# FORECASTING URBAN WATER DEMAND IN WA MUNICIPALITY

**1.Donatus Nyaaba, 2. John Ayuekanbey Awaab, 3. DuwaraAweh Moses, 4.Tule Clement Kani**
1.Bolgatanga Polytechnic, Department of Statistics, P. O. Box 767, Ghana -West Africa,
2.University for Development Studies, Department of Statistics, P. O. Box 1350, Ghana,-West Africa,
3.Bolgatanga Polytechnic, Department of Statistics, P. O. Box 767, Ghana -West Africa,
4.Zuarungu Senior High School, P. O. Box 133, Ghana -West Africa.

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**Abstract** – The study assessed water demand in WA municipality. The methodology employed time series technique using Box-Jenkins methodology to describe the water demand situation in WA municipality. The findings revealed that water demand are skewed to the left, indicating that most of the values are concentrated at the left of the mean and this means that majority of the values are below the average indicating high water demand in the WA municipality. The peakness demonstrated that a platykurtic has a flattened than normal peak and this suggests that most of the water demands are spread to the extreme sides of the curve also exhibiting high water demand in the WA Municipality . The findings also revealed that ARIMA (1, 1, 0) best fit the water demand in WA municipality. Based on the findings of the study the researcher can conclude that water demand in the WA municipality is likely to experience steady increase from 2019-2021. ARIMA (1, 1, 0) was identified to be the best fit model for water demand situation in the WA municipality. Nevertheless, quadratic trend model was noted to be the best model that described the water demand. The management of Ghana Water Company can resort from Donor countries to come to the aid of the company by donating money or equipment for the improvement of the water demand situation in the urban areas. The government of Ghana should allocate more resources to the water companies in order to acquire water plants so as to increase water distribution in the urban areas.

**Keywords:** Time Series Analysis, Linear trend model, Quadratic trend model, Autocorrelation Function, Partial Autocorrelation Function, Stationarity, Parameter Estimation, Parsimonious model and Differencing.

## Introduction

In this study, results refer to the outcome of the various statistical procedures used in analyzing the data collated and coded. The results served as the foundation for interpretation, discussion and drawing conclusion for the purpose of achieving the research objectives. This chapter is also divided into sub-headings such as summary statistics for water demand and trend analysis of water demand using time series analysis technique.

## Background of the Study

Among all the regular assets accessible to humankind, water holds a noticeable spot, especially in view of its significance for human work sustenance. All individuals, whatever their level of advancement and their social and monetary conditions, reserve the option to approach appreciating water amounts and of a quality equivalent to their fundamental needs (Doe, 2007). Water accessibility, just as the measure of water use is a critical factor for social and financial exercises (Stanhill, 1982). The difficulties confronting numerous nations on the planet today in their battle for financial and social improvement are progressively identified with water. There are still in any event 1.1 billion individuals around the globe who don't approach safe drinking water. Dominant part of these individuals live in countryside regions and are among the least fortunate and most powerless on the planet (IAH Burdon Ground Water Network, 2007).

As per IPCC (2008), the four principle elements maddening the water crisis the world over are populace development and abnormal state of utilization where the world turns out to be increasingly created and the measure of local water utilized by every individual rises essentially. Different components identify with expanded urbanization, which spotlights on the interest for water among a progressively focused populace, and essentially, environmental change, which is contracting freshwater assets.

 

Subsequently, various investigations on water request have been completed in both created and creating nations ( Lamptey, 2010). These investigations are important to plan for the cases of water assets accessibility which is being experienced by numerous countries. The investigation of interest for water (non-consumable and consumable water), accordingly, incorporates rationally determining future dimensions of interest which is a significant and basic advance in the financial examination of water supply ventures (Lamptey, 2010). Lately, the meaning of water request has changed from the sum required by the supply dispersion to the measure of water required by the client (Lamptey, 2010). The water assets required to fulfill customer request are considerably higher than the customer request itself. Spillage when water treatment is a key component. About 22% of water does not achieve the end client on account of spillage in the UK alone (MacDonald, 2007); and in Ghana, it is as high as about half (PURC, 2010). On a nation premise, the interest for water per individual isn't even. For instance, in the UK, Denmark, Spain, and Ghana, the interest is 150, 220, 289 and 140 liters for each capita every day, individually; speaking to changing needs in every nation henceforth conflicting adjustment techniques. The water scarcity situation is severe in developing countries, with an estimate of about 1.2 billion people in 20 "water-scarce" developing countries without access to "safe water"
(Asare, 2004). The World Resources Institute (2000) evaluated that more than one billion individuals in creating nations don't approach clean water while 2 billion need satisfactory sanitation. A lot of worldwide freshwater assets is around 9 %. These water assets are circulated unevenly crosswise over Africa, with western and focal Africa having fundamentally more noteworthy precipitation than northern Africa, the horn of Africa and southern Africa. Africa is in this manner noted to have huge inconsistencies in water accessibility, and the most minimal water supply and sanitation inclusion on the planet. These troubles have prompted risky wellbeing circumstances in numerous districts, where appetite and water related illnesses are customary dangers. On account of Sub-Saharan Africa, Rosen and Vincent (1999) assessed that 67 % of the country populace (around 250 million individuals) need sheltered and open water supply while 81% did not approach sanitation offices. Sub-Saharan Africa is gaining the slowest ground in gathering the Millennium Development objectives (MDGs) target, tries to "split by 2015 the extent of individuals without access to safe drinking water and sanitation" (UNDP, 2005), it is foreseen that Sub-Saharan Africa will just achieve the water focus by 2040 (Sutton, 2008).

As indicated by the Ghana Environment Outlook Report (GEOR) (2006), freshwater covers almost 5 percent (11,800km2) of the complete land region. This is made up for the most part of three noteworthy stream frameworks. The Volta River System, which contains streams Oti, Sissili, White Volta and Black Volta, covers 70% of the complete freshwater assets of the nation. The South Western River System, for example, Birim, Ankobra, Pra, and Offin, takes 22% while the Coastal River System, which incorporate streams like Todzi and Aka, covers the remaining 8% (National Water Policy, (NWP) 2007; Ghana Environment Outlook Report (GEOR), 2006). Opposing Ghana's accessible freshwater assets and different nations like South Africa, Israel, Cyprus, and Australia that are considered as water shortage countries (Global Water Intelligence, 2009), Ghana can advantageously be portrayed as having abundant freshwater assets (NWP, 2007). In any case, gauges demonstrate that by 2015, Ghana, together with different countries in the sub-locale would achieve water focused on status (GEOR, 2006). At the nearby dimension, in both the urban and country territories, there are various individuals without access to consumable water. The issue is firmly identified with insufficient supply, absence of upkeep bringing about broken hand siphons and silted dams just as failure to pay for water in light of absence of salary producing exercises (GEOR, 2006).

Fundamentally, populace development and fixation, quick urbanisation and industrialisation bringing about increment in individual and aggregate needs have made water progressively rare and frequently of low or decreased quality (GEOR, 2006). Notwithstanding these, flow worldwide climatic change procedures are required to influence both the spatial and fleeting unreliability of water accessibility in Ghana (Minia et. al 2004). The water asset base in Ghana, is along these lines, under danger.

For most urban zones in Ghana, the arrangement of safe water administrations remains a basic test, not just for the acknowledgment of the Millennium Development Goals (Goal 7), which look to guarantee natural manageability, yet additionally for neediness decrease (MDG Report, 2006). As per the NWP (2007), the complete interest for consumable water in Ghana is 1967,744 m3/day. The Ghana Water Company Limited (GWCL) supplies 605,469.69m3/day, adding up to 62 percent of absolute interest. Thus, there are not kidding shortfalls in inclusion. Fundamentally, the National Water Policy archive (2007) takes note of that, of the assessed half of Ghana's populace who dwell in urban regions, 90% approach improved drinking water sources. In any case, it is

 

critical to stress that, just about 30% of this approach consumable water, which, by and large, is provided irregularly. The other 60% rely upon other secured sources, for example, standpipes, ensured burrowed wells, ensured springs and water collecting (NWP, 2007).
While supplies have not kept pace with interest, the administration of what is accessible has likewise gone under open investigation. For example, concerns have been raised as to the utilisation of treated water for other reason outside drinking and it is deplorable that notwithstanding these difficulties, numerous individuals still water their yards and wash vehicles with lavishly treated water that different Ghanaians would line to approach (Water Focus, 2010).

The proficient activity and the board of urban water supply framework requires accurate water demand forecasts and the estimation of future urban water demand is critical to the sustainable planning of regional water supply system (Zhou et al, 2002).The resulting issue of water pressure and scarcity are complicated and the firmly coupled interactions of human and natural system of multiple scales pose numerous urban water demand management challenges (House-Peters and Chang 2011)
Long range urban water demand forecasting helps in the planning and design of water supply frameworks, while short term water demand forecasting helps in the operation and management of water supply systems. Momentary urban water demand forecast allows for optimal pump, siphon, well, store and mains operations, balance distribution among urgent water needs and the improvement strategies (Kame'enui, 2003; Herrera et al 2010).

Medium term urban water demand forecasts help water managers more informed water management decisions when balancing the needs of water supply Presidential/Industrial demands. Accurate forecast also aid in decision making such as when to implement regulatory water use restrictions in times of water stress and draught.( Herrera et al 2010).

A comprehension of water demand behaviour notwithstanding the capacity to anticipate it's utilisation would help open substances, for example, Ghana Water Company Limited (GWCL), Community Water and Sanitation Agency (CWSA) and the Water Resource Commission (WRC), and other government establishments and so on to successfully design and deal with the improvement of urban communities, particularly in light of the significance of water in a city's advancement. By comprehension and foresee water use, positive environmental impacts can be produced.

Moreover, doing as such would add to the urban water cycle the management in the different urban areas in Ghana in terms of strategies for the optimal development of drinking water infrastructure, water demand control, the environment and sanitation.

It is accordingly perceived that for an outcomes to be accomplished in adequately overseeing urban water framework, there is the need to device an instrument that can rationally forecast the water demand of the different urban communities in the country based on which informed water the management decisions can be made.
The study is therefore focused on the short, medium and long term forecast of the water demand in the WA municipality as an expansion to the various mediations by the current and successive governments as well as the various organisations in managing the persistent water crisis in the territory.

**Profile of the Study Area**

The WA Municipal is one of the 260 Metropolitan, Municipal and District Assemblies in Ghana and forms part of the fifteen (15) Municipalities and Districts in the Upper East Region with the Administrative Capital as WA . The WA Municipality was established in 2004 by legislative instrument (LI) 1797 and is located in the center of the Upper East Region, approximately between latitudes 10o 30' and 10050' north and longitude 0o 83' and 1o 00' West. It is also the Regional Capital for the Upper West Region.

In terms of water supply, Urban water system exist pipe borne limited to WA Township , Rural system is undertaken by COWAP, Rural Aid and covers mainly rural settlements. GWSC provides water through the treatment plant at Gowrie , two (2) mechanised and 331 hand pump boreholes. All these sources

provide sustainable and constant drinking water to the people in the area to address water challenges that might have cropped up.
The local economy of the WA Municipality is predominantly agricultural based with the sector (including forestry) accounting for more than 30 percent of the economic activities in which the working population in the municipality are engaged.

The technology employed in agricultural production in the municipality is largely the traditional cutlass and hoes. Mechanized farming is very limited and the rate at which the farmers within the municipality are adapting to other agricultural related technologies is equally low even though there are several potential irrigation sites in the municipality. Farming is entirely rain –fed because the irrigation sites are not well developed and hence get low patronage.

Access to market from the farms is very poor hence hampering the food chain within the area. Those coupled with lack of storage facilities contributes to massive post-harvest losses.

**Problem Statement**

It is recognized by every country that water is an important component of human development and the entire progress of their economies . This commodity is considered as an important component in the measure of human being through Human Development Index (HDI). Therefore the availability and non-availability of water poses a serious threat to the progress of every country.

The efforts of successive governments towards an equitable provision of water to the citizenry is not to be underestimated but these efforts seem not to be enough and hence massive and sustained investments are seriously needed if positive results are to be achieved.
All the efforts made seemed not to be improving the situation simply because of lack of proper planning, institutional failures, inadequate investment, obsolete equipment and erratic power outage among other factors.

The demand for water within the WA Municipality is in the increase and due to the above mentioned challenges, the municipality is always in water crisis.
In October 2018, the Ghana Water Company Limited incurred the wrath of the residents in WA Municipality due to the water crisis that hit the area. This situation compelled the company to begin water rationing. The residents were not happy with the situation as the water rationing was carried out without a time table. Some statistics have shown that the daily capacity of the water treatment plant in the area is estimated as 7200 cubic meters but hardly meet this production capacity. Around that period the plant was said to produce only 4000 cubic meter which is way below the estimated daily demand of 8400 cubic meters. This situation clearly demonstrates that half of the demand was not met.

For this persistent challenge of insufficient and erratic water situation in the municipality to be permanently addressed for the residents of the area to enjoy constant flow of water as it is their basic human right, the challenges highlighted above should be seriously dealt with once and for all. As part of the several measures to bring an end to the water crisis in the municipality is to develop a suitable time series model for forecasting water demand of the residents and other non-domestic users in the Municipality. The model will aid proper planning and management of water systems into the future which by extension will help reduce the challenge of water crisis which deny the people of one of their basic human rights.

This study therefore seeks to develop an appropriate time series model for the Ghana water company in the WA Municipality .

**Research Questions**

This study seeks to provide answers to the following questions.

1. What is the trend of water demand in the WA municipality?
2. What will the model for water demand forecast mean?
3. What will be the water demand level of the area in the next five years?

**Objectives of the Study**

This study seeks to achieve the following objectives;

1. To determine the trend of water demand in the WA municipality
2. To develop an appropriate model for water demand in the Municipality
3. To make five year forecast of water demand in the Municipality

**Significance of the Study**

Water is a resource which everybody must get access to in order to survive and that is the reason international organisation agreed that access to water is a basic human right. And for countries not to infringe upon the right of her own citizens must put measures in place to ensure constant flow of water. In as much as it is a basic human right of everybody to have access to improved and sustained sources of water, the limited nature of the resource need not be underestimated. Therefore the challenge now is how to achieve a balance between water production and meeting an increasing demand of the commodity.

WA Municipality consisting of several communities with a population growth rate of 1.7 percent means that the population of the area keeps on increasing as time goes on and hence proper measures need to be put in place to ensure that residents within the area enjoy one of their basic human rights that is to have access to an improved and sustained sources of water to meet the growing demand. And the responsibility is on the government and the various stakeholders including Ghana Water Company Limited, WA , to ensure that water crisis which persistently hit the area become the thing of the past . Therefore , the findings of this study will help augment the efforts made so far toward achieving that course. These research findings will assist the government to make long term planning of how to handle the water sector in the WA municipality . It will also help the Ghana Water Company Limited in WA through the use of the fitted model to forecast into the future the water demand in the area which will properly guide it's operation .

Finally, researchers in the academia would also benefit from this study since it can be used as literature in other related areas.

## METHODOLOGY

**Data and Source**

The data for the study was mainly secondary historical monthly data of urban water demand in WA municipality since inception, the data spans from 2010 to 2015.

**Statistical Technique**

Time series is an ordered sequence of values of a variable at equally spaced time interval. It can also be described as a collection of observation made sequentially in time, a set of observations (Yt) each one being recorded at a specific time (t). Time series occur in a variety of field ranging agriculture to engineering. Many sets of data appear as time series, examples include; hourly observations made on the yield of chemical processes, a monthly sequence of goods sold in a supermarket and so on. Due to the frequent encounter of data of this form methods of analyzing time series constitute a great importance in the area of statistics.

**Normality Test**

The normality test is to investigate the extent to which the data collected approximate a normal distribution. The extent of normality of the data will be determined using skewness and kurtosis.

• Skewness; is the degree to which a data set is not symmetrical. Skewness can be evaluated via the skewness statistic. As data becomes more symmetrical, its skewness value approaches zero. Positive skewed or right skewed data has a value greater than 0 and the tail of such distribution points to the right. The reverse case applies for negatively skewed data.

• Kurtosis; is the degree to which a data set is peaked. Normally distributed data establishes the baseline for kurtosis not too flat or sharply peaked with a statistic of 0. A distribution with a sharper than normal peak will have a positive kurtosis value and is termed leptokurtic distribution, whereas, a platykurtic distribution has a flatter than normal peak and a negative kurtosis value.

**Trend Analysis**

Trend analysis fits a general trend model, thus, the linear, quadratic or exponential growth models to the time series data. This procedure is often used to fit trend when there is no seasonal component to the series. The trend most accurate to describe the series will be determined using the measures of accuracy, MAPE, MAD and MSD. The model with the minimum measure of accuracy is what best describes the series.

**Trend Models**

- Linear Trend Model; is estimated using the Ordinary Least Square estimation with a general model of

  $$y_t = \beta_0 + \beta_1 t + e_t$$

  Where $y_t$ is the projected value of the y variable for a selected value of t, $\beta_o$ is the constant intercept; $\beta_1$ represents the average change from one period to the next.

- Quadratic Trend Model; which accounts for a simple curve is of the form

  $$y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + e_t$$

- Exponential Growth Trend Model; accounts for exponential growth or decay. Mathematically,

  $$y_t = \beta_0 * \beta_1^t * e_t$$

**Measures of Accuracy**

Three measures of accuracy of the fitted model are computed, MAPE, MAD, and MSD for each of the simple forecasting and smoothing methods. For all three measures, the smaller the value, the better the fit of the model. We use these statistics to compare the fits of the different methods.

- Mean Absolute Percentage Error (MAPE); measures the accuracy of fitted time series values, specifically in trend estimation. It usually expresses accuracy as a percentage and is defined by,

  $$MAPE = \frac{100\%}{n} \sum_{t=1}^{n} \left| \frac{A_t - F_t}{A_t} \right|$$

  Where $A_t$ is the actual value, $F_t$ equals the fitted value, and n equals the number of observations.

- Mean Absolute Deviation (MAD); expresses accuracy in the same units as the data, which helps conceptualise the amount of error. The mean deviation is a measure of how much the fitted value of the data is likely to differ from the actual value. The absolute value is used to avoid deviation with opposite sides cancelling each other out. Its mathematical form is,

$$MAD = \frac{1}{n}\sum_{t=1}^{n}|A_t - F_t|$$

- Mean Squared Deviation (MSD); measures the square forecast error, error variance and also recognise that longest errors are disproportionately more expensive than small errors. It is expressed mathematically as,

$$MSD = \frac{1}{n}\sum_{t=1}^{n}|A_t - F_t|^2$$

**Autocorrelation Function**

Autocorrelation is the correlation (statistical relation) between observations of a time series separated by k time units such that systematic changes in the value of one variable are accompanied by systematic changes in the other. The plot of autocorrelations is called the autocorrelation function or correlogram. The ACF is extremely useful in helping to obtain a partial description of the process for developing a forecasting model. ACF is mathematically the proportion of the autocovariance of $y_t$ and $y_{t-k}$ to the variance of a dependant variable $y_t$.

$$ACF(k) = \frac{cov(y_t, y_{t-k})}{var(y_t)}$$

**Partial Autocorrelation Function**

Partial autocorrelation function measures the degree of association between $Y_t$ and $Y_{t+k}$ when the effect of other time lags on Y are held constant. In other words, PACF is the simple correlation between$y_t$ and $y_{t-k}$ minus the part explained by the intervening lags.

$$\text{PACF} = \text{corr}(y_t, y_{t-k}|y_{t-1}, y_{t-2}, \ldots, y_{t-k+1})$$

**Stationarity**

A stationary process has a mean and variance that do not change over time and the process does not have trends. To proceed with the estimation of an ARIMA model, the series is required to be stationary and to test for stationarity under this study we consider the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test.

**Augmented Dickey-Fuller Test**

For the ADF test, we test the hypothesis that;

- $H_0$: the series is not stationary.
- $H_1$: the series is stationary.

At 95% significance level, a p-value less than 0.05 means we reject $H_0$ meaning the series is stationary, else it is not stationary

**Kwiatkowski, Phillips, Schmidt and Shin Test**

The KPSS test has a reverse hypothesis to the ADF test hence;

- $H_0$: the series is stationary.
- $H_1$: the series is not stationary.

This means that at 95% significance level, a p-value less than 0.05 means we reject $H_0$ and say the series is not stationary, otherwise it is stationary.

**Model Identification**

After the series has been made stationary, the next step is to identify which model best describes the series. At this stage we decide how many autoregressive (p) and moving average (q) parameters are necessary to yield an effective but still parsimonious model of the process (parsimonious means that it has the fewest parameters and greatest number of degrees of freedom among all models that fit the data). In practice, the numbers of the p or q parameters very rarely need to be greater than 2 and the primary tools for doing this are the ACF and the PACF. The sample autocorrelation plot and the sample partial autocorrelation plot are compared to the theoretical behaviour of these plots shown below.

**Autoregressive Process (Ar)**

In statistics, an autoregressive (AR) model is a type of random process which is often used to model and predict various types of natural and social phenomena. Autoregressive models are based on the idea that the current value of the series, $y_t$, can be explained as a function of p past values, $y_{t-1}$, and $y_{t-2}$. . . $y_{t-p}$, where p determines the number of steps into the past needed to forecast the current value. Mathematically, a time series autoregressive model is given by:

$$Yt = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \ldots + \phi_p y_{t-p} + e_t$$

Where $e_t$ is assumed to be a white noise process, $\phi_1$, $\phi_2$, …, $\phi_p$ are the autoregressive model parameters and $1<\phi<1$ for all p. Each observation is made up of a random error component ($e_t$) and a linear combination of prior observations.

**Moving Average Models (MA)**

The moving average process expresses the current value of the observation in terms of the past shocks or residuals. This means that condition on the past values of the residuals, the future values of the series can be predicted. The notation MA (q) refers to the moving average model of order q. A moving average model of order q, abbreviated MA (q), is defined mathematically as:

$$Y_t=\mu+e_t-\theta_1 e_{(t-1)}-\ldots-\theta_q e_{(t-q)}$$

Where μ is the mean of the serieset, et-1… are white noise error terms and θ1…θq are the parameters of the model.

That is, a moving average model is conceptually a linear regression of the current value of the series against previous (unobserved) white noise error terms or random shocks. The random shocks at each point are assumed to come from the same distribution.

**Autoregressive Moving Average Model (ARMA)**

Autoregressive Moving Average (ARMA) models are typically applied to auto correlated time series data. Given a time series of data Yt, the ARMA model is a tool for understanding and, perhaps, predicting future values in this series. The model consists of two parts, an autoregressive (AR) part and a moving average (MA) part. The model is usually then referred to as the ARMA (p, q) model where p is the order of the autoregressive part and q is the order of the moving average part. The notation ARMA (p, q) refers to the model with p autoregressive terms and q moving average terms. This model contains the AR (p) and MA (q) models.

An Auto-Regressive Moving Average model of order (p, q) abbreviated as ARMA (p, q), is defined mathematically as

$$Y_t=\mu+\phi_1 Y_{(t-1)}+\phi_2 Y_{(t-2)}+\cdots+\phi_p Y_{(t-p)}+e_t-\theta_1 e_{(t-1)}-\ldots-\theta_q \theta_{(t-q)}$$

Where Yt is a mixed autoregressive moving average process of orders p and q abbreviated ARMA (p, q).

**Autoregressive Integrated Moving Average Models (ARIMA)**

If a non-stationary time series which has variation in the mean is differenced to remove the variation the resulting time series is known as integrated time series. It is called integrated because the stationary model which is fitted to the differenced data has to be summed or integrated to provide a model for the non-stationary data. All AR (p) models can be represented as ARIMA (p, 0, 0) that is no differencing and no MA (q) part, also MA (q) models can be represented as ARIMA (0, 0, q) meaning no differencing and no AR (p) component.

The general model is ARIMA (p, d, q) where p is the order of the AR part, d is the degree of differencing and q is the order of the MA part. The general ARIMA (p, d, q) model can be expressed in terms of the backward shift operator as

$$(1-Ø1B-Ø2B2-\ldots-ØPBP)(1-B)dYt=(1+\theta1B+\theta2B2+\ldots+\theta qBp)et \qquad (3.12)$$

Where (1-B)d is the non-seasonal differencing filter.

**Information Criteria**

The following tools (criteria) are used in the selection of best fit model out of suggested models. The model with the minimum of these statistics is selected as the best fit.

Akaike's Information Criteria (AIC); uses the maximum likelihood method. In the implementation of the approach, a range of potential ARMA models is estimated by maximum likelihood methods, and for each, the AIC is calculated, given by:

$$AIC(p,q)=\ln(\sigma_e^2)+r\,2/n+constant$$

Where, n is the number of observations in the historical time series data, $\sigma_e^2$ is the maximum likelihood estimate of $\sigma_e^2$, and $r=p+q+1$ denotes the number of parameters estimated in the model. Given two or more competing models the one with the smaller AIC value will be selected.

Schwarz's Bayesian Criterion (BIC); like AIC uses the maximum likelihood method. The BIC imposes a greater penalty for the number of estimated model parameters than does the AIC. The use of minimum BIC for model selection results in a chosen model whose number of parameters is less than that chosen under AIC. It is given by,

$$BIC(p,q)=\ln(\sigma_e^2)+r(\ln(n))/n$$

Corrected Akaike's Information Criteria (AICC); the AIC is biased estimator and the bias can be appreciable for large parameters per data ratios. Hurvich and Tsai (1989) showed that the bias can be approximately eliminated by adding another non – static penalty term to the AIC, resulting in the corrected AIC, denoted by AICC and defined by the formula:

〖AIC〗 _C=AIC+(2(r+1)(r+2))/(n-r-2)

**Parameter Estimation**

Once a model is identified the next stage of the ARIMA model building process is to estimate the parameters. Estimating the parameters for the ARIMA (Box- Jenkins) models is a quite complicated non-linear estimation problem. For this reason, the parameter estimation was done using a statistical package called Gretel.

**Model Diagnosis**

To ensure that the selected model is the best model that suits the data the following diagnostics are performed.

- Time Plot of the Residuals; is a plot of the standardised residuals against time. For a fit model, it should not show any fixed pattern, trend in the residuals, no outliers and in general case no changing variance across time.
- Plot of Residual ACF; allows one to examine the goodness of fit by means of plotting the ACF of residuals of the fitted model. If most of the sample autocorrelation coefficients of the residuals are within the 5% significance limits in a random pattern, then the model is a good fit.

- The Normal Q-Q Plot; is another diagnostic check on the residuals to determine whether it follows the normal distribution. This is done by using the normal probability plot Q–Q plot. It is a plot of the quantiles of two distributions against each other, or a plot based on estimates of the quantiles. The normal Q-Q plots is used to compare the distribution of a sample to a theoretical distribution. If most of the points are in line and closer to the normal line, then the model is a good fit.

- Ljung-Box Q Statistics; is a check of the overall model adequacy. The error terms are examined and for the model to be adequate the errors should be random. If the error terms are statistically different from zero, the model is not adequate. The test statistic used is the Ljung-Box statistic, a function of the accumulated sample autocorrelations, $r_j$, up to any specified time lag *m*. As a function of m, it is determined as:

$$Q(m) = n(n+2)\sum_{j=1}^{m}\frac{r_j^2}{n-j}$$

Which is approximately chi-square distributed with n-p-q degree of freedom. Here p and q are orders of AR and MA respectively and n is the number of usable data points after any differencing operations. This statistic can be used to examine residuals from a time series model in order to see if all underlying population autocorrelations for the errors may be 0 (up to a specified point). If the corresponding p-value is greater than 0.05, then the model is considered adequate.

**Forecasting**

Once an appropriate time-series model is selected and established fit, we can now forecast future values of the series. Once a forecast is made for $y_{T+1}$ it is added to the series and used to forecast for $y_{T+2}$. The process continues into the desired future for which a forecast is desired which for this study is the next five years.

**The Box-Jenkins Method of Modelling Time Series**

The Box-Jenkins methodology (Box & Jenkins, 1976) is a step-wise statistical method used in analysing and building forecasting models which best represents a time series. This method of forecasting implements knowledge of autocorrelation analysis based on autoregressive integrated moving average models.

The methodology has the following advantages;

- It is logically and statistically accurate
- It makes great use of historical time series data
- Forecasting accuracy is increased

The procedure is of four distinct stages namely; Identification, Estimation, Diagnostic checking, Forecasting.

•Identification: Identification methods are procedures applied to a set of data to indicate the kind of representational model that will be further investigated. The aim here is to obtain some idea of the values p, d and q needed in the general linear ARIMA model and to obtain initial estimates for the parameters. The task here is to identify an appropriate subclass of models from the general ARIMA family which may be used to represent a given time series. This requires examining the autocorrelation and partial autocorrelation coefficients calculated for the data.

• Estimation: Once the preliminary model is chosen, the estimation stage begins. The purpose of the estimation is to find the parameter estimates that minimise the mean square error. An iterative non-linear least squares procedure is applied to the parameter estimates of an ARMA (p, q) model. The method minimises the sum of squares of error given to form the model and data. The estimates usually converge on an optimal value for the parameters with a small number of iterations.

• Diagnosis Checking: Residuals from the fitted model are examined to ensure that the model is adequate (random). Autocorrelation of the error term are estimated and plotted to determine whether they are statistically zero. Thus the observed value is test as a result of sampling error. This is the first test for adequacy. The second test for adequacy is the Q-test as discussed earlier. Under circumstances of unsatisfying results, other ARMA model may be tried until a satisfactory model is obtained.

• Forecasting: When a model is identified and validated, forecast for one period can be made and there on several periods. As the forecast period becomes further ahead, the chance of forecast error becomes larger. As new observations for a time series are obtained, the model should be re-examined and checked for adequacy. If the time series seem to be changing over time, the parameters of the model should be recalculated or a new model may have to be developed. When small differences in forecast error are observed, only a recalculation of the model parameters is required. However, if larger differences are observed in the size of the forecast error, then a new model is required, thus, returning to the first step of the Box-Jenkins process.

## RESULTS AND DISCUSSION

**Table 1: shows summary statistics,**

| *Water Demand* | |
|---|---|
| Mean | 101046 |
| Standard Error | 1231.125 |
| Median | 102448.5 |
| Standard Deviation | 10446.44 |
| Sample Variance | 1.09E+08 |
| Kurtosis | -0.13255 |
| Skewness | -0.64528 |
| Range | 43146 |
| Minimum | 74527 |

| | |
|---|---|
| Maximum | 117673 |
| Sum | 7275310 |
| Count | 72 |

The minimum value in the data set was found to be 74527(000) litresand maximum 117673 (000) whilst the average water demand was 101046(000) litreswith accompanying standard deviation of 101046 (000) litres, indicating that the data is widely dispersed across the mean. The coefficient of variation of 10.34% also shows that the data has a very high variance. The water demand distribution also exhibits negative skewness of -0.64528 indicating that most of the water demand are concentrated to the left of the mean and also has a kurtosis value of -0.13255 also indicating that the data is platykurtic, thus, has a flattened than normal peak.

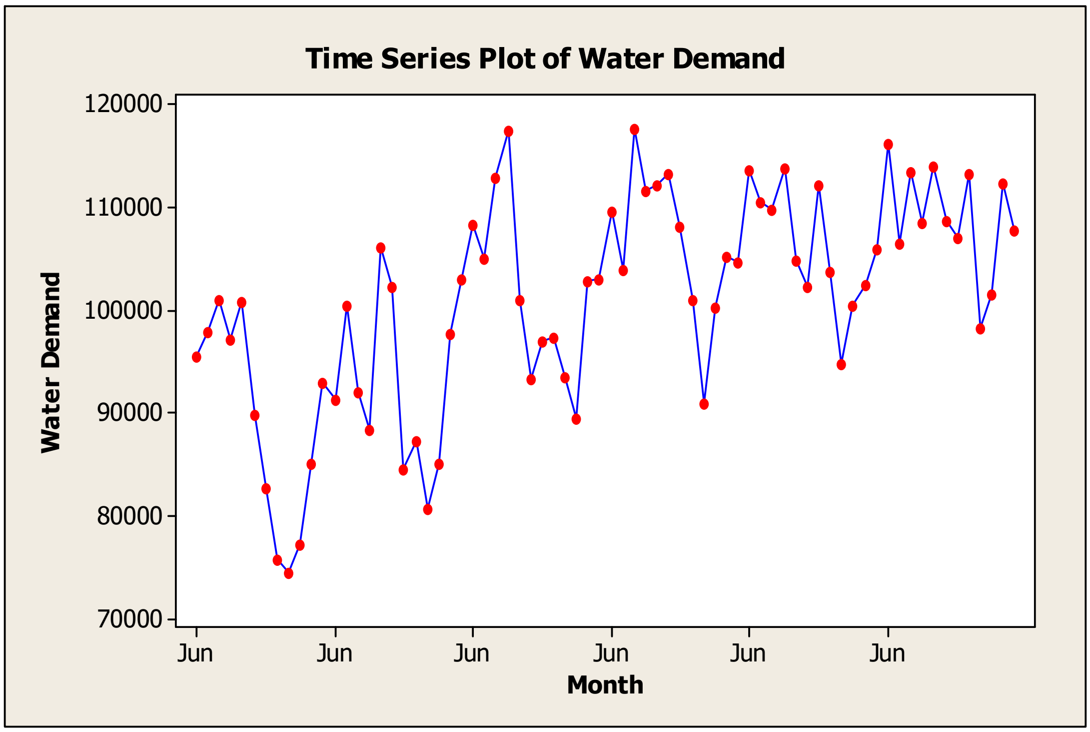


**Figure 1: shows Time series plot of water demand**

The plot in Figure 1 shows the fluctuation pattern of water demand with respect to time. It can be observed, generally, from the figure that increasing trend in the plot is significantly sharp. Water demand however, took a significant upward and trend over the time downward respectively. The generally increasing pattern in the time graph shows a gradual change of the mean whilst the flattened fluctuations over time shows an unstable variance suggesting the series is not stationary.

**Tests for Stationarity**

A stationary process has a mean and variance that do not change over time and the process does not have trends. To proceed with the estimation of an ARIMA model, the series is required to be stationary, as such this study employed the **Augmented Dickey-Fuller (ADF) test** and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test for evidence of stationarity in water demand in the WA municipality.

**Augmented Dickey-Fuller Test**
For the ADF test, we test the hypothesis that;
H0: the series is not stationary.
H1: the series is stationary.
At 95% significance level, a p-value less than 0.05 means a rejection of H0, meaning the series is stationary, otherwise the H0 is upheld.

**Kwiatkowski, Phillips, Schmidt and Shin Test**
The KPSS test has a reverse hypothesis to the ADF test hence;
H0: the series is stationary.
H1: the series is not stationary.
This means that at 95% significance level, a p-value less than 0.05 means we reject H0 and say the series is not stationary, otherwise it is stationary.

**Table 2: Stationary Test**

| TEST | TEST STATISTIC | P-VALUE |
|---|---|---|
| KPSS | 0.0792963 | 0.148 |
| ADF | -0.084144 | 0.4173 |

From the KPSS test values on table 3.2 above**,** at 5% significance level, the conclusion is that the series is *stationary* since the p-value (0.148) is greater than 0.05. However, the ADF test with a reverse null hypothesis indicates that the data is not stationary with p-value 0.4173. In all, the data is concluded not to be stationary based on the evidence of the time plot, correlogram, KPSS and ADF test, hence the data need to be differenced.

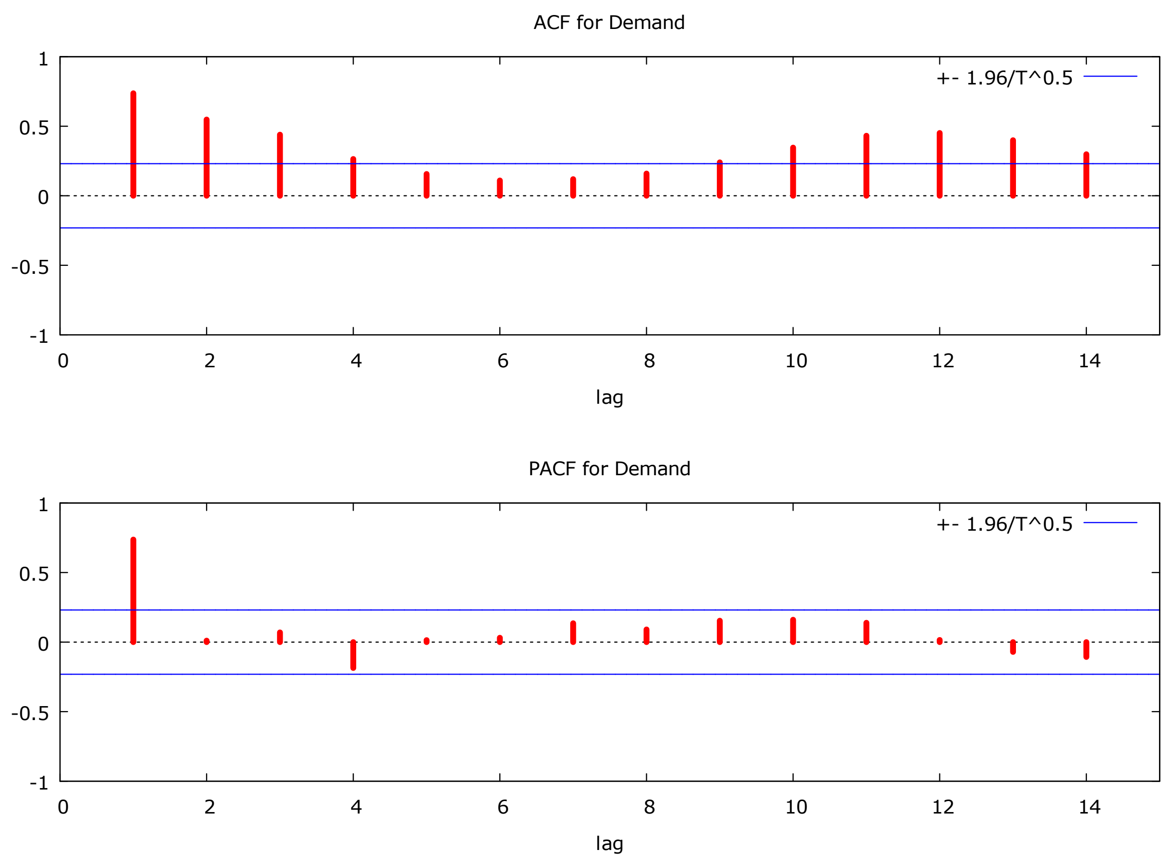


**Figure 2: shows the ACF and PACF for water demand**

Further analysis was conducted and checks made on the Autocorrelation Function (ACF) plots and those of the Partial Autocorrelation Function (PACF). It can be observed that with 95% confidence interval the data appears not to be stationary. The ACF is dying down slowly with significant spikes at lags 1, 2, 3 and 4 of the PACF as illustrated in Figures 2

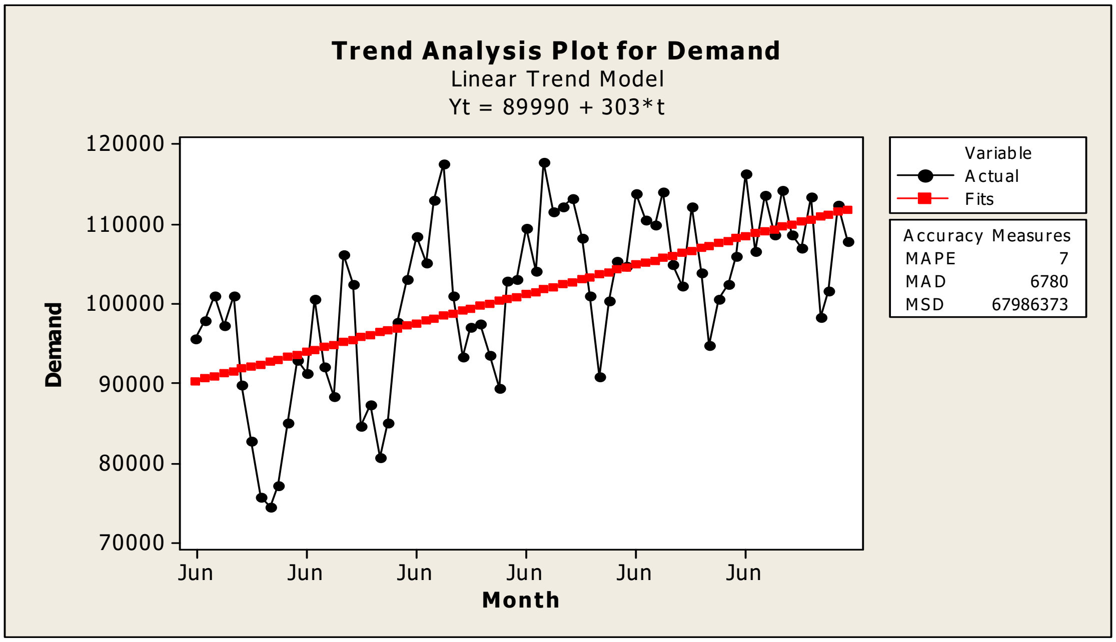


**Figure 3: shows the trend plot of water demand**

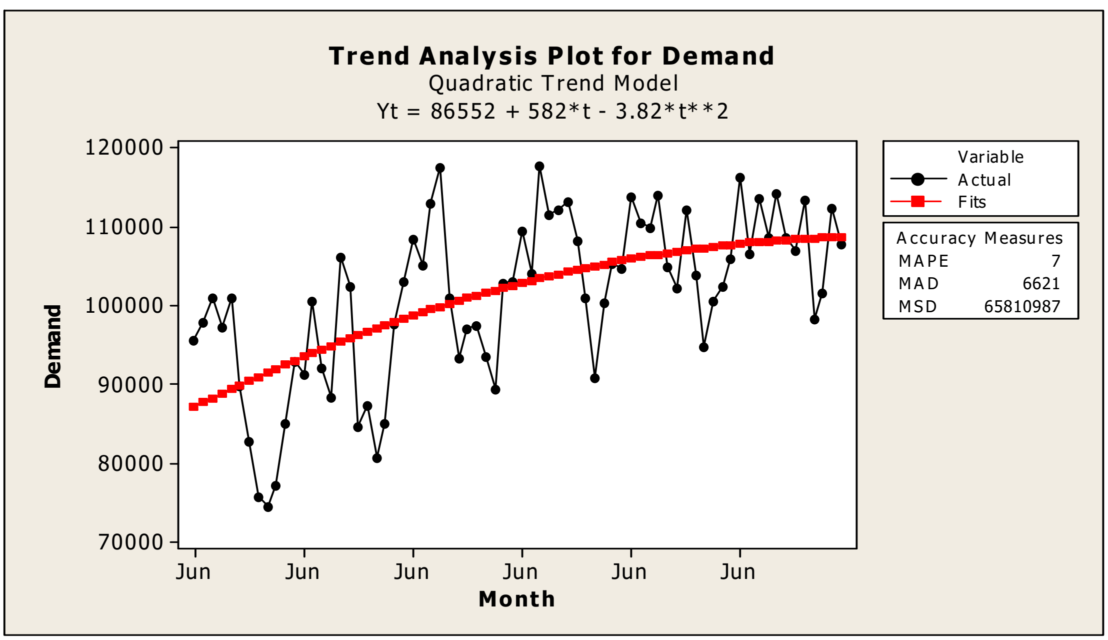


**Figure 4: shows quadratic trend**

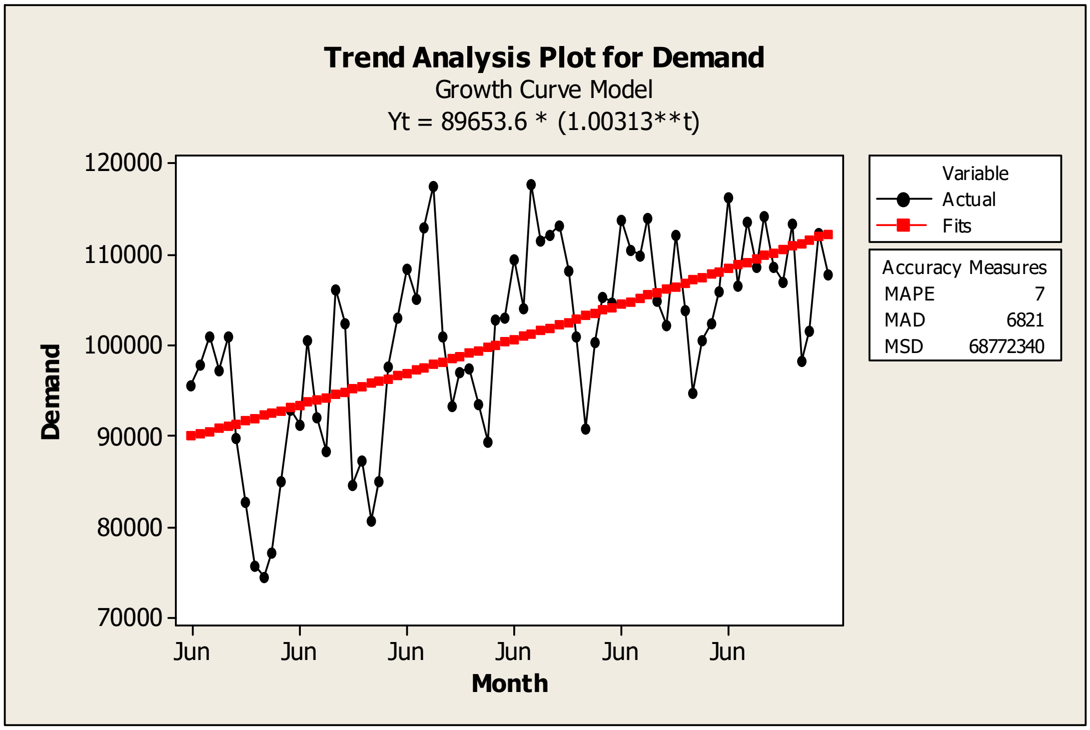


**Figure 5:shows exponential trend**

Figures 3, 4, 5 and 6 below show the linear, quadratic, exponential and curve linear models respectively. In each of the figures, round dotted lines represent the actual values of water demand whereas the square dotted lines represent the fitted values based on the various models.

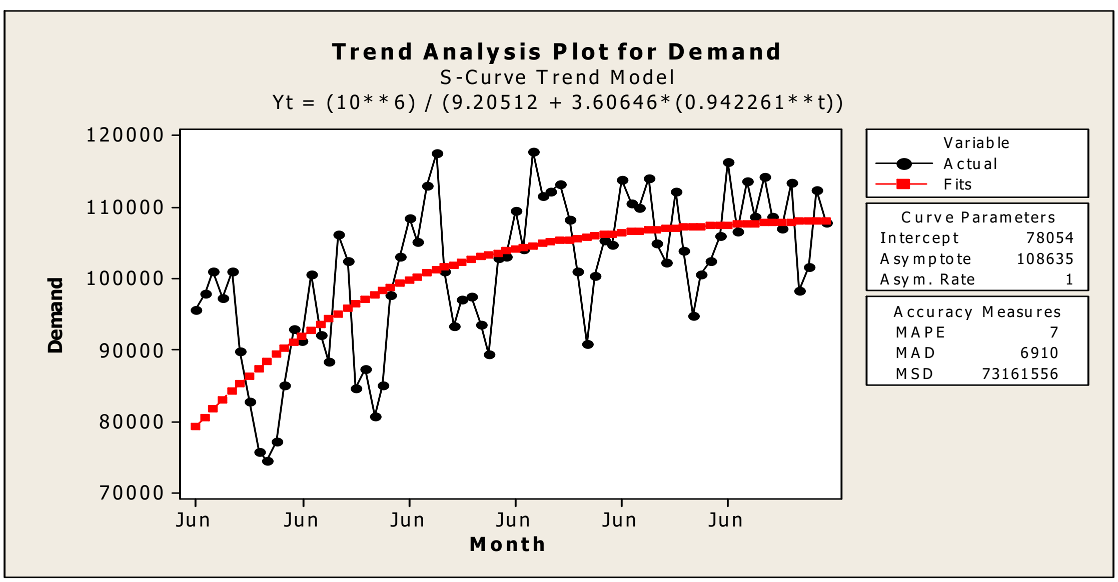


**Figure 6: shows curve linear trend**

**Table 3: Measures of accuracy**

| Model | MAPE | MAD | MSD |
|---|---|---|---|
| Linear | 7 | 6780 | 67986373 |
| Quadratic | 7 | 6621 | 65810987 |
| Exponential | 7 | 6821 | 68772340 |
| Curve linear trend | 7 | 6910 | 73161556 |

From **Table3** the most appropriate model to describe the trend in water demand in WA municipality is the one with the minimal errors. A closed observation of the errors produced by the four models, the quadratic model has the minimum MAPE, MAD and MSD thus, is considered to be the best model in describing the trend in water demand in WA municipality.

**Achieved Stationary**

As a result of the not stationarynature of the data, there was the need for it to be differenced in order to obtain stationary before building any model. Since the series has quadratic growth trend and increasing variance over time it was necessary to transform the data by differencing it. A time plot of the transformed data is examined and tested for stationarity.

**Table 4: Stationary Test**

| TEST | TEST STATISTIC | P-VALUE |
|---|---|---|
| **KPSS** | 0.0273819 | 0.148 |
| **ADF** | -4.86654 | 1.409e-006 |

From the KPSS test values on table 4.4**,** at 5% significance level, the conclusion is that the series is *stationary* since the p-value (0.148) is greater than 0.05. However, the ADF test with a reverse null hypothesis indicates that the data is stationary with p-value 0.000001409. In all, the data is concluded to be stationary based on the evidence of the correlogram, KPSS and ADF test.

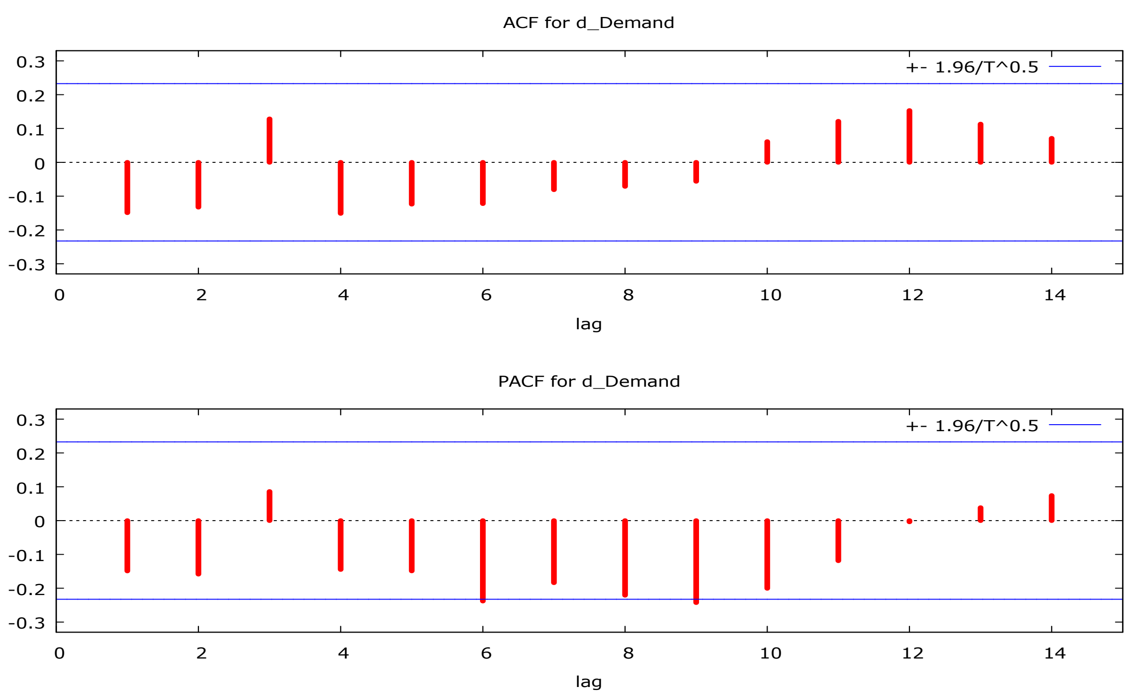


**Figure: 7 Time Series Plot of Differenced urban water demand**

Figure 7 shows the correlogram of the differenced water demand data. It shows a rapid decay indicating stationary. The stationary of the differenced data however, must be confirmed by performing the ADF test and the KPSS test once again. The results in Table 4.4 above shows that both tests confirm stationary after first differential.

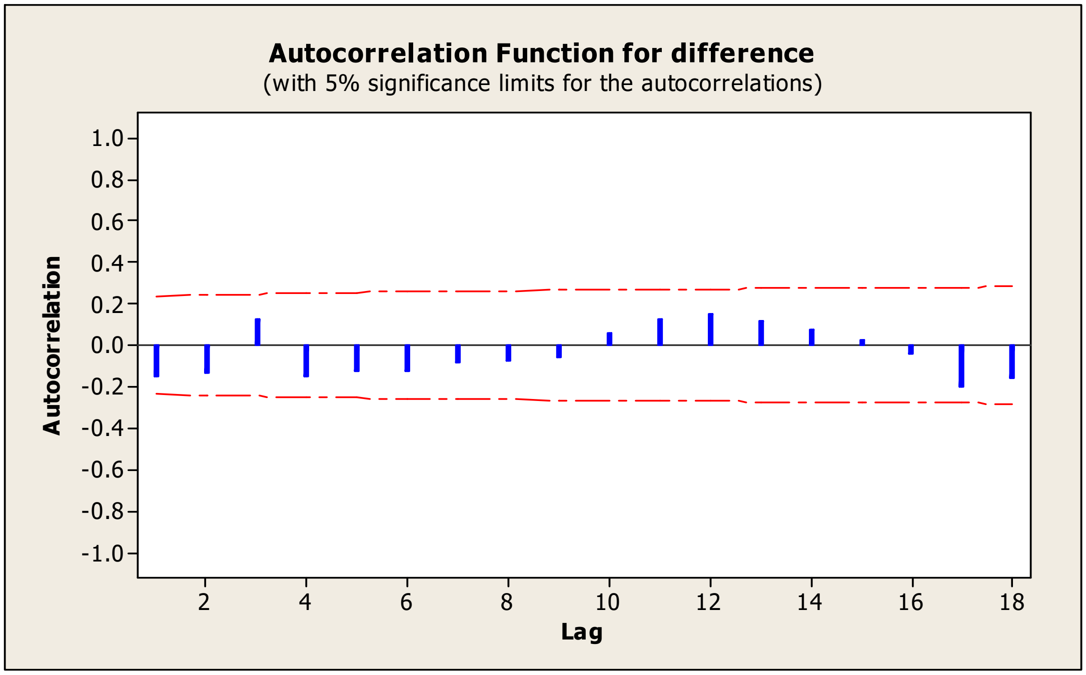


**Figure 8: shows ACF plot of differenced water demand**

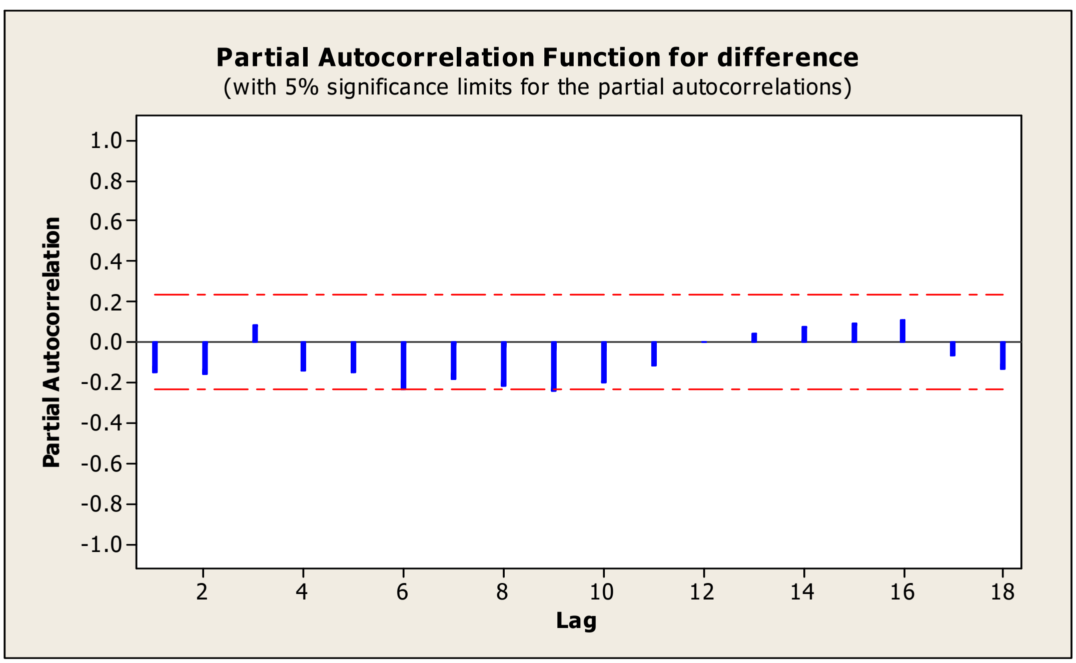


**Figure 9: shows PACF plot of differenced water demand**

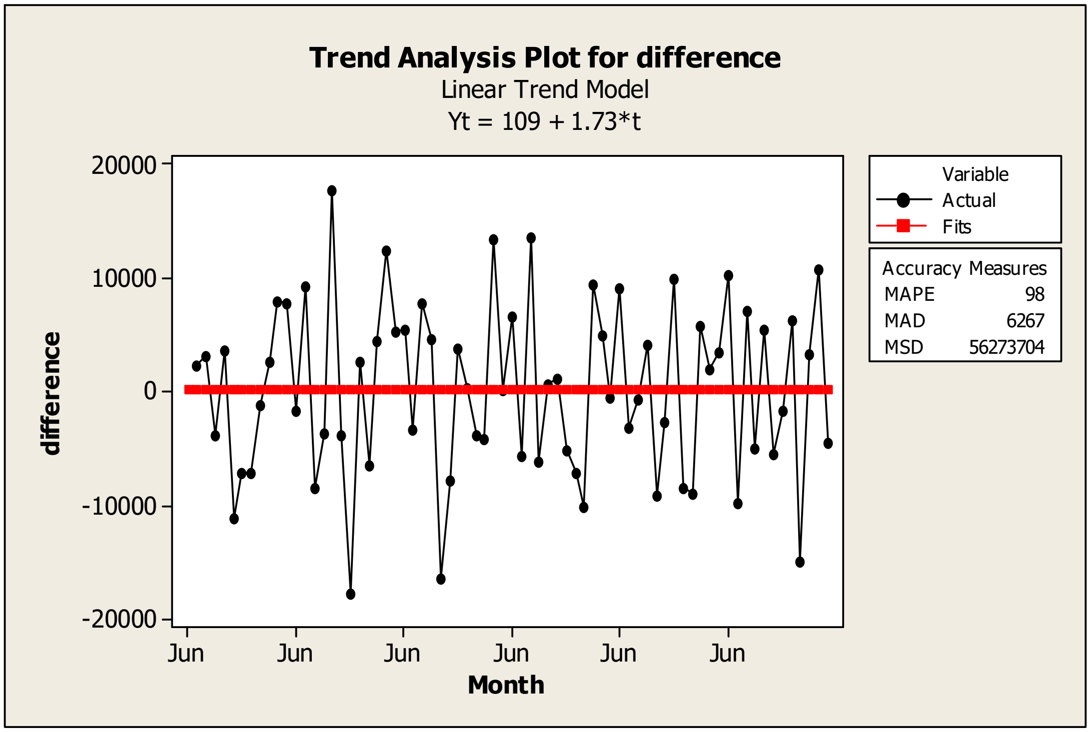


**Figure 10: shows trend plot for differenced water demand**

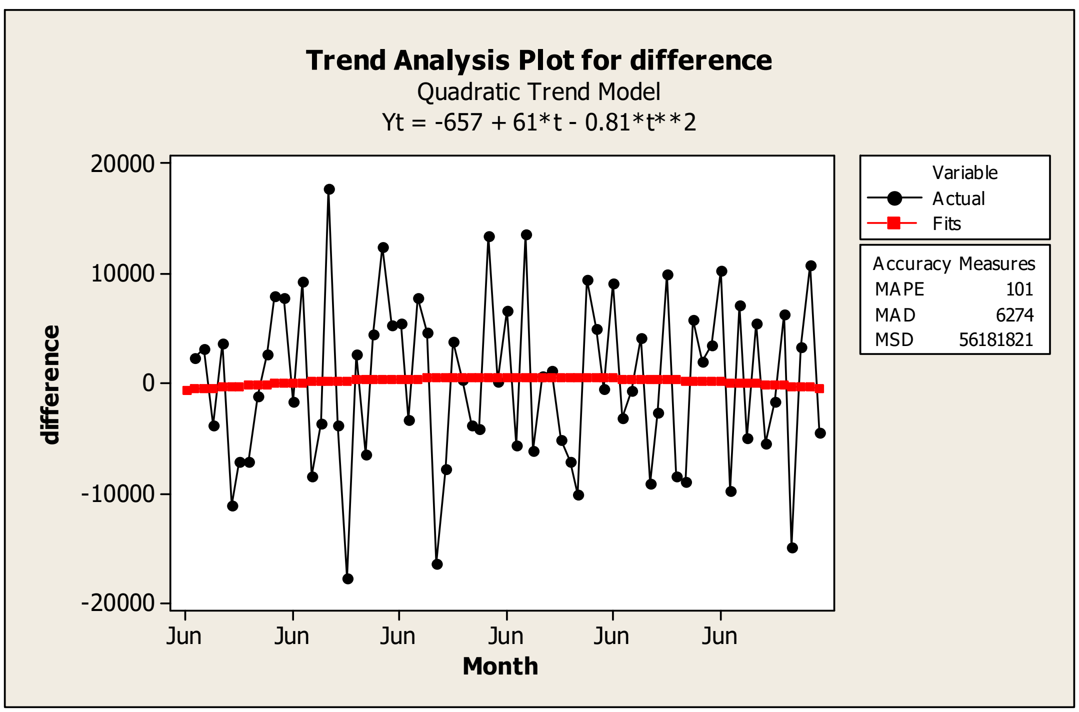


**Figure 11: shows quadratic trend plot for differenced water demand**

**The Box-Jenkins Method of Modeling Time Series**

The Box-Jenkins methodology (Box & Jenkins, 1976) is a step-wise statistical method used in analyzing and building forecasting models which best represents a time series. This method of forecasting implements knowledge of autocorrelation analysis based on autoregressive integrated moving average models. The methodology makes great use of historical time series data, is logically and statistically accurate and increase forecasting accuracy. The procedure is of four distinct stages namely; Identification, Estimation, Diagnostic checking, Forecasting.

**Model identification**

**Table 5: model identification**

| Model for water demand | AIC | BIC | HQ |
|---|---|---|---|
| **Arima(1,1,0)** | 1470.538 | 1472.801 | 1471.438 |
| **Arima(2,1,1)** | 1472.411 | 1479.199 | 1475.110 |
| **Arima(2,1,2)** | 1478.483 | 1477.534 | 1472.083 |

The most appropriate model for the series is the one with the minimum Akaike Information Criteria (AIC), Bayesian information criterion (BIC) and Hannan-Quinn (HQ). Thus, by an inspection of all the computed models in Table 4.5 the ARIMA (1, 1, 0) model has the minimum values and therefore the best model for forecasting.

**4.3.2 Parameter Estimation**

Table 4.6 below displays estimates of the parameters of the ARIMA (1, 1, 0) model. The parameters of both MA(0) and AR(1) are significant at 5% levels with coefficients and p-values of and respectively less than 0.05 indicating the significance of the parameters.

**Table 6: Parameter Estimates**

| | coefficient | std. error | z | p-value |
|---|---|---|---|---|
| const | 155.533 | 752.876 | 0.2066 | 0.8363 |
| AR(1) | 0.147860 | 0.116873 | 1.265 | 0.2058 |

**Model Diagnosis**

To ensure that the selected model is the best model that suits the data the following diagnostics are performed

**Residuals Plots**

The patterns of the residuals over time around the zero mean as seen in figure 4.8 below indicating that the residuals are random and independent of each other, thus, indicating that the model is fit.

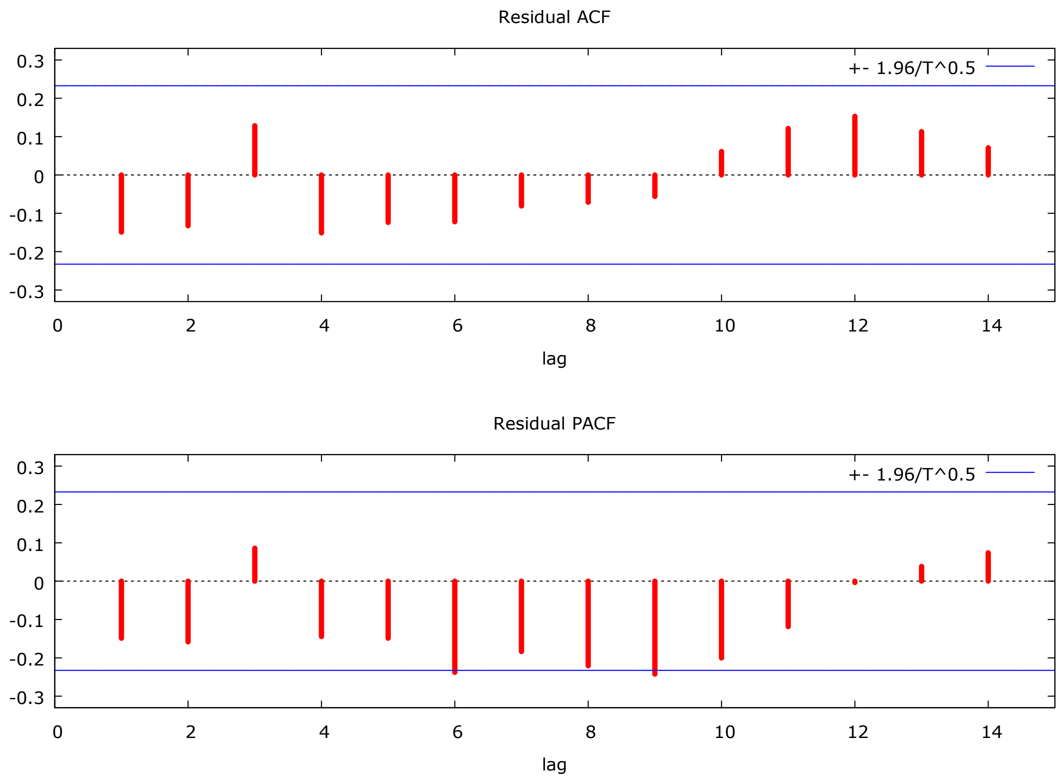


**Figure 12: residual plot of ACF and PACF**

Figure 12 shows all autocorrelation spikes within the 95% confidence interval. This means that there is no serial correlation between residuals indicating that they are accurate and the model is adequate.

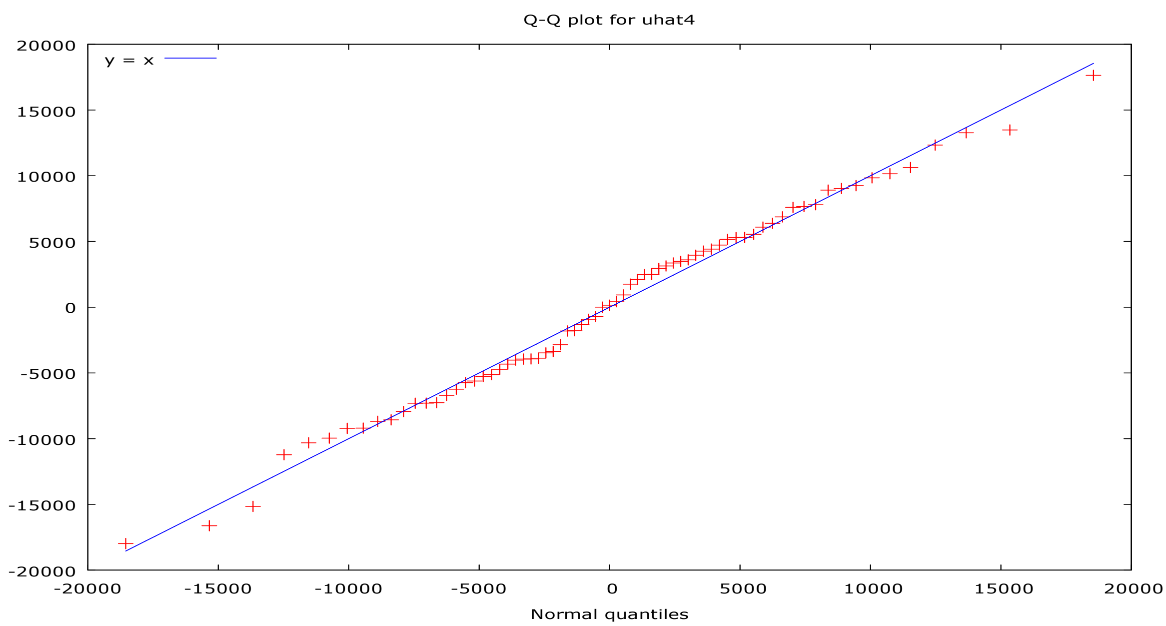


**Figure 13: shows Q-Q plot of residuals**

The Q-Q plot in Figure 4.13 shows all points along the normality line except for one outlier hence the model is deemed fit.

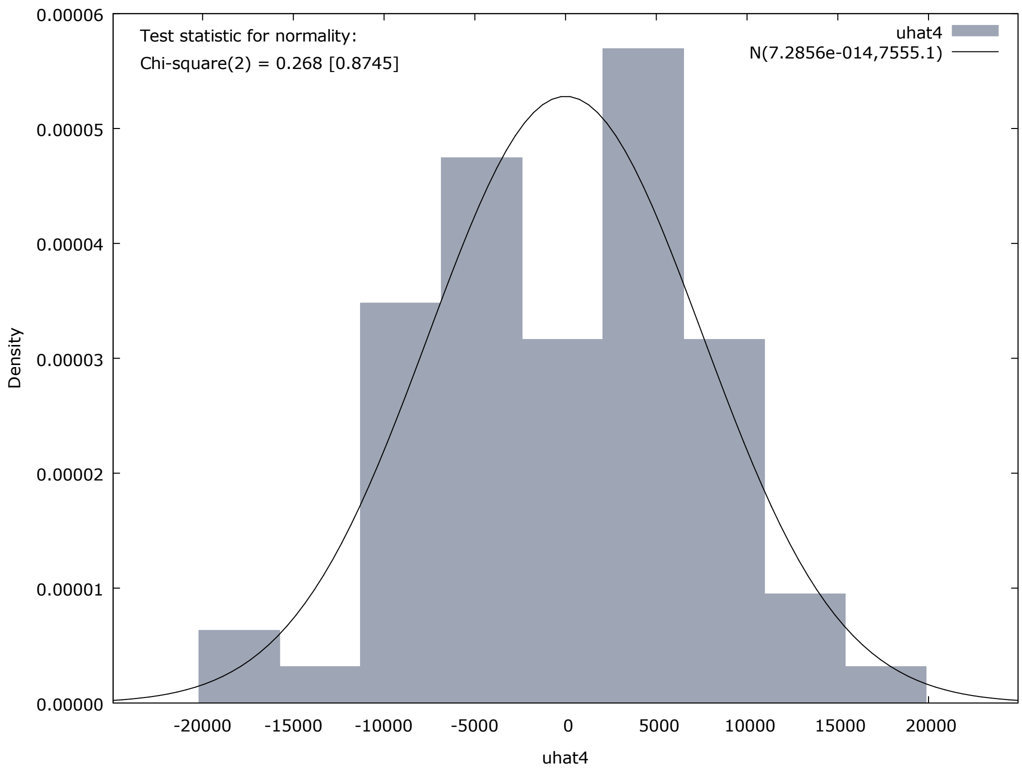


**Figure 14: shows normality plot**

**4.4 Forecast values**

For 95% confidence intervals, z (0.025) = 1.96

| | Demand | prediction | 95% interval |
|---|---|---|---|
| 2016:01 | 108074.94 | 7555.057 | 93267.30 - 122882.58 |
| 2016:02 | 108247.89 | 10684.464 | 87306.72 - 129189.05 |
| 2016:03 | 108420.83 | 13085.743 | 82773.25 - 134068.42 |
| 2016:04 | 108593.77 | 15110.114 | 78978.49 - 138209.05 |
| 2016:05 | 108766.72 | 16893.621 | 75655.83 - 141877.61 |
| 2016:06 | 108939.66 | 18506.035 | 72668.50 - 145210.82 |
| 2016:07 | 109112.61 | 19988.802 | 69935.27 - 148289.94 |
| 2016:08 | 109285.55 | 21368.929 | 67403.22 - 151167.88 |

| | | | |
|---|---|---|---|
| 2016:09 | 109458.49 | 22665.172 | 65035.57 - 153881.41 |
| 2016:10 | 109631.44 | 23891.189 | 62805.57 - 156457.31 |
| 2016:11 | 109804.38 | 25057.290 | 60692.99 - 158915.77 |
| 2016:12 | 109977.32 | 26171.486 | 58682.15 - 161272.49 |
| 2017:01 | 110150.27 | 27240.146 | 56760.56 - 163539.97 |
| 2017:02 | 110323.21 | 28268.435 | 54918.10 - 165728.33 |
| 2017:03 | 110496.15 | 29260.611 | 53146.41 - 167845.90 |
| 2017:04 | 110669.10 | 30220.229 | 51438.54 - 169899.66 |
| 2017:05 | 110842.04 | 31150.299 | 49788.58 - 171895.51 |
| 2017:06 | 111014.99 | 32053.393 | 48191.49 - 173838.48 |
| 2017:07 | 111187.93 | 32931.731 | 46642.92 - 175732.94 |
| 2017:08 | 111360.87 | 33787.243 | 45139.09 - 177582.65 |
| 2017:09 | 111533.82 | 34621.621 | 43676.69 - 179390.95 |
| 2017:10 | 111706.76 | 35436.359 | 42252.77 - 181160.75 |
| 2017:11 | 111879.70 | 36232.781 | 40864.76 - 182894.65 |
| 2017:12 | 112052.65 | 37012.070 | 39510.32 - 184594.97 |
| 2018:01 | 112225.59 | 37775.286 | 38187.39 - 186263.79 |
| 2018:02 | 112398.54 | 38523.384 | 36894.09 - 187902.98 |
| 2018:03 | 112571.48 | 39257.229 | 35628.72 - 189514.23 |
| 2018:04 | 112744.42 | 39977.605 | 34389.76 - 191099.09 |
| 2018:05 | 112917.37 | 40685.228 | 33175.78 - 192658.95 |
| 2018:06 | 113090.31 | 41380.752 | 31985.53 - 194195.09 |
| 2018:07 | 113263.25 | 42064.778 | 30817.80 - 195708.70 |
| 2018:08 | 113436.20 | 42737.857 | 29671.54 - 197200.86 |
| 2018:09 | 113609.14 | 43400.499 | 28545.73 - 198672.56 |
| 2018:10 | 113782.08 | 44053.175 | 27439.45 - 200124.72 |
| 2018:11 | 113955.03 | 44696.321 | 26351.85 - 201558.21 |
| 2018:12 | 114127.97 | 45330.343 | 25282.13 - 202973.81 |
| 2019:01 | 114300.92 | 45955.619 | 24229.56 - 204372.27 |
| 2019:02 | 114473.86 | 46572.500 | 23193.44 - 205754.28 |
| 2019:03 | 114646.80 | 47181.317 | 22173.12 - 207120.48 |

| | | | |
|---|---|---|---|
| 2019:04 | 114819.75 | 47782.377 | 21168.01 - 208471.48 |
| 2019:05 | 114992.69 | 48375.970 | 20177.53 - 209807.85 |
| 2019:06 | 115165.63 | 48962.367 | 19201.16 - 211130.11 |
| 2019:07 | 115338.58 | 49541.823 | 18238.39 - 212438.77 |
| 2019:08 | 115511.52 | 50114.580 | 17288.75 - 213734.29 |
| 2019:09 | 115684.46 | 50680.864 | 16351.80 - 215017.13 |
| 2019:10 | 115857.41 | 51240.891 | 15427.11 - 216287.71 |
| 2019:11 | 116030.35 | 51794.863 | 14514.29 - 217546.42 |
| 2019:12 | 116203.30 | 52342.972 | 13612.96 - 218793.63 |
| 2020:01 | 116376.24 | 52885.400 | 12722.76 - 220029.72 |
| 2020:02 | 116549.18 | 53422.322 | 11843.36 - 221255.01 |
| 2020:03 | 116722.13 | 53953.900 | 10974.43 - 222469.83 |
| 2020:04 | 116895.07 | 54480.292 | 10115.66 - 223674.48 |
| 2020:05 | 117068.01 | 55001.646 | 9266.77 - 224869.26 |
| 2020:06 | 117240.96 | 55518.105 | 8427.47 - 226054.44 |
| 2020:07 | 117413.90 | 56029.804 | 7597.50 - 227230.30 |
| 2020:08 | 117586.85 | 56536.871 | 6776.61 - 228397.08 |
| 2020:09 | 117759.79 | 57039.431 | 5964.56 - 229555.02 |
| 2020:10 | 117932.73 | 57537.601 | 5161.11 - 230704.36 |
| 2020:11 | 118105.68 | 58031.495 | 4366.04 - 231845.32 |
| 2020:12 | 118278.62 | 58521.221 | 3579.13 - 232978.11 |

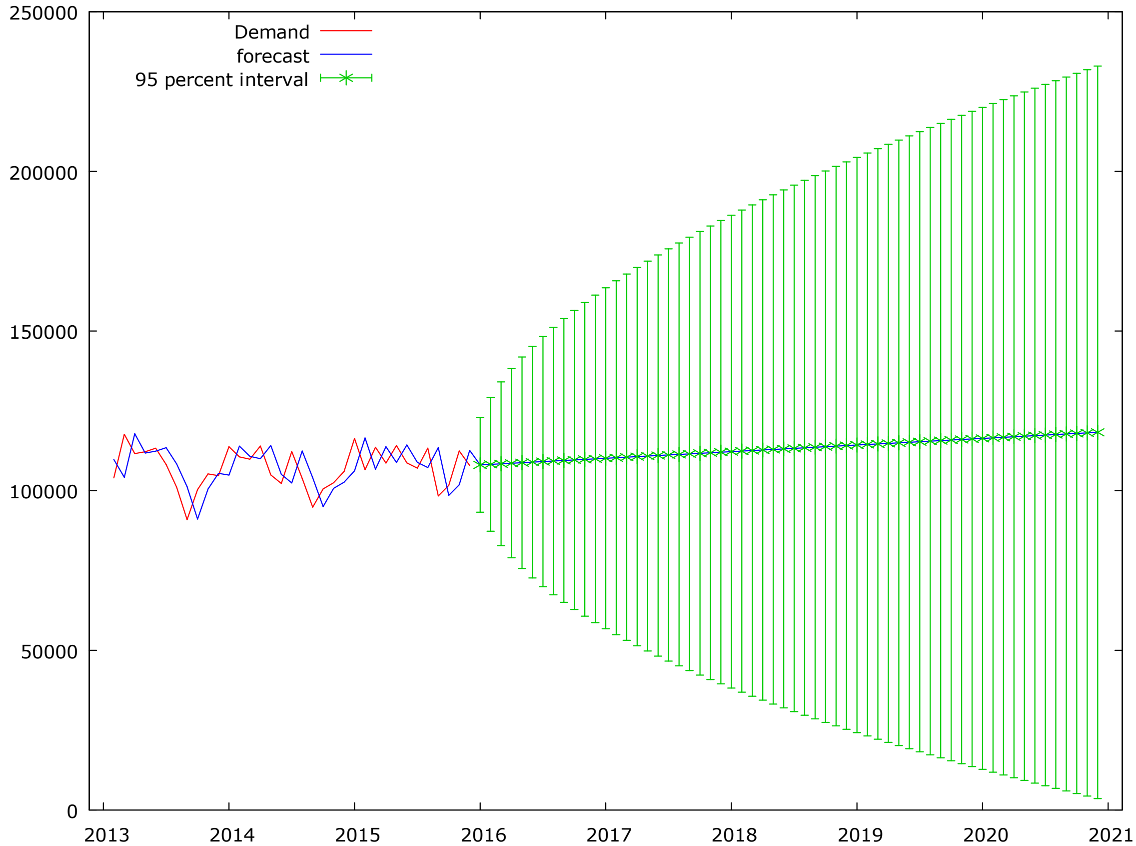


**Figure 15: Forecast graph**

From figure 4.15, it can be observed that water demand will be experiencing steady increases in the municipality as indicated on figure 15 range of 2016-2021.

**Summary of the findings**

The findings revealed that water demand are skewed to the left, indicating that most of the values are concentrated at the left of the mean and this means that majority of the values are below the average indicating high water demand in the WA municipality. The peakness demonstrated that a platykurtic has a flattened than normal peak and this suggests that most of the water demand are spread to the extreme sides of the curve also exhibiting high water demand in the WA municipality.

*Figure 4.1* shows an upward and downward trend with high and low peak indicating an irregular or random trend with the series showing a generally increasing trend. The generally increasing pattern in the time graph shows a gradual change of the mean whilst the flattened fluctuations over time shows an unstable variance suggesting the series is not stationary.

*Figure 4.2- Figure 4.6*describe various trend models of the series and the best trend that described water demand per the measures of accuracy in *Table 4.3 is* the quadratic trend model. Secondly, even though the data was transformed by way of differencing to achieve stationarity and the tests of best fit also confirmed that the final model was adequate for the forecast, the five years forecasted outcomes showed very steady increase in water demand over time. Thus, further demonstrating that water demand are likely to receive steady increase in the future if the government, non-governmental organizations, developed countries and world health organization do not introduce innovative water plant in order to arrest the water demand canker in the urban areas. The findings also revealed that ARIMA (1,1,0) best fit the water demand in WA municipality.

**Conclusion**

Based on the findings of the study the researcher can conclude that water demand in the WA municipality is likely to experience steady increase from 2019-2021. ARIMA(1,1,0) was identified to be the best fit model for water demand situation in the WA municipality. Nevertheless, quadratic trend model was noted to be the best model that described the water demand. water demand are skewed to the left, indicating that most of the values are concentrated at the left of the mean and this means that majority of the values are below the average indicating high water demand in the WA municipality. The peakness demonstrated that a platykurtic has a flattened than normal peak and this suggests that most of the water demand are spread to the extreme sides of the curve also exhibiting high water demand in the WA municipality.

**Recommendations**

Based on the findings of this study, couples with the fact that WA municipality is located in the savanna zones the study, commends/suggests the following:

- The management of Ghana Water Company can resort from donor countries to come to the aid of the company by donating money or equipment for the improvement of the water demand situation in the urban areas.
- The government of Ghana should allocate more resources to the water companies in order to acquire water plants as such to increase water distribution in the urban areas to satisfy their numerous customers.
- Both Governmental and Non-Governmental Organizations should work tirelessly to support the water company to arrest the water demand canker in WA municipality.
- The Ghana Water Company in case of rationing the water, should educate the customers and make the rationing timetable available to them early to enable them manage their consumptions.

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