borne in mind that as the world’s largest user of groundwater, India’s water economy has a unique dynamic of its own which demands a unique strategic response. Shah and Van Koppen (2006) in their study pointed out that as India urbanises and gets richer, highly formalised segments would emerge in cities. To manage the demand of these formal segments, ideal IWRM framework has to be formed and pursued vigorously to safeguard our water economy.

According to UNDP, IWRM requires spatial focus on hydrological units like river basins for initiation of any experimentation and then implementation of the same successfully (Taylor et al. 2008). Harsha 2012, pointed out that in India, the very spatial focus is distorted in several parts of the country. In the present scenario, policies applied on bits and pieces of river basins contradict the hydrological unit concept and intended integrated basin planning. The reason why policies are applied in bits and pieces is that not all river basins or hydrological units in India are under the control of the government completely – a fact ignored by Indian water policies. As per the Annual Report of the Ministry of Home Affairs, Government of India (2010–11), in several parts of the country, even after 60 years of independence and democracy, governance structures are absent; and as a consequence there exist several functional inadequacies hindering initiation of development work. With these functional inadequacies, the existing water management models like IWRM and IRBM are an obstruction for achieving the objectives demanded by multiple development sectors like agriculture, energy, industry, health, transportation, communication, and fulfilling the objectives of the social sector and environment, finally effective water management. Not able to implement water management models means limitation on sustaining the economic growth in future.
In India, IWRM have to be strengthened by making and implementing appropriate laws. However, operationalizing and implementing the IWRM approach in practice, is a big challenge. Insufficient networking and collaboration between the different government departments and the practices of different water-use sectors is the major reason behind the non-implementation or limited successes of IWRM in India. For instance, rather than estimating total water availability at a place, surface water and groundwater are assessed separately in India. In addition, about a dozen different ministries look after the different aspects of water management, with little cooperation among them. To make the concept of IWRM implementable, the difficulty in integrating the actions of different sectors (agriculture, energy, environment, etc.) has to be overcome. The IWRM process should be driven by local interests and should address real needs without which it cannot work (Dzwairo et al. 2010). IWRM could be one of the best approach to overcome the adverse impacts of climate change, land-use/land-cover changes and demographic drivers (Jain, 2012).

The International Water Management Institute (IWMI) analysed challenges that are faced by IWRM in developing countries and reported that what usually gets passed-off in the name of IWRM at the operational level, is a rather narrow view of the philosophy. According to IWMI 2007, “some reasons behind ineffective IWRM in developing countries with particular reference to India are: (i) the uniquely informal nature of developing country water economies; (ii) transformation of informal water economies with overall economic growth; (iii) institutional environment versus institutional arrangements; (iv) Interventions with poor implementation efficacy; (v) promising but transaction-costly interventions and (vi) vibrant but ignored institutional innovations. For effective IWRM, it is necessary to overcome the above drawbacks and fragmentation in water management at the central
government and state government levels. All decisions related with water, from supply to treatment, should be taken and implemented in a coordinated manner”.

Reddy and Char, 2006 analysed the gap and illustrated few steps to bridge the same between the lake restoration plans and IWRM. The management of lakes which is still considered, from environmental angle only depends on MOEF at the National level and with the state level organizations for their restoration activities. There is inadequate recognition that IWRM is very essential at the Basin level to ensure environmentally sustainable lakes and reservoirs, knowing that these water bodies cannot be isolated from their drainage basin. The author suggested that way forward for better management of the lakes, reservoirs and tanks in the country could be achieved by evolving strategic integrated management action plans with the guidelines issued by MOEF. The first step is to survey and invent arise all water bodies and categorize them, as per their utility, problem and region to enable impact analysis of ecosystem and evolve suitable restoration works for problem lakes. The surveys should cover Post Project Evaluation and Hydrological studies of the lakes, as part of the drainage basins. The next step is to initiate action on IWRM with specific emphasis on lakes and reservoirs at the basin or sub-basin levels. Lake Management should be a subset of IWRM at the basin level. Permanent solution depends on Institutional restructuring for effective governance. The components which need to be addressed are a) enabling environment and b) Institutional frame work.

2.8 SUMMARY

The literatures reviewed above indicated that tank systems are important socio-economic assets. Most of the tank systems are stressed due to anthropogenic activities like encroachment in and around tank, discharge of
untreated wastewater, poor maintenance and management etc. Thus water quality of tanks and lakes is getting deteriorated day by day. Physicochemical analysis helped to monitor the health of water resources. As tank systems provide ecosystem services that support many livelihoods, their revival are important from sustainable point of view. Water resources plays an important role, as a natural wetland in assimilating the waste that are discharged into them. While treatment wetlands are efficient and economic way of treating all types of wastewater, in India practice of it for restoring large tanks is very little. Hence to fill this gap the tank restoration works need to be done by constructing a wetland treatment system in the tank catchment area. The treated wastewater that enters the tank will maintain a healthy ecosystem. Institutions and stakeholders at the tank level should be capacitated to get an integrated solution. To accomplish this, at the tank level all the stakeholders need to be involved and capacitated.