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Assessment of Future Water Demand Utilizing the Weap Model in Bhavnagar City, Gujarat, India

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Abstract: ***Water resources management and analysis is very critical in today's ever increasing and demanding world. Different types of schemes and software for management are available to meet these requirements. WEAP (Water Evaluation and Planning) software is an integrated approach towards evaluating and planning of water demand and supply that can be very helpful in analysing and understanding water requirements of a particular city, area or region based on various inputs and further trying to understand and predict the future requirements. In this study, a WEAP model for future water demand of Bhavnagar city in Gujarat, is developed, that can predict the water demand requirement upto year 2041. Evaluation of WEAP is done based on census data for 2011 (as census data for 2021 for 10 year period was discontinued due to Covid-19 pandemic), considering 1.67% of growth rate. The final results include three scenarios, namely, Low population growth rate 1.5%, Moderated population growth rate 2%, High population growth rate 2.5%.***
Keywords: WEAP, Population growth rate, Bhavnagar, water demand, future assessment

I. INTRODUCTION

Bhavnagar is city located in Saurashtra region of Gujarat, India. Rapid urbanization has extended the boundaries of cities all over the world. In order to meet these requirements, various resources need to be explored. Also, the population needs to be fed with safe and hygienic drinking water. In alignment with the research objectives, this study employs the Water Evaluation And Planning (WEAP) software to assess the current and future water demands of Bhavnagar city.

The combination of population growth, urbanization, industrialization, and the expansion of irrigated agriculture, tourism, and navigation has led to a rapid escalation of demands and pressures on water resources (Mensah et al. 2022). Socioeconomic changes, including population growth and improved living standards, are projected to further strain water resources, resulting in higher water demand (Psomas et al. 2017).

The demand for water resources is rising all over the world (Xu et al. 2017). Equally, water scarcity is among the limiting factors in local socioeconomic development. Water scarcity is mainly caused by climate change, rapid urbanization, population growth, increasing demand for economic development, pollution, and over-exploitation of water resources (Divakar et al. 2011; MacDonald et al. 2011; Roozbahani et al. 2015). or advances, including a modern Graphic User Interface and a robust solution algorithm to solve the water allocation problem. Rosenzweig et al., 2004 analyzed the application of WEAP models to major agricultural regions in Argentina, Brazil, China, Hungary, Romania, and the US, by simulating future scenarios about climate change, agricultural yield, population, technology, and economic growth. Van Loon & Droogers, 2006 studied about water evaluation and the planning system in Kitui-Kenya and clearly demonstrated that WEAP is a powerful framework in the evaluating of current and future options of water resources.

II. STUDY AREA

Bhavnagar district is located in the east of Saurashtra Region of Gujarat State It lies between 20° 45′ to 22° 15′ north latitudes and east longitude of 70° 13′ to 71° 45′. Bhavnagar borders with Ahmedabad District to the northeast, Botad District the northwest, the Gulf of Cambay (Gulf of Khambhat) to the east and south and Amreli District to the west. Umarala taluka, Palitana, Sihor well connect with railway line as well State highway. Ghogha taluka of Bhavnagar is Developing Taluka of Bhavnagar district (By State Government).

Bhavnagar city is spread across 53.3 km^2 and had a population of 643263 at the time of census 2011. It has decadal growth of 18% approximately.

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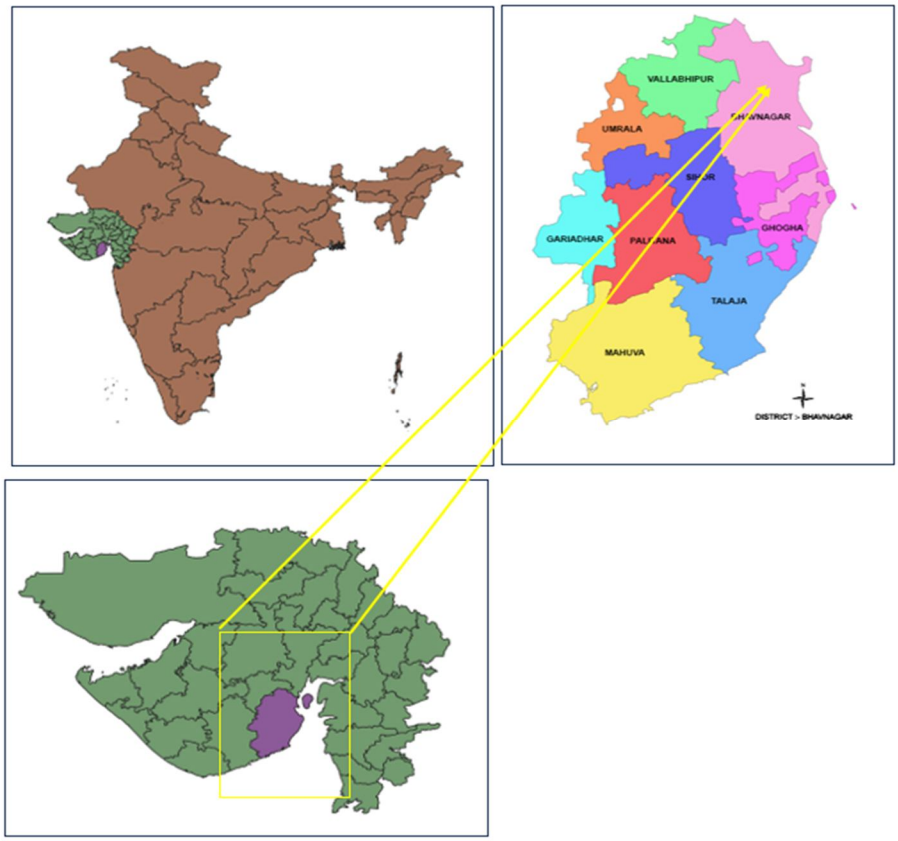


Fig 1: study area map
(https://en.m.wikipedia.org/wiki/File:Bhavnagar_Gujarat_map.svg)

A. Sources Of Water Supply – Bhavnagar

There are no perennial rivers in the near vicinity of Bhavnagar. The resources therefore are very limited and water supply is through dams/ canal systems of large river. Supply of water to Bhavnagar, therefore is presently being sourced from following:

1) Shetrunji Pumping Station (Shetrunji Dam)
2) Budhel Sump (Mahipariej Yojana)
3) Khodiyar Dam (Bhavnagar)
4) Gaurishankar Lake (Bhavnagar)

The Shetrunji is one of the major rivers of Saurashtra. It flows towards east direction and empties into the gulf of Cambay. The total length of this east flowing river from its origin to the outfall is 182 km. The basin is situated approximately between east longitudes of 70^{0} 50' and 72^{0} 10' and between north latitudes of 21^{0} 00' and 21^{0} 47'.

A 77 km long pumping and distribution piping system exists between Navda pumping station and Budhel sump. Water for Bhavnagar is tapped from Budhel pumping station.

B. WEAP Model

This section includes the development of WEAP model for (Bhavnagar City Water Supply System). In order that the water supply in the future is sustainable and adequate in quality and quantity to meet the booming demand, WEAP model will be developed and applied to evaluate the existing BCWSS and expected future scenarios for BCWSS by taking into account the different factors and policies that may affect demand and supply sources.

WEAP is a practical tool for water resources planning which incorporates not only water supply and demand-side issues, but also water quality and ecosystem preservation issues, by its integrated approach to simulate water systems and by its policy orientation.

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In this study, WEAP model is selected to use as a forecasting tool and database tool, and policy analysis tool to analyse about Bhavnagar City Water Supply System to forecast for the future options.

Generally, application of WEAP model includes the following steps:

1) Setting up study definition, including the spatial boundary, the time frame, system components and problem configuration.

2) Entering data in Current Accounts, this provides an overview of the actual situation of the system under study, this can be viewed as a calibration step in model development.

3) Creating Key Assumptions in Current Accounts, if necessary.

4) Based on the Current Accounts, scenarios are developed to explore the impact of alternatives on future water supply and demand.

5) Evaluation of scenarios, regarding water demand coverage, costs, sensitivity to uncertainty, and compatibility with environmental targets.

III. MODEL DEVELOPMENT

The model was developed with a systematic procedure and data required for data analysis was collected from various sources. The collected data was then properly charted out as required for input into the WEAP model.



Fig 2 Schematic View of WEAP model

After creation of study area, the study period of the model is needed to be defined. For this study model, the Current Accounts Year is set as 2021 and the last year of analysis is set as 2041. The time steps per year is taken as 12 based on calendar month by starting in January and adding leap days. Year 2021 is taken as Current Accounts year and shall work as the base year for the model. Demand and supply data which form part of system information has been included in the Current Accounts as input. Monthly Data of all demand nodes is entered as average water supply.

Month	Takhteshwar	Tarsamiya	Nilambaug	Chitra
January	46.23	52.14	24.68	29.55
February	51.8	54.35	24.314	29.68
March	51.56	56.75	23.96	30.43
April	48.35	59.21	23.88	32.52
May	47.62	61.24	23.59	30.83
June	53.55	57.77	27.1	29.61
July	52.27	57.66	25.47	32.09
August	49.13	59.35	25.05	33.59
September	51.93	62.11	24.8	34.53
October	51.6	61.34	25.76	32.13
November	51.47	62.59	25.09	31.62
December	52.37	58.42	24.74	32.66

Table 1 Monthly Average Water Supply to Demand Nodes in MLD

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In this study, demand data is available for individual sites of Bhavnagar city. Annual activity level is chosen as population for different demand sites as follows:

Filter Plants	Population (2021)
Takhteshwar	245125
Tarsamiya	243047
Nilambaug	132499
Chitra	86573

Table 2: Annual Activity level entered for demand sites

In WEAP model, demand sites can be defined according to the following, as major cities or country, individual users, filtration or pumping plants, irrigation sites, demands with return to wastewater treatment plant, water utility.
In this study, Takhteshwar Filtration Plant, Tarsamiya Filtration Plant, Chitra Filter Plant, Nilambaug Pumping Station. The gross daily average water supply in Bhavnagar city is 170 MLD.

IV. SIMULATED SCENARIOS

In this study, reference scenario was applied to analyse the situation of Bhavnagar City Water Supply System without any development of the system except the population growth with normal growth rate 1.67%.

Three different scenarios were generated as follows:

1) High Population Growth Scenario: it analyses the situation with high population growth rate of 2.5%.
2) Moderated Population Growth Scenario: it analyses the situation with moderated population growth rate of 2%.
3) Low Population Growth: it analyses the situation with low population growth rate of 1.5%.

V. RESULT AND VALIDATION

The WEAP model has brought out the water demand and supply according to the set parameters and helped us evaluate the future demand requirements upto 2041 given the population growth rates as per three different scenarios. The results thus obtained are represented below graphically as per the model. The water supply of Bhavnagar city of an average of 170 MLD thus stand exceeded as per the years marked against each population scenario in the given graphical representation.

As given in the WEAP model representation below, following can be derived:

1) Reference scenario indicates water demand in excess of 170 MLD after 2040.
2) Low population growth rate scenario indicates water demand in excess of 170 MLD after 2040.
3) Moderate population growth rate scenario indicates water demand in excess of 170 MLD after 2038.
4) High population growth rate scenario indicates water demand in excess of 170 MLD after 2035.

Water Demand (not including loss, reuse and DSM)
All Scenarios, Branch: Demand Sites, Annual Total
million Liter

Scenario	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
high population growth rate	113.15	116.01	118.88	121.74	124.61	127.47	130.34	133.2	136.07	138.93	159.52	162.74	165.96	169.19	172.41	175.63	178.85	182.08	185.3	209.47	213.05
low population growth rate	113.15	114.86	116.58	118.29	120	121.71	123.42	125.13	126.84	128.55	146.54	148.47	150.39	152.31	154.24	156.16	158.09	160.01	161.93	182.07	184.2
moderated population growth rate	113.15	115.38	117.63	119.88	122.13	124.37	126.62	128.86	131.11	133.36	152.55	155.08	157.61	160.13	162.66	165.19	167.71	170.24	172.77	194.77	197.58
Reference	113.15	115.12	117.12	119.11	121.1	123.1	125.09	127.08	129.07	131.06	149.69	151.93	154.17	156.41	158.65	160.89	163.13	165.37	167.61	188.73	191.22

Table 3: Water demand situation exceeding 170 MLD with comparison to growth rate

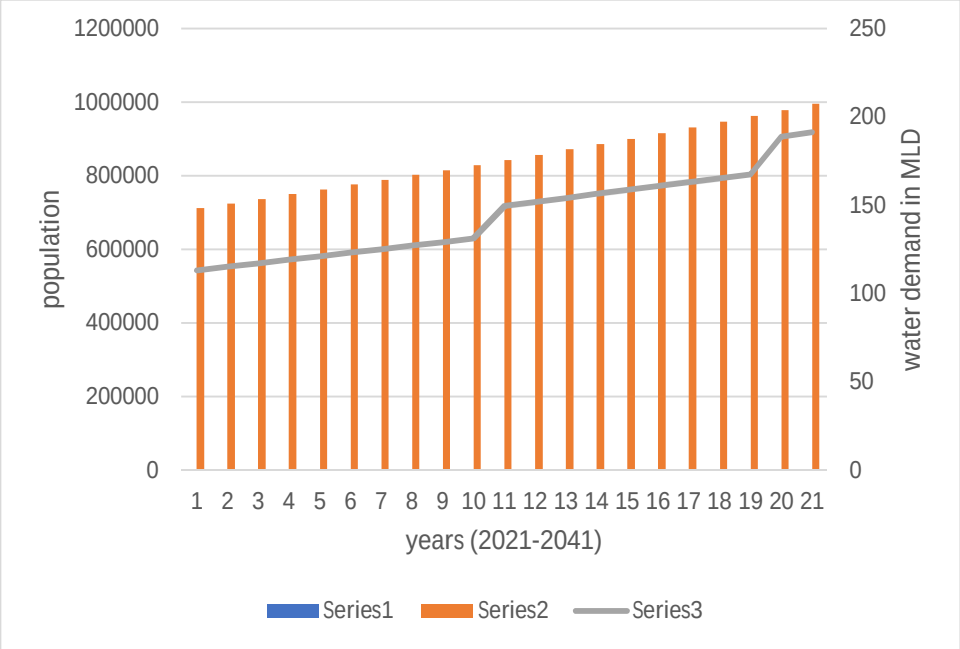


Fig 3: water demand forecasted for normal growth rate

Further, the WEAP model also derives results to indicate that assuming 1.67% of normal population growth rate as reference, the water demand as per reference (2021) which stands at 113.15 MLD grows to 191.22 MLD in 2041 which indicates a 68.99% growth in water demand over 2021. The relevant model is represented below:

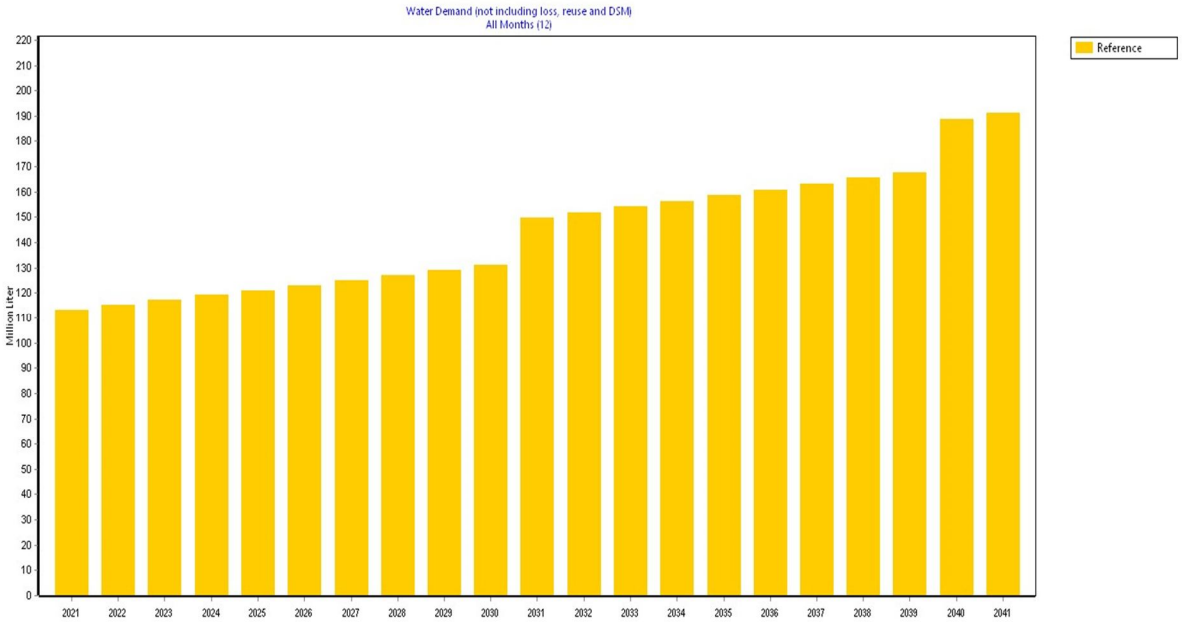


Fig 3: Water demand at normal population growth rate

Assuming 1.5% of low population growth rate as reference, the water demand as per reference (2021) which stands at 113.15 MLD grows to 184.20 MLD in 2041 which indicates a 62.79% growth in water demand over 2021. The relevant WEAP model is represented below:

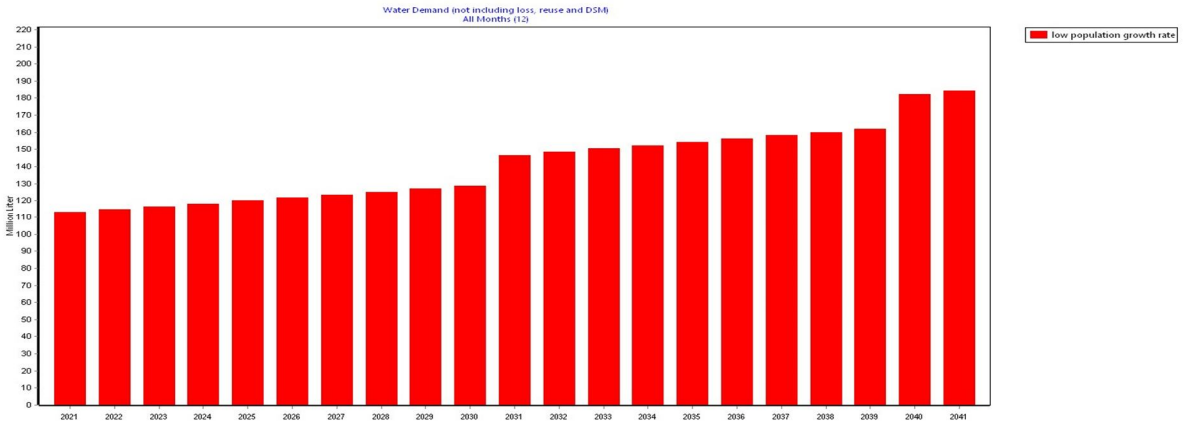


Fig 4: Water demand at low population growth rate

Assuming 2.0% of moderate population growth rate as reference, the water demand as per reference (2021) which stands at 113.15 MLD grows to 197.58 MLD in 2041 which indicates a 74.62% growth in water demand over 2021. The relevant WEAP model is represented below:

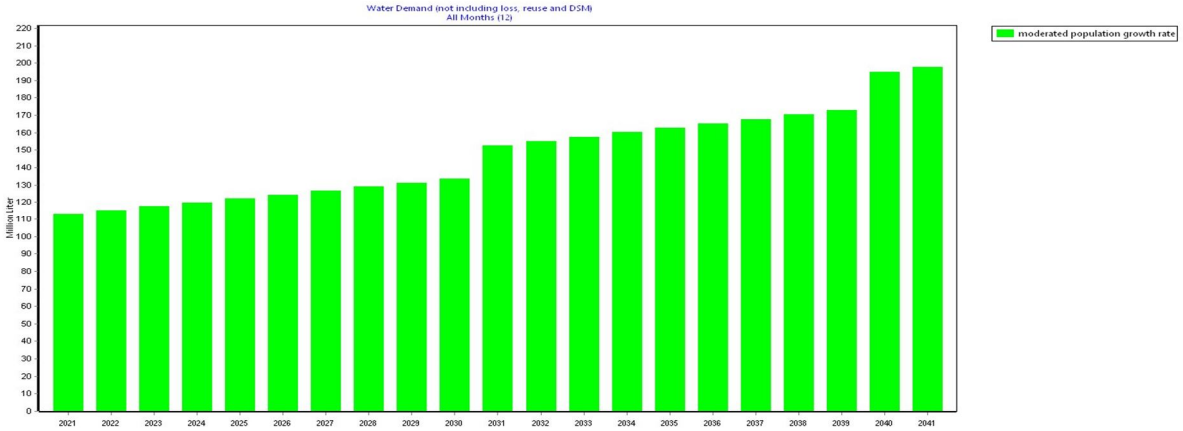


Fig 5: Water demand at moderate population growth rate

Assuming 2.5% of high population growth rate as reference, the water demand as per reference (2021) which stands at 113.15 MLD grows to 213.05 MLD in 2041 which indicates a 88.29% growth in water demand over 2021. The relevant WEAP model is represented below:

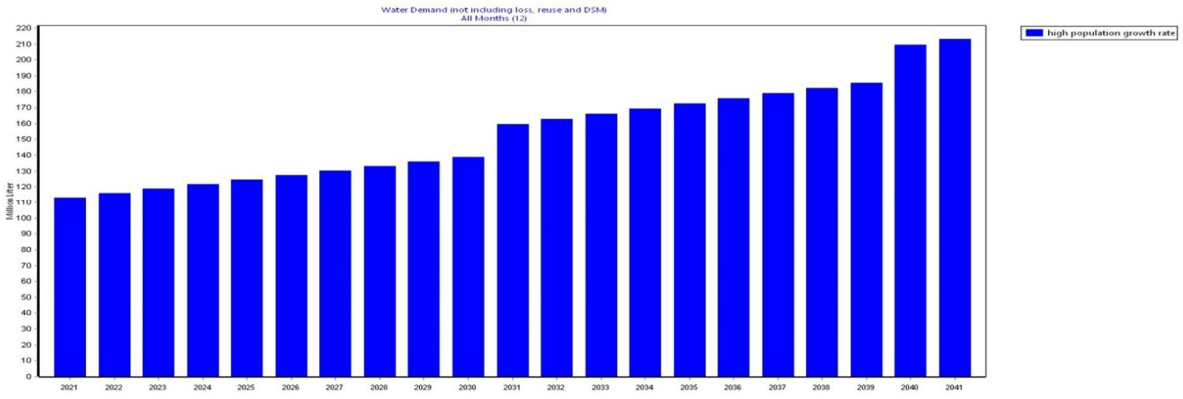


Fig 5: Water demand at high population growth rate

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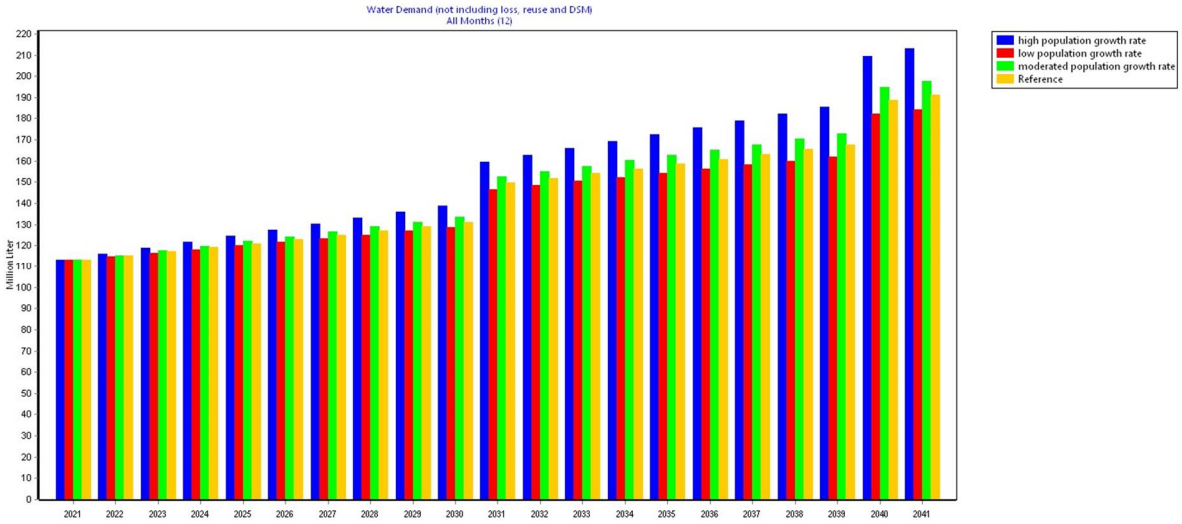


Fig 6: Comparative graph of all scenarios

VI. CONCLUSION

Following conclusions are drawn from this study:

1) As WEAP model utilizes an integrated approach to simulate water systems, it was chosen for this study. This study recommended that WEAP is very helpful in evaluating the current as well as future options in water supply system.

2) WEAP model was validated by checking the water supply data with predicted water demand.

3) The present water supply of Bhavnagar city is 170-172 MLD at normal rate of population growth is sustainable till year 2040.

4) Results indicate that the water demand in year 2021 under normal population growth rate is 113.15 MLD and in year 2041 is 191.22 MLD.

5) The results obtained from WEAP model indicates that the model performs well in evaluating and assessing water demands in the future.

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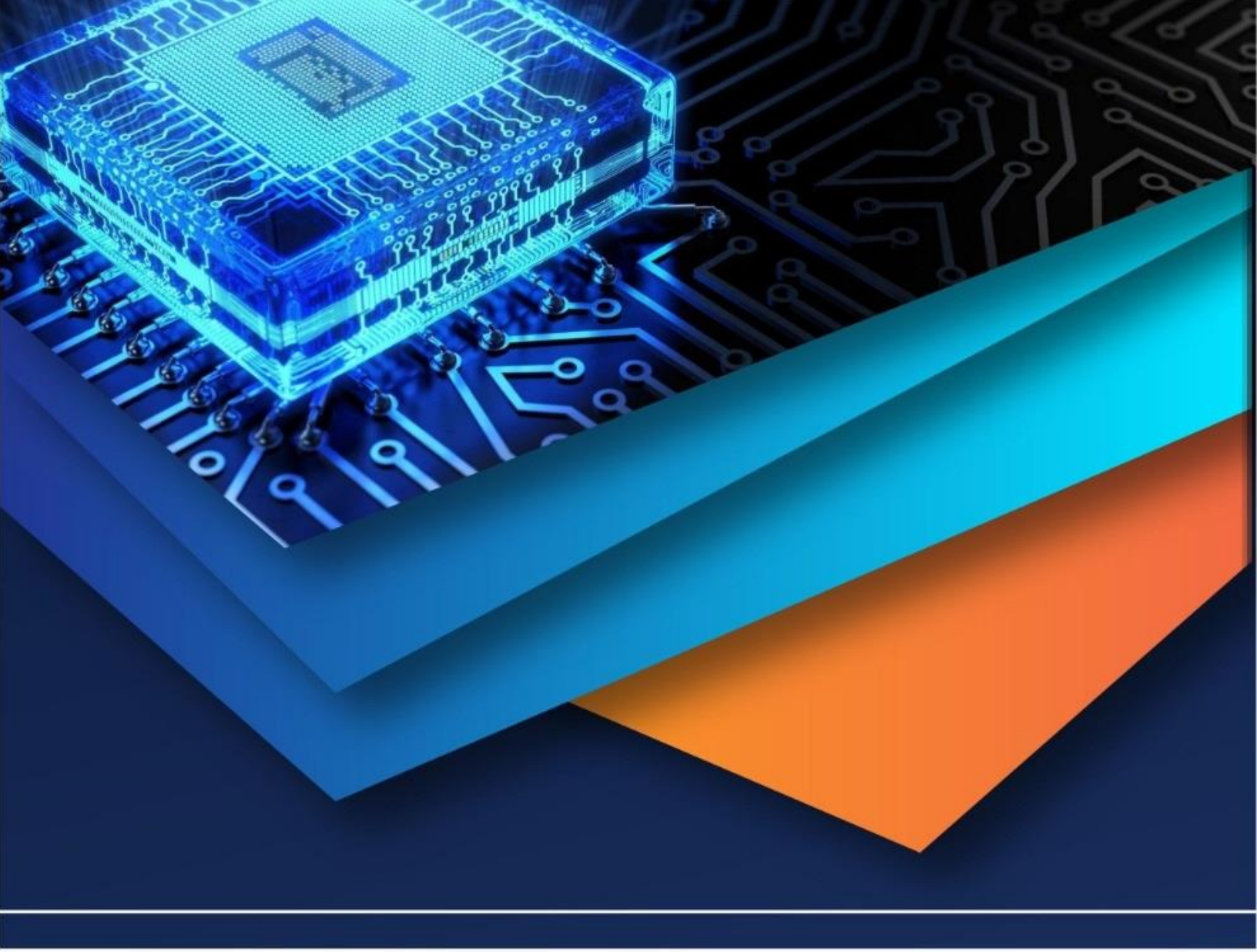
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