The primary objective of this study has been the development of stochastic models for forecasting and to use GIS in management of river water quality. Reliable forecast of river water quality can help the management of river basin to keep the various pollutants within the permissible limits. Since the concentration of the quality variables is dependent on the quantity of flow, it is likely that these variables have a persistence structure as well as the effect of seasonality in them as observed in flows. The review of literature shows that some studies have been attempted to mimic such behaviour through use of time series models, no systematic study covering the various possible aspects is available. In view of which, this study to develop forecasting models for water quality parameters recorded monthly at ten typical locations along the river Ganges has been attempted. Based on the availability as well as their importance, parameters under three categories viz. the physical parameters such as temperature and pH; parameters describing mineral constituents such as chlorides and electrical conductivity; and parameters indicative of organic pollution such as DO and
BOD, observed between the years 1981 and 1990, have been used in this study.

6.1 CONCLUSIONS

The following are the conclusions drawn from the present study:

1. Four of the six water quality parameters viz. temperature, pH, electrical conductivity, and DO were generally normally distributed except for one or two stations. However, the chlorides and BOD were skewed and not normally distributed at most of the stations with coefficient of skewness varying from 1 to 8.

2. Most of the stations did not show any significant trend in the water quality parameters. Marginally increasing and decreasing trends were detected at only a small number of stations. At some stations the observed decreasing trend in water quality parameters may be attributed to the preventive measures taken for the abatement of pollution under the Ganga Action Plan.

3. Study undertaken to detect any possible intervention in the data series, capable of causing either a decrease or increase in mean levels, did not show any significant change.

4. Most of the water quality parameters showed seasonal patterns. This pattern in water quality may be due to the influence of annual cyclic pattern of the hydrological inputs to the river water environment.

5. Analyses of these data using an ARIMA model framework such as correlogram structure, minimization of sum of squares of the residuals.
diagnostic checks (Portmanteau Q-statistics, residual autocorrelation function and Akaike information criteria) indicated that the models having both nonseasonal and seasonal components were, in general, appropriate for modelling the water quality time series at all the stations.

6. A procedure for modelling of possible persistence structure in the data after removal of seasonality by the Fourier Series has been attempted. It was found that in general first harmonic or first and second harmonics represented more than 95% of the variance of means and about 40% of variance of total series. The lower order nonseasonal ARIMA models adequately described the persistence structure of the stochastic component of the water quality parameters.

7. Sets of Thomas-Fiering models developed for forecasting purposes are given in Tables 4.33 to 4.42, which can be used for the purpose of long term forecasting and simulation.

8. Error estimates of forecasts from the three different approaches have been compared and it was found that for temperature, pH and DO the results were satisfactory in all the approaches. It was observed that Thomas-Fiering model failed to model the chlorides and BOD data and it could also not adequately fit electrical conductivity data. Multiplicative ARIMA model and deseasonalised model provided satisfactory forecasting results for all the water quality parameters. However, from the point of view of over all error estimates, the deseasonalised model with a Fourier Series technique
performed better and is, therefore, recommended for forecasting of water quality parameters of the river.

9. A GIS database has been created, in which water quality data and the results of analysis/forecast have been linked as attributes and hypertext to spatial features. The data required for planning and management of river water quality can be easily accessed through readily available query options.

6.2 SPECIFIC CONTRIBUTION

A few studies were attempted in the past for forecasting of water quality using either of the three different approaches of stochastic modelling viz. (i) Multiplicative ARIMA model (ii) Deseasonalised model and (iii) Thomas-Fiering model, for one or two parameters. However, no comparative study of the three approaches is available in literature. Further, the models have been developed for Western countries and may not be applicable in India due to diverse climatic, economic, physical and cultural conditions. In the present work a comparative study of the three approaches have been performed using real life data of river Ganges. The most suitable model has been identified for the purpose of reliable forecasting. Further, a GIS database has been developed for the spatial variations in water quality data of river Ganges. This study is expected to be useful for effective planning and management of the water quality of river Ganges.
6.3 SCOPE FOR FUTURE WORK

The scope of the future work in the area of stochastic modelling and GIS in river water quality management is given below:

1. The application of Artificial Neural Networks to forecast the water quality parameters of a river may be studied and the results may be compared with those of the other available methods.

2. The GIS database may be interfaced with modelling and forecasting of river water quality.

3. Other water quality parameters may be included for modelling and forecasting of river water quality.