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Time Series Analysis for Water Inflow

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***Abstract*—The main sources of water are natural sources like rainwater, oceans, rivers, lakes, streams, ponds, springs etc., and man-made sources like dams, wells, tube wells, hand-pumps, canals, etc. Agriculture and plantation depends heavily on water and its source is rainfall. Mathematical models are required to predict future water demand and climate changes. Time series are valuable sources of information that can be consulted for the characterization of variables in several areas of knowledge. It is basically a measurement of data taken in chronological order within a certain time. In hydrology, such series are employed in water systems management as tools for the hydrological cycle understanding. The purpose of most water quality and stream flow studies is to point out the information and necessary knowledge to manage water resources as well as their use, control and development. This paper uses a statistical approach to analyze Cauvery water inflow into Karnataka Reservoir. Data used in the study is taken on a monthly basis during the period from 1974 to 2014.**

Keywords—Water Management, Water Inflow, Time serier Analysis, ARIMA model

I. INTRODUCTION

Water, once an abundant natural resource, is becoming a more valuable commodity. Climate change, redistribution of annual rainfall, more frequent occurrence of hydrological extremes in the form of floods and droughts are all phenomena that have a major effect on the management of water resources. Worsened conditions of outflow from the landscape causes a decrease of values of long term mean flow rates in the river network and a long term decrease of underground water sources. The hydrological regimes in river basins are affected because of this [1]. Water management is the management of water resources under set policies and regulations. The availability of water resources depends on water inflow, the consumption of water, pollution, extreme events such as droughts, land-use change, climate change etc. Water resource management is the activity of planning, developing, distributing and managing the optimum use of water resources.

Time series analyses is used in water resources engineering because many characteristics of water bodies, streams and groundwater resources as well as lakes and seas can be defined using time series of data. It helps in understanding and modeling the process of a phenomenon through which the past observations are generated [2]. In order to analyze complex water resources systems forecasted time series are used. Many possible hydrologic conditions and operational strategies can be expressed using generated series. In order to evaluate real system operation known historic observations are used [3].

This paper aims at a time series analysis of Cauvery water in Karnataka. In particular time series of data is plotted to find any possible trend. Using ARIMA model future water inflows is plotted. We would like to use the data for water management analysis and for model based statistical inference of environmental systems that account for the need of using prior information, input and model structure uncertainty. In order to analyze the water inflow the average wet weather flow can be estimated from water flow data. Water inflow is defined as the water other than sanitary wastewater that enters a sewer system from sources such as roof leaders, cellar/foundation drains, yard drains, area drains, drains etc.

Cauvery is one of the sacred rivers in South India. Rising from the Western Ghats range of Karnataka at Talakaveri the river usually runs in a southeastern itinerary across the states of Karnataka and Tamil Nadu and merges into the Bay of Bengal. The river covers a distance of about 765 km and on its journey to the Bay of Bengal, the river is joined by its tributaries, which include Honnuhole,,Shimsa, Hemavathi, Kapila Kabini, Arkavathi, , Lakshmana Bhavani, Theertha, Lokapavani, Noyil and Amaravathy. “Fig. 1,” depicts the flow of the Cauvery River. The catchment area of Cauvery River has been calculated at 72,000 km2 or 27,700 square miles. For hundreds of years people have been using the water from this river for drinking and farming. It was regarded as the lifeline of the old empires and contemporary urban settlements in Southern India. Irrigation, household usage, and electricity generation are the primary uses of Cauvery water. The river functions as the principal resource of potable water for various villages and townships in cities like Bangalore, Mysore and Mandya. It has many channels carrying water for irrigation use. Water into Cauvery River comes mainly from monsoon rains. The water level is low during the months of February to May, and in a number of distributaries and watercourses, the embankments may get dehydrated. During June or July the discharge usually starts to grow. The two main dams in this river are Krishna Raja Sagara Dam and Mettur Dam which holds water from monsoon seasons and discharges it during the summer months based on the requirements. In 1924 across river Cauveri Krishna Raja Sagara Dam (KRS Dam) was built. It is the main source of water for irrigation in the most fertile Mysore and Mandya region and the main source of drinking water for all of Mysore city and almost the whole of Bangalore city, the capital of the state of Karnataka. The dam is named for the then ruler of the Mysore Kingdom, Krishnaraja Wodeyar IV. The Chief Engineer, Sir M. Vishveswaraya engineered the construction of the dam during the Wadeyar kings regime in 1932.

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Fig. 1 : Flow of the Cauvery River

II. RELATED WORKS

Regression analysis techniques dominated the water demand literature among the different statistical analysis methods. A number of statistical performance indices such as relative error, the coefficient of determination, the percent bias and the accuracy factor were evaluated to study the performances of the developed linear and nonlinear multiple regression models [4]. ARIMA model of Time-series analysis was used by Rao et al., Papamichail and Georgiou, Yurekli et al. to observe runoff and river discharge [3]. Irvine and Eberhardt, Sheng and Chen used it to study water levels in lakes. Hanh et al. used it for modeling sediment yield and erosion. ARIMA model and seasonal modeling was used by McKerchar and Delleur to analyze seasonal characteristics of stream parameters. Zhang forecasted the real data sets more accurately using hybrid of ARIMA and ANN model. Monthly inflows to Jiroft dam was analyzed by Jalal Kamali using time series model. Based on inter annual variability Jassby et al. developed a time series model for Secchi depth in Lake Tahoe. USA [2]. Time series analysis of wastewater inflow into treatment plants based on the current observed values of inflow recorded at regular intervals of time was done by Chuchro. Momani and Naill forecasted rainfall using ARIMA modeling. It consists of an integrated component (d), which performs differencing of the time series to make it stationary, and autoregressive (p) and moving average (q) components. AR component correlates the relation between the current value and the past value of time series. The moving average captures the duration of random shock in the series. Westerberg I.K. et al. studied the uncertainties of flow rates in the hydrometric profile on river basins in Great Britain using Monte Carlo method [1]. For optimal water allocation under vague and fuzzy conditions within the Alfeios river basin in Greece an optimization technique named fuzzy-boundary interval stochastic programming was developed by Eleni Bekri [5]. For calculating and forecasting the water quality index in the surface water of Brahmani river basin in Odisha, Binayini Bhagat and D. P. Satapathy used artificial neural network and they used only six water quality parameters [6].

III. PREREQUISITES

Time series is a sequence of discrete-time data. That is a series of data points listed or graphed in time order. When the data points taken over time may have an internal structure, such as autocorrelation, trend or seasonal variation that should be accounted for, time series analysis comes into picture. Time series models is used for understanding the underlying forces and structure that produced the observed data for forecasting or monitoring. Statistical techniques that deal with time series data is called time series analysis. To study the seasonal variation in water inflow data points taken over time can be used. When there is an equal interval between all data, time series analysis is used. In this paper the interval considered is monthly and yearly. Time series analysis is used to understand and model the stochastic mechanism of hydrologic phenomena and to forecast the future values of the phenomena [2]. The basic objectives of time series is to illustrate the important features of the time series pattern, to understand how the past affects the future or how two time series can interact to forecast future values of the series. Time series forecasting is done with the help of ARIMA. In ARIMA model, AR stands for auto-regression and MA stands for moving average. In ARIMA the non seasonal part is represented using (p.d,q) where p is the number of autoregressive values, d is the order of differencing and q is the number of moving average values [7]. With the help of ARIMA model, we can make predictions on the future time points and find system dynamics information. We can also visualize the trends to cross validate if the model works fine. And we can relate the present value of a series to past values and past prediction errors.

IV. PROBLEM DEFINITION

National Statistical Institutes is instrumental in collecting the data related variety of data sources, which includes: regional or local authorities, environmental administrations and industry, where suitable and necessary methods are applied to perform statistical estimations. Water statistics is collected from the PMP Atlas for Cauvery and Other East Flowing River Basins, Final Report Volume I: Main Report, May 2015. Water flow during 42 years data has been taken from the report. In this paper authors have analyzed the data based on Time series analysis technique using R programming. The auto.arima() function in R uses a variation of the Hyndman and Khandakar algorithm which combines unit root tests. Last 42 years Cauvery water inflow data have been collected and were used to develop flow-duration curves. The internal flow is calculated using precipitation and actual evapotranspiration.

V. RESULTS

Four decades average water inflow into Karnataka Reservoir is depicted in “Fig. 2,” . The inflow volume is calculated using direct and delayed inflow. The area between the storm event hydrograph and the dry weather hydrograph is the total inflow. The average water inflow in million cubic feet is represented in Y axis and the years in X axis. The average water inflow was above 40,000 MCFT for two years. The month wise water

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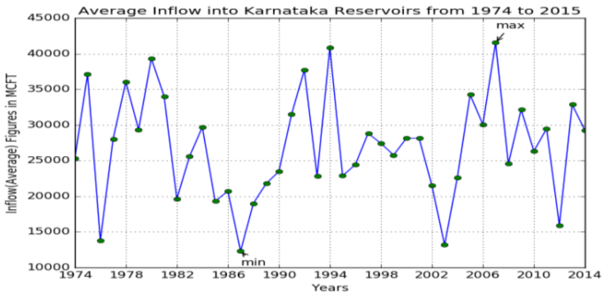
Fig. 2: Average water inflow



inflow for the past four decades is depicted in “Fig. 3”. Water inflow is more during the month from July to December, therefore the forecasts is done for these months. “Fig. 4 to Fig. 10,” shows the water inflow forecasts from ARIMA with non zero mean for different months starting from June to December. The X axis represents the year and the Y axis represents the inflow in a particular month. The month wise trend clearly shows that in few months the water inflow is more and it shows the inflow forecasts for future months in the coming years. The variance and the mean value in July, August and September is much higher than rest of the months. Exploring data becomes most important in a time series model – without this exploration, you will not know whether a series is stationary or not. Using ARIMA model it was possible to forecast the inflows on a monthly basis till the year 2020.

Fig. 3 : Month wise water inflow analysis

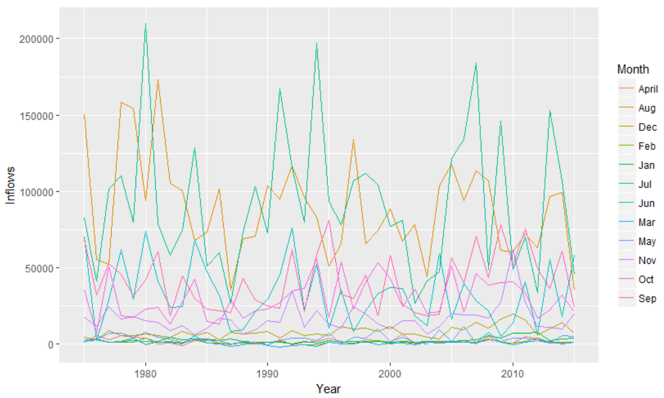


Fig. 4 : Graphical representation of June water inflow

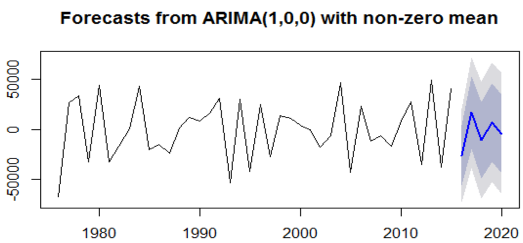


Fig. 5 : Graphical representation of July water inflow

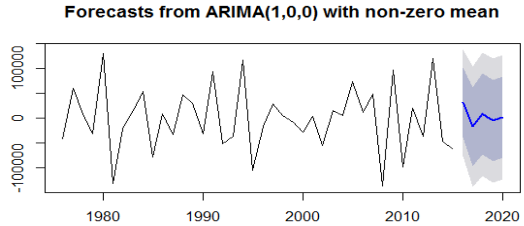


Fig. 6 : Graphical representation of August water inflow

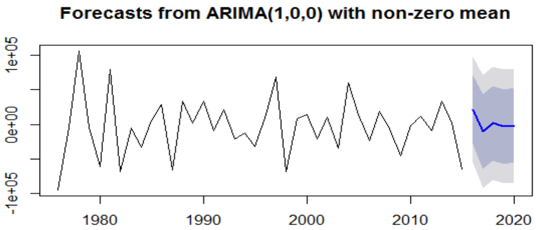


Fig. 7: Graphical representation of September water inflow

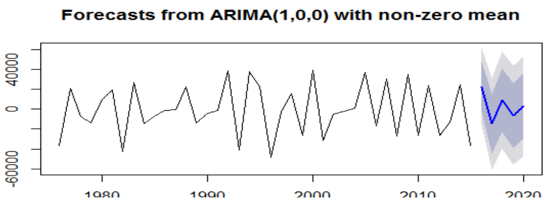


Fig. 8: Graphical representation of October water inflow

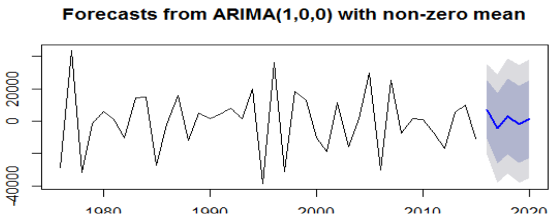


Fig. 9: Graphical representation of November water inflow

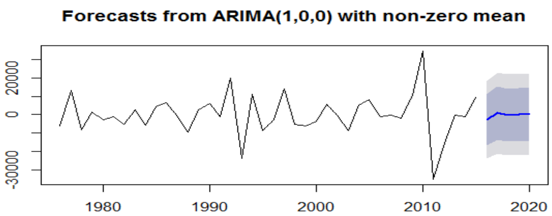


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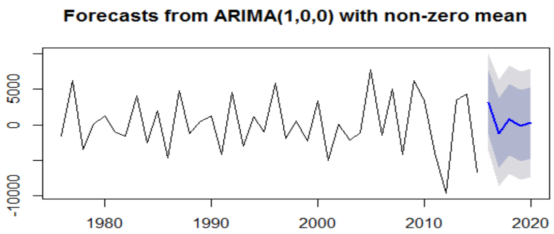
Fig. 10: Graphical representation of December water inflow



VI. CONCLUSION

The results of this study shows that time series modeling is capable of identifying and forecasting monthly stream pattern. June and September are the months where the inflow is more. Traditional methods for modeling time series come from the statistics literature and address the issue of deriving linear models. Although the resulting models are easy to interpret, these modeling methods impose strong limitations, such as the stationarity of the time series, the independence, and normality of the residuals and lack of ability to detect non-linear traits in data. The results of this study showed that time series modeling is capable of identifying and forecasting monthly stream pattern and integrated water resources management.

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