CHAPTER 7
SUMMARY AND CONCLUSION

Water resources are dwindling very fast in recent years as the demand has been steadily increasing several folds on various accounts. The growing crisis on the availability of fresh water has been addressed in various fora throughout the world. Recently the water problem has been discussed simultaneously at two different international meetings held in the month of March 2003 in Japan and Italy. The major problem discussed in both these meetings has been about the severe shortage of adequate quantities and qualities of clean water particularly for drinking and sanitation. One of their suggestions has been to find out new ways for the extraction of more groundwater safely and environment friendly. Areas far away from river courses and in hard rock terrains, groundwater are the only source for drinking water that leads to over exploitation.

The present investigation on the Muvattupuzha river basin is an integrated approach based on hydrogeological, geophysical, hydrogeochemical parameters and the results are interpreted using satellite data. GIS has also been used to combine the various spatial and non-spatial data. The salient findings of the present study are accounted below to provide a holistic picture on the groundwaters of the Muvattupuzha river basin.

In the Muvattupuzha river basin the groundwaters are drawn from the weathered and fractured zones. The groundwater level fluctuations of the basin
from 1992 to 2001 reveal that the water level varies between a minimum of 0.003 m and a maximum of 3.45 m. The above water level fluctuations are almost a constant all over the years when compared to the adjoining Periyar river basin. Based on the water level data the basin is divided into a negative zone or discharge area (western part of the basin), which covers more than 70% of the study area, and a positive zone or recharge area covering the rest of the area mainly on the eastern part of the basin. The average annual rainfall of the basin is 2677 mm. The groundwater level fluctuation and rainfall show good relation, which means that the groundwater fluctuation is affected by rainfall.

Various aquifer parameters like transmissivity, storage coefficient, optimum yield, time for full recovery and specific capacity indices are analysed. The transmissivity values obtained from sensitivity analysis vary from 4.51m²/ day to 225.63m²/ day with an average of 68.81m²/ day. Transmissivity shows a general increase towards the southwestern part of the basin. Storage coefficient obtained from sensitivity analysis ranges from 0.012 to 0.393 with an average of 0.241. The high storativity on the southwestern part of the Muvattupuzha sub basin is related to the occurrence of Miocene formation and presence of large number of irrigation canals. In this basin the optimum yield varies from 0.9m³/ day to 50.1m³/ day with an average value of 14.29m³/ day. Relatively high values are observed in the southwestern and north central parts of the basin. These areas are suitable for well development.
The analysis on the time required for full recovery indicates that the maximum value of 68.55 h is recorded in the western part of the Kothamangalam sub basin at Kozhipalli while the minimum of 2.7 h in the southern part of the Thodupuzha sub basin at Kolani. Based on this it is found that an increase in the radius of wells in crystalline terrain will reduce the time for recuperation. The highest Slichter's capacity indices are recorded in the central and the northern parts of the Thodupuzha sub basin and the southwestern part of the Muvattupuzha sub basin. Based on the Slichter's specific capacity indices it is found that the specific capacity indices of dug well are controlled by the equatorial radius rather than the lithology of the basin.

Based on the VES analysis the general sequence of high resistivity is in the first layer consisting of dry lateritic soil followed by low resistivity layer (fractured and or weathered saturated zone) and again high resistivity layer (massive rock). Most of the sounding curves obtained in the basin are H type and different combinations of H type. Also resistivity contour map of the second layer of the basin depicts hydrogeological condition of phreatic aquifer; a resistivity value of below 500 ohm -m is considered as good prospective zone for ground water.

The depth to the bedrock of the basin varies widely from 1.5 to 17 mbgl. A ground water prospective map for phreatic aquifer has been prepared based on thickness of the weathered zone and low resistivity values (<500 ohm-m) and accordingly the basin is classified into three phreatic potential zones as good, moderate and poor. The southern part of the Muvattupuzha sub basin
and few pockets in the Kaliyar sub basin are identified as good prospects zone though limited in areal extent. Certain promising stations have been identified from vertical electrical sounding analysis (st. 2, 7-9, 11, 12, 15, 16, 18, 19, 24, 29, 30-32, 35-37 and 40) for drilling medium to deep bore wells that can be made up to third or fourth layers in view of moderate resistivities (≈ 200 ohm-m).

The groundwater of the Muvattupuzha river basin is acidic in nature as the pH value ranges from 5.5 to 8.1. A major part of the study area during pre and post monsoon seasons show pH values less than 6.5, which is below the values prescribed by WHO and ISI. The groundwater of the basin is having low electrical conductivity (av. pre monsoon - 97.9 µS/cm and post monsoon - 69.2 µS/cm), low total dissolved solids (av. pre monsoon - 40.0 mg/l and post monsoon - 61.7 mg/l) and low hardness (av. pre monsoon- 23.8 mg/l and post monsoon- 19.3 mg/l), which are within the potable limits of WHO, ISI and EEC. So the water is good for other domestic consumption, irrigation practices and industrial uses particularly for low-pressure boilers.

The total iron content in the western part of the basin is more than 0.3 mg/l indicating contamination in ground water and this is mainly due to leaching of iron from laterite under low pH condition. The fluoride content of the basin is very negligible; the maximum value of 0.4 mg/l has been recorded during pre monsoon season.

Durov's diagram indicates that over two third of the pre monsoon samples have shifted towards the mixing zone during post monsoon, however, about 31% of the samples do no show any shifting. The trilinear diagram shows
that the groundwater of the pre monsoon are \( \text{CaCl}_2 \), \( \text{Ca(HCO}_3\text{)}_2 \), and \( \text{NaCl} \) types whereas in the post monsoon the water types are \( \text{Ca(HCO}_3\text{)}_2 \), \( \text{NaHCO}_3 \) and \( \text{NaCl} \) and this is due to the shift of samples towards the zone of bicarbonate and sodium. The overall increase in bicarbonate again attributes that the groundwater is recharged by rainfall so that it plays a vital role in the groundwater chemistry of this basin.

Hydrochemical facies diagram reveals that most of the samples in both the seasons fall in mixing and dissolution facies and a few in static and dynamic regimes. Indicating an overall shift of pre and post monsoon samples from static regime to mixing and dissolution zone of the facies diagram. Thus it is concluded that mixing and dissolution plays a vital role for shifting one facies to another. It is clear from the facies diagram groundwater is having neither too much in contact with the rock nor in a dynamic condition.

In general the percentage of Na in groundwater is at a bearable limit (< 10%). However, a few pockets show high Na percent, but within the standard limit and is attributed to the use of fertilizers. U.S.S.L. diagram clearly indicates that most of samples fall in CISI field and a very few in C2SI indicating low salinity/low sodium alkali hazard. Likewise the concentration of Residual Sodium Carbonate (RSC) in the study area is within the limit (<1.25 meq/l). These indicate that the groundwater of Muvattupuzha river basin is good for irrigation.

A corrosivity ratio of <1 is considered as a safe zone. During pre monsoon more than 70% of the area comes under safe zone, but in the post
monsoon period the areal coverage of both safe and unsafe zones are equally distributed. It is therefore, recommended that PVC pipes will have to be used for water transportation in those areas falling under unsafe zone.

Based on Gibb’s diagram it is concluded that the groundwater chemistry is primarily controlled by precipitation rather than lithology and the above finding is substantiated by trilinear facies diagram in which most of the samples fall around dissolution and mixing zone. The mixing in this basin is characterized by high rainfall and seepages from canal network.

Hydrogeomorphological map prepared from the satellite data exhibits nine geomorphic landforms. Among the major landforms, the valley fills are proved to be the best landform for the occurrence of ground water quantitatively. By the integration of various thematic maps the ground water potential zones of the basin is classified into four categories viz., (i) very good, (ii) good, (iii) moderate and (iv) poor. The structural hills on the eastern part of the basin are characterized by poor groundwater prospect and this is due to steep slope and high drainage density. The southwestern part of the Muvattupuzha sub basin comes under the category of very good and is matched well with the high optimum yield and storage coefficient. The groundwater prospect map indicates that the down stream part of the Muvattupuzha river basin is good prospect zone than the upstream part.

The current landuse pattern of the study area have been demarcated into 20 classes and the major landuse pattern in the area is rubber plantation followed by mixed plantation, evergreen dense and open forest etc. Based on
the NDVI analysis it is concluded that more than 60% of area is having a good vegetative status and also it is evident that the southwestern part is in better health status than the rest of the area.

A strong database on the hydrogeology of the Muvattupuzha river basin is generated by integration of spatial and non-spatial data using Arc/Info. The above data could be used for information extraction and base line inventory for future sustainable development.

The major conclusions drawn from this study are:

- The movement of groundwater is mainly controlled by topography, lithology and lineaments and the basin experiences a low level of water fluctuation.
- Based on aquifer parameter analysis the southwestern part of the basin is having very good prospect zone with high optimum yield, low time for recuperation and high storage coefficient.
- Resistivity analysis indicates that the Muvattupuzha sub basin is having good groundwater phreatic potential zone and certain promising zones for medium and deep bore wells in the entire basin.
- Geochemically the groundwater is good for all domestic, irrigational and industrial uses because of low content of EC, TDS, total hardness, fluoride, major cations (Na+, K+, Ca++ and Mg++) and anions (HCO₃⁻, CO₃²⁻, SO₄²⁻ and Cl⁻). The salinity and sodium alkali hazards are also low.
• The significant environment, which represents the chemical characteristics of the groundwater is dissolution and mixing rather than static and dynamic conditions.

• The prime mechanism controlling the groundwater chemistry is precipitation; lithology and evaporation play only a minor role.

• Integrated study reveals that among the four sub basins, the Muvattupuzha sub basin is having good groundwater prospect zone.

• Based on various status and other integration study it is clear that the groundwater condition of the Muvattupuzha river basin is highly satisfactory.

Further study is needed on:

➢ Impact of dykes on the occurrence and movement of groundwater.

➢ Impact of seepages from irrigation canals on the groundwater quality and resources of this basin.

➢ Influence of inter-basin transfer of surface water (from Periyar to Muvattupuzha basin) on groundwater.