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Investigating the Water Demand and Supply Situation in Baljurashi Governorate, Saudi Arabia

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Abstract: This study examines the water demand and supply situation in the Baljurashi Governorate of Saudi Arabia during 2018, along with the anticipated changes in these dynamics as a result of upcoming project scenarios from 2018 to 2030. The Water Evaluation and Planning Tool (WEAP) model was utilized to analyze both current and projected domestic water distribution in the region through 2030. Initially, an assessment of current water demand and supply for household use was conducted. Relevant data were collected from a local branch of the Ministry of Environment, Water, and Agriculture (MEWA) in Baljurashi Governorate. This data was input into the WEAP model, which then produced projections for water demand, supplied resources, and unmet needs based on the reference scenario pertaining to the current accounting year. The findings revealed no unmet water demand, according to the model results. To enhance future water availability, the expansion of the Um-ghaith reservoir as a new water source is to be taken into consideration.

Keywords: Baljurashi Governorate, KSA, Water supply, Water Demand, Water Evaluation and Planning, WEAP Software.

دراسة حالة العرض والطلب على المياه في محافظة بلجرشي بالمملكة العربية السعودية

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المستخلص: تختبر هذه الدراسة وضع الطلب والعرض على المياه في محافظة بلجرشي بالمملكة العربية السعودية خلال عام 2018، إلى جانب التغييرات المتوقعة في هذه الديناميكيات نتيجة لسيناريوهات المشاريع القادمة من عام 2018 إلى عام 2030. تم استخدام نموذج أداة تقييم وتخطيط المياه (WEAP) لتحليل توزيع المياه المنزلية الحالي والمتوقع في المنطقة حتى عام 2030. في البداية، تم إجراء تقييم للطلب والعرض الحاليين للمياه للاستخدام المنزلي. تم جمع البيانات ذات الصلة من الفرع المحلي لوزارة البيئة والمياه والزراعة في محافظة بلجرشي. تم إدخال هذه البيانات في نموذج WEAP، والذي أنتج بعد ذلك توقعات للطلب على المياه والإمداد والاحتياجات غير الملباة بناءً على السيناريو المرجعي المتعلق بالسنة المحاسبية الحالية. كشفت النتائج عن عدم وجود طلب غير ملبى على المياه، وفقًا لنتائج النموذج. ولتعزيز توافر المياه في المستقبل، يجب أخذ توسعة خزان أم غيث كمصدر جديد للمياه في الاعتبار.

الكلمات المفتاحية: محافظة بلجرشي، المملكة العربية السعودية، إمدادات المياه، الطلب على المياه، تقييم وتخطيط المياه، برنامج WEAP.

1. Introduction

Water sits at the center of a constellation of unprecedented global challenges. Changes such as rapid urbanization, economic growth, increasing populations and evolving consumption patterns are individually and collectively stressing water supplies. Securing urban water supply is crucial since the number of urban dwellers living with seasonable water shortages is expected to grow from close to 500 million people in 2000 to 1.9 billion in 2050 (World Bank, 2018). There are significant regional variances in water supply alternatives. In more developed nations, where most of the urban population has access to public water, the focus has recently shifted to demand-side policies to encourage water conservation. This could be accomplished by education, the introduction and retrofitting of water-efficient devices, or the reorganization of tariffs to establish thresholds at which water use becomes much more expensive. Many of these regions/ countries' regulatory bodies additionally mandate that any water supplier wanting to enhance the extraction of new water resources must first examine and demonstrate that they have studied all possible demand-side and water efficiency measures accessible to them.

One of the biggest issues facing Saudi Arabia in particular and the world at large is the lack of freshwater resources. Saudi Arabia is regarded as one of the nations with the worst water scarcity, and since 1990, it has been listed as one of the ten nations worldwide and the five Arab nations with the worst water scarcity (United Nations, 2015). Now Saudi Arabia is witnessing ever-decreasing per capita water availability, while on the contrary, there is continuously increasing water consumption due to high population growth, household consumption patterns and the ever-increasing consumption of production sectors. This, in turn, has led to growth in freshwater demands for different purposes. Saudi Arabia's urban water context is characterized by a high per capita water requirement and high reliance on non-renewable groundwater.

The primary goal of water management is to save water and protect it from quality degradation, minimize capital intensity in infrastructure development, and maximize the advantages of using a unit flow of water. This entails monitoring water demand, decreasing water losses, increasing overall water transport and usage efficiency, and preventing water waste and loss caused by quality degradation. Demand for fresh water is on the rise, there is no longer sufficient water to meet our daily needs. 95% of water comes from aquifers, 4% from desalination and 1% from wastewater reclamation. Thirty percent of household water comes from desalination and users of desalinated water in the world represent about 26% of the world total. At present and in the future, we have to shift from the supply side to the demand management and conservation side, which means that we must use our water resources efficiently considering economic, social and environmental conditions (Al-Zahrani, 2010).

Hamid, et al., (2023) reported that the planning of water resources requires a multidisciplinary strategy that incorporates all the system's intricacies. The only effective management technique, then, can be the design of water allocation regulations that use an integrated approach.

The use of modelling tools to conduct scenario analysis is a key step toward developing water management strategies and achieving integrated water management. Computer-based Decision Support Systems (DSS) are highly important tools for this because they allow the user to foresee and analyze the implications of many conceivable future trends and management methods before they are implemented.

1.2 Water Supply and Demand

An approach to management known as "water demand management" seeks to meet the demand for water by applying appropriate, effective measures and incentives to promote equitable and efficient use of water resources. Saudi Arabia's water needs are rising quickly due to the country's expanding population and rising standard of living. The amount of water needed now and, in the future, will demand more than what is currently available (Al-Zahrani, 2010).

According to a report issued by the World Bank (2018), the increasing and changing population patterns are an important worldwide reality that most water supply providers are facing. The report mentioned the examples of Marrakech and Amman which provide clear illustrations of how social, political and economic dynamics can magnify already tense water situations and lead to drastic changes in urban water demand. As well, in Lebanon, Jordan and Iraq, major population influxes of refugees and internally displaced persons are already water-scarce cities. In such a context of fragility, water insecurity can precipitate violence and conflicts.

Chowdhury and Al-Zahrani (2015) have addressed water demand in Saudi Arabia. They have stated that the water demand in 2009 was 18.5 BCM of which 83.5% were for agriculture. From 2004 to 2009, agricultural water demand was decreased by 2.5%/ year, while the domestic and industrial water demands were increased by 2.1%/ year and 2.2%/ year, respectively. They have added that the industrial water demands increased from 56 to 713 MCM/ year between 1980 and 2009. Ouda (2013a) stated that water demand in Saudi Arabia far exceeds the sustainable yield of both conventional and non-conventional water resources. He added that the resulting demand-supply gap is being bridged through groundwater depletion. Also, he has shown that Saudi Arabia will not be able to bridge the demand-supply gap shortly. Eventually, he recommended that Intensive water demand management measures are needed in all sectors to minimize future demand-supply gaps. The volume of daily demand for water in the Kingdom reached 9 MCM and the individual consumption in a day is 256 liters (Saudi Gazette, 2016).

Al-Zahrani & Baig (2011b) reported that water demand has been growing at the rate of 4.3% per annum during (1999-2004). They added that household water consumption reaches around 260 l/c/d in Riyadh city, the average domestic water use in 2004 was 320 l/c/d (Figure 1). The amount of water required to sustain life and health in an emergency, varies according to the climate, the people's overall health, and their level of physical activity. People's expectations have a crucial role in determining how much water is necessary.

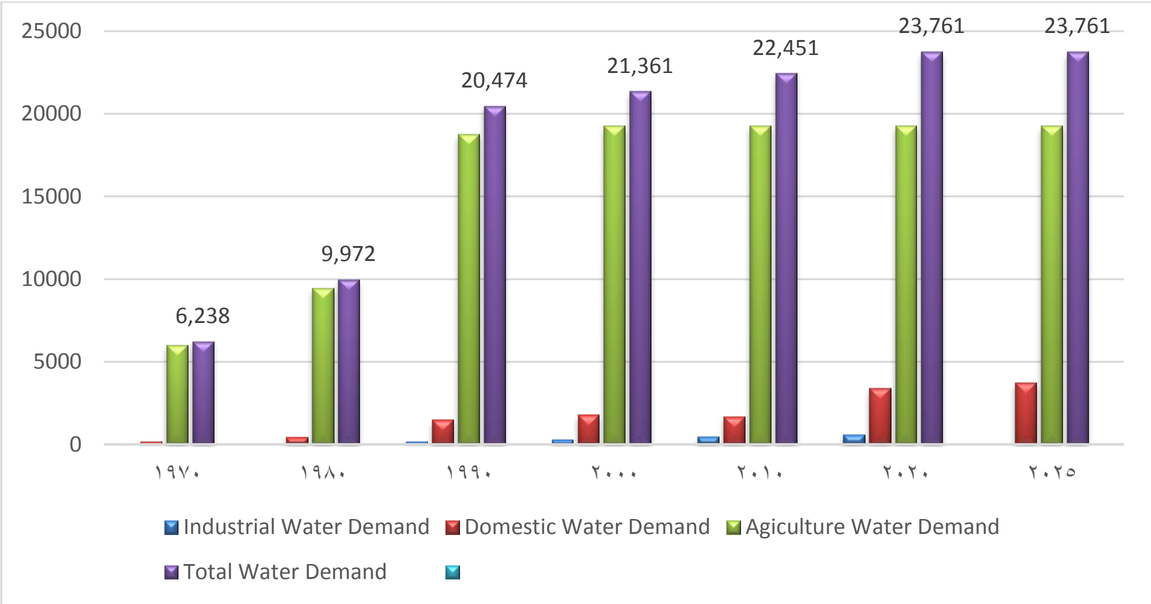


Figure (1): Growth in water demand in Saudi Arabia in Mm^3

Source: Abderrahman, 2006

2. Methodology

2.1 Description of the Study Area

Baljurashi Governorate is one of the governorates of the Al-Baha Region in southern Saudi Arabia. Baljurashi lies 2000 meters above sea level, between 19.42° N and 20.17° N latitudes and 30.00° E and 41.58° E longitudes (Figure 2). The Governorate has an area of approximately 1362 km2 and is distinguished by flat lowlands bordered by tall mountains.

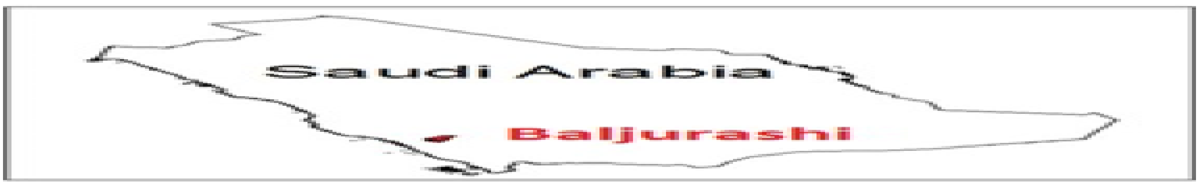


Figure (2): Location of Baljurashi Governorate within Al-Baha Region

Source: The Encyclopedia of the Earth (2020)

The average precipitation in Baljurashi is 316 mm (Alkhulaidi, et al., 2016). Figure (3) shows the annual rainfall in Al-Baha Region including Baljurashi. The rainfall is irregular and variable with heavy sporadic rains of frequent occurrence. The monthly mean ranges between 54 mm in October and 97.9 mm in January (El-Karemy and Zayed, 1992). Part of the surface runoff percolates through the sedimentary layers in the valleys and recharges the groundwater, while others evaporate (FAO, 2009). The soils in the area vary considerably, being shallow and coarse-textured in elevated and sloping sites; it is deep in alluvial texture in protected locations (El-Karemy and Zayed, 1992). According to the General Authority for Statistics (2019), the Baljurashi Governorate has a human population of approximately 78,536 people.

2.2 Water Supply in Baljurashi Governorate

Baljurashi Governorate gets its water from three sources (Figure (3)). The first source is Aljanabain Dam, which is located within the Governorate. Rainfall that falls on the governorate's mountains provides water for the dam. Consequently, the yield of dam water fluctuates from one month to the next, as well as throughout the year. Due to insufficient rains in 2007, the dam's water supply was inadequate. In addition to ceramic membranes, carbon and sand filters are used in the dam's purification station (H. Al-Ghamdi, Personal communication, July 22, 2020).

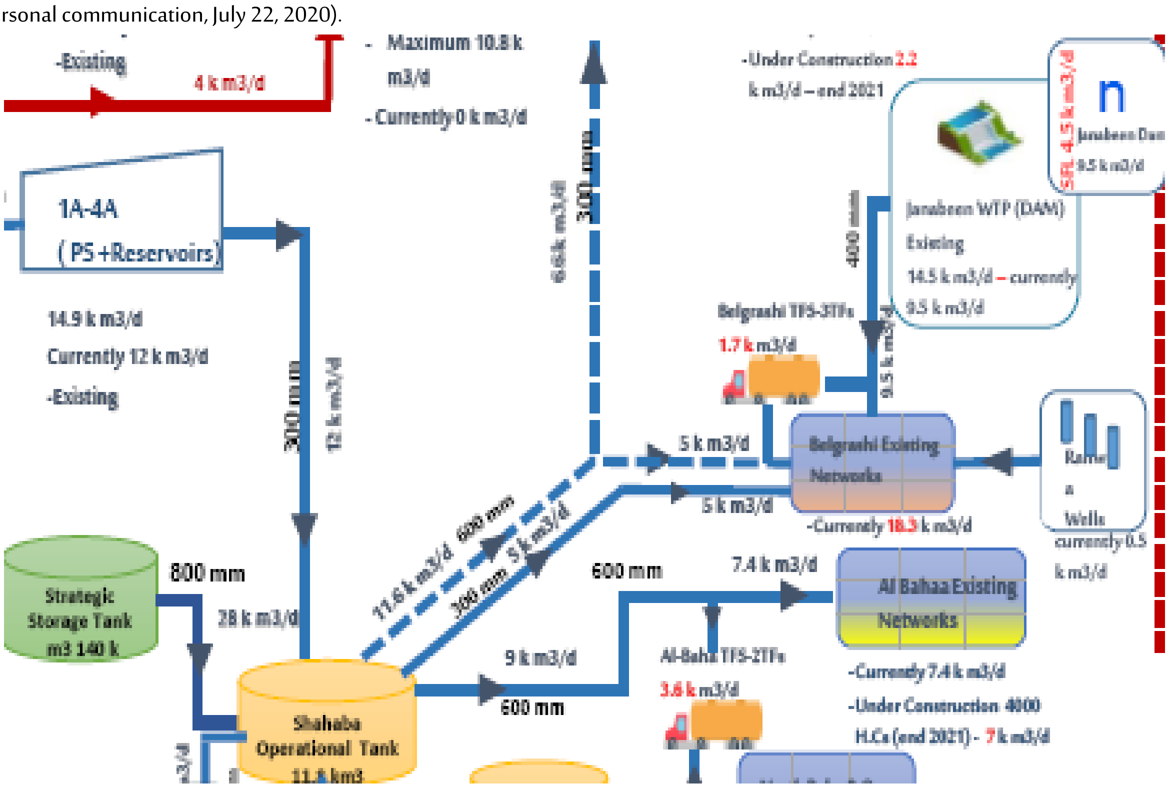


Figure (3): Distribution of water supply in Baljurashi Governorate

Source: MEWA (Al-Baha branch), 2020

The second source is desalinated water from the Red Sea's Al-Shoaiba desalination plant. Baljurashi receives between 8000 and 10000 m^3/ day of desalinated water. The third source of water is three wells (producing 70 m^3/day) which supply water to a limited area. According to H. Al-Ghamdi (Personal communication, July 22, 2020), the MEWA branch in Baljurashi operates eight tank reservoirs that supply water to all water-using sectors throughout the Governorate. Within the Governorate of Baljurashi, eight operational storage reservoirs are fed by Aljanabain dam, desalinated water and Alrahwa and Alsehaima wells. The size of these reservoirs varies (Table 1). Pumping stations are combined with all storage reservoirs.

2.3 Water Distribution System

The 1072 km of water pipes that make up the Baljurashi Governorate's water distribution network have main lines that range in diameter from 300 to 225 mm and lateral lines that range from 160 to 110 mm (Figure 4). UPVC, HDPE, carbon steel, ductile iron, and other pipe materials comprise the existing distribution system. The water network's leakage rate was discovered to be 7% (A. Al-Ghamdi, Personal communication, June 04, 2020).

The Baljurashi network supplies water to nine service zones. A group of skilled water workers periodically deliver water to these areas, primarily through control valves that feed each client once a week (A. Al-Ghamdi, Personal communication, June 04, 2020).

Table (1): The Storage Reservoirs of Baljurashi Governorate (2020)

Reservoir	Capacity m^3	Elevation m (amsl)	Coordinates	
			X	Y
New Bani-Saeed	10,000	2224	19°55′47.34″	41°31′55.24″
Bani-Kabeer	5,000	2137	19°56′ 57.18″	41°32′32.41″
Um-Ghaith	10,000	2184	19°53′ 24.69″	41°32′13.88″
Baljurashi	5,000	2095	19°53′00.41″	41°33′47.06″
Abdan	11,800	2135	19°50′27.48″	41°37′05.06″
Al-Rahwa & Sehaima	2,500	1984	19°56′44.80″	41°43′28.01″
Alfrya	5,000	2071	19°56′18.72″	41°41′27.11″
Algimia	5,000	1961.8	19°48′55.17″	41°43′42.58″
Shura	5,000	2052	19°47′25.97″	41°45′08.39″
Total	54,300			

Source: MEWA (Al-Baha branch), 2020

Figure (4): Baljurashi Governorate's water distribution network

Source: MEWA, Al-Baha branch, 2021

The daily water consumption is 250 l/c. Water billing in Baljurashi Governorate began in 2016 after water was previously provided free of charge. The water administration will turn to the National Water Company (NWC) by September 2021. (H. Al-Ghamdi, Personal communication, July 22, 2020).

2.4 Water Evaluation and Planning System (WEAP)

The Stockholm Environment Institute (SEI) created WEAP, a modelling and planning tool for water resources that is utilized all around the world. It is structurally similar to other tools for decision support management of water resources and has a straightforward design. Kiniouar, et al., (2017) reported that the WEAP offers considerable versatility to support various levels of data availability while maintaining a friendly graphical user interface. It is an effective method for managing water resources, including both supply and demand issues, as well as water quality and ecosystem preservation, as required by an integrated approach to watershed management. WEAP is a laboratory that examines alternative development and water management strategies by modelling "what if" scenarios and water regulations.

The scenarios can address a broad range of "what if" questions, such as: What if population growth and economic development patterns change? What if reservoir operating rules are altered? What if groundwater is more fully exploited? What if water conservation is introduced? What if ecosystem requirements are tightened? What if new sources of water are added? What if a water-recycling program is implemented? (SEI, 2015).

Elsadik, et al (2023) reported that WEAP model functions as a decision support system, facilitating integrated management of water resources and policy analysis. They added that the model enables the simulation of water demand, supply, crop water requirements, and various other parameters, enabling a comprehensive analysis of the water system across different scales within Egypt.

In this study, (WEAP 21) was used to assess the existing state of the water supply and demand system in Baljurashi Governorate. The assessment model was built with WEAP, which works on the core premise of water balance for each node and links in the system based on demand priorities and supply preferences.

The Baljurashi WEAP model is shown in Figure (5). It comprises one return flow site area (green square), eight water supply sources (green triangles), and one demand site (red circle).

Transmission links (the green lines) connect the demand site to the water sources. The return flow link (the red line) that connects to a receiving body represents the wastewater outflows from the demand site.

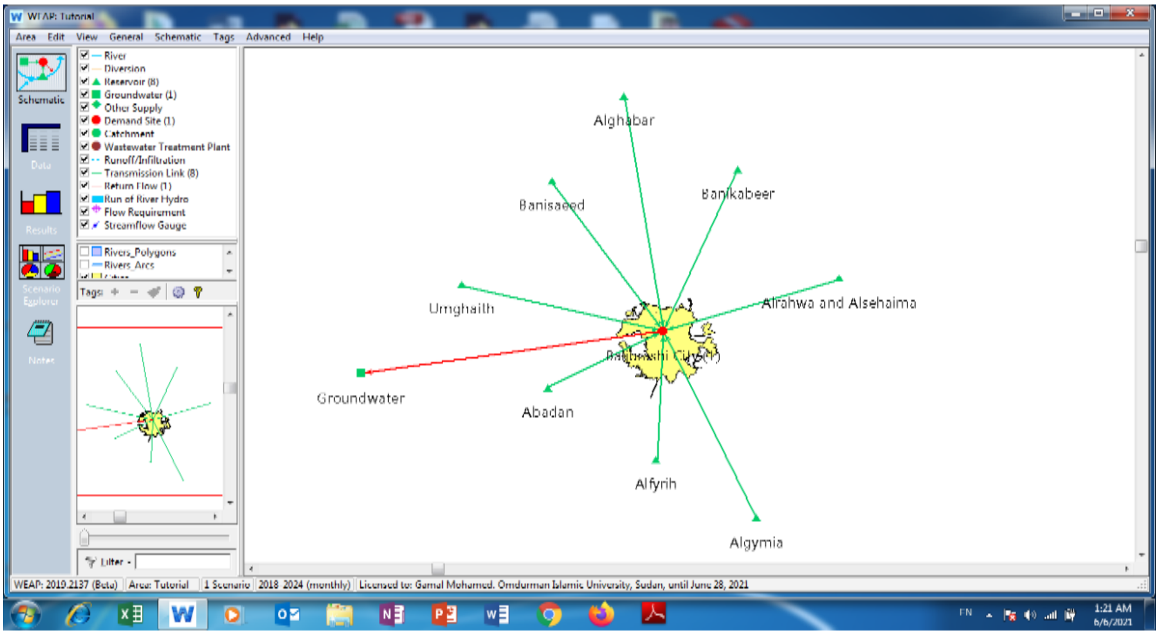


Figure (5): Baljurashi Governorate WEAP model

2.4.1 Setting up the Current Account in WEAP

The current account defines the water system as it exists today. In this scenario, the model simulation period is designed to last from 2018 to 2030, with 2018 serving as the current year. The initial step in this project was to design a WEAP schematic that illustrated all of the model's components (water resources, which are reservoirs connected to the demand site via transmission lines, as well as the return flow link. The model uses data from the year 2018, specifying the population, population growth rate, and per capita water use rate. Monthly inflow and reservoir storage capacity were also evaluated.

Demand in WEAP: The demand represents the quantity of water required for the demand site's water use. This is how the water demand is determined:

Total demand = Total activity level × Water use rate

Supply Elements: Alghabar, Bani-Kabeer, Bani-Saeed, Um-Ghaith, Abadan, Algymia, Alfyrih, and Alrahwa and Alsehaima Reservoirs were the key reservoirs that characterized these elements. Three wells, the Aljanabain dam, and desalinated water supply these reservoirs. For every reservoir, the monthly input, storage capacity, and net evaporation (which is zero because the reservoirs are closed) were determined.

Transmission Links: In the WEAP model, a transmission link must be established from the supply nodes to the demand site to satisfy the demand. This link must connect supply sources to the demand site. Roughly 7% of these transmission connections will experience losses (A. Al-Ghamdi, Personal communication, June 04, 2020).

Return Flow Links: Wastewater is transferred over this link from the demand location to receiving water bodies or wastewater treatment facilities.

Priorities for water allocation: Water is distributed based on demand priorities among competing demand sites. When there is a water scarcity, these priorities are helpful because they allow higher-priority sites to be fully satisfied before lower-priority sites are taken into consideration.

WEAP Input Parameters: Data on supply and demand were incorporated into the WEAP model to develop it. The supply and demand data entering in WEAP are displayed in Figures (6) and (7), respectively.

3. Results and Discussion

The WEAP model examined the various management possibilities associated with situations. Scenarios were created using WEAP, and their impacts on water availability and unmet water demands in the Governorate were evaluated.

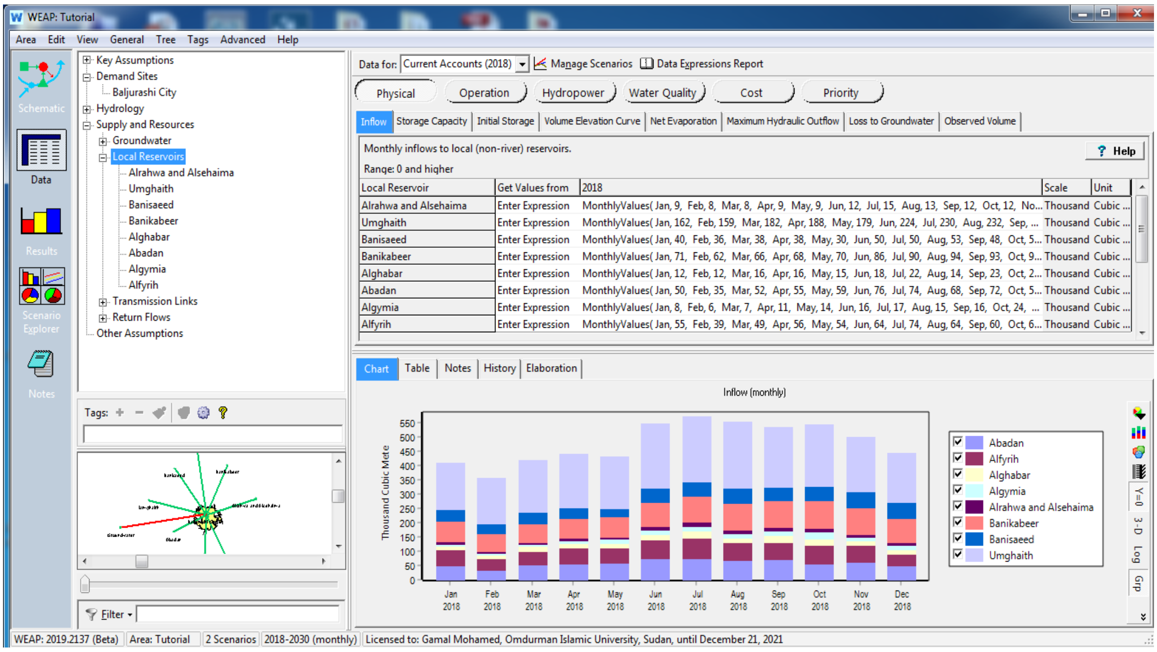


Figure (6): Supply data entry

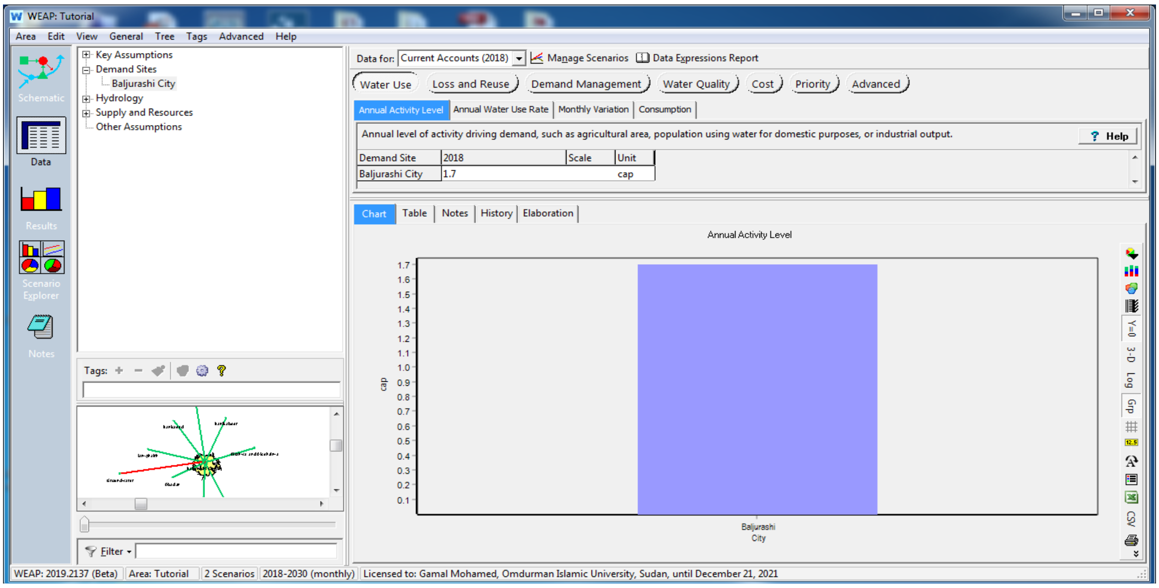


Figure (7): Demand data entry

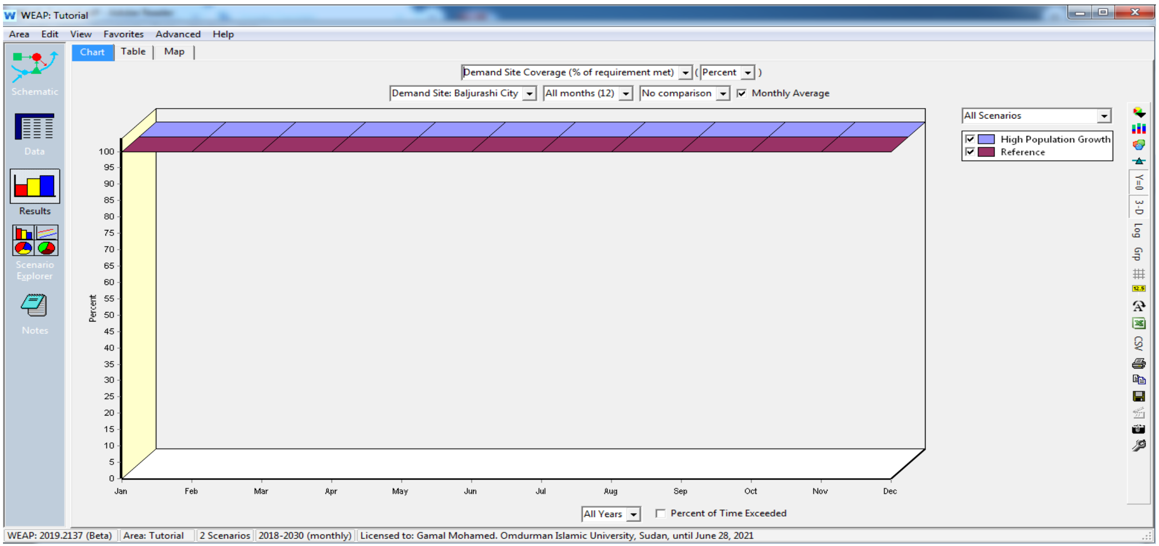
3.1 Scenario 1 (Reference Scenario)

This scenario illustrates the current state of the Baljurashi Governorate's water supply and demand systems. The current account figures are established based on the conditions of the year 2018. Figures (8), (9) and (10) show the demand site coverage, unmet demand and supply delivered by Baljurashi Governorate for scenario 1. According to the model result, the Governorate was fully met with the required demand and the demand side is fully covered.

3.2 Scenario 2: (If the population grows at an average annual rate)

Water planners must consider how population growth will impact supply and demand because it poses a serious threat to the water situation. The impact of a growing population with a 1% annual growth rate is illustrated by this scenario. The General Authority of Statistics (2018) estimates that between 2018 and 2030, the Baljurashi Governorate's average annual growth rate could be 1.7%. Figures (9), (10), and (11) illustrate scenario 2 for Baljurashi Governorate's demand site coverage, unmet demand, and supply requirements. In this scenario, the demand side is completely covered, and there is no unmet water demand either. The MEWA states that a new reservoir with a 75,000 m3 capacity will be built.

Saudi Arabia will not be able to bridge the demand-supply gap shortly. Intensive water demand management measures are needed in all sectors to minimize future demand-supply gaps (Ouda, 2014).



Figures (8): Demand site coverage for Baljurashi Governorate

3.3 Scenario 3 (After completion of Um-Ghaith big reservoir project)

According to the MEWA master plan, the new Um-Ghaith reservoir project will be finished by 2023. This project will provide 75000 m^3 to Baljurashi Governorate. This scenario depicts the state of the water supply and demand situation following the combination of scenario 2 and the completion of this project. The model findings showed that Baljurashi satisfied the required demand from the project's completion year of 2020 to 2027 as shown in figures (11) and (12).

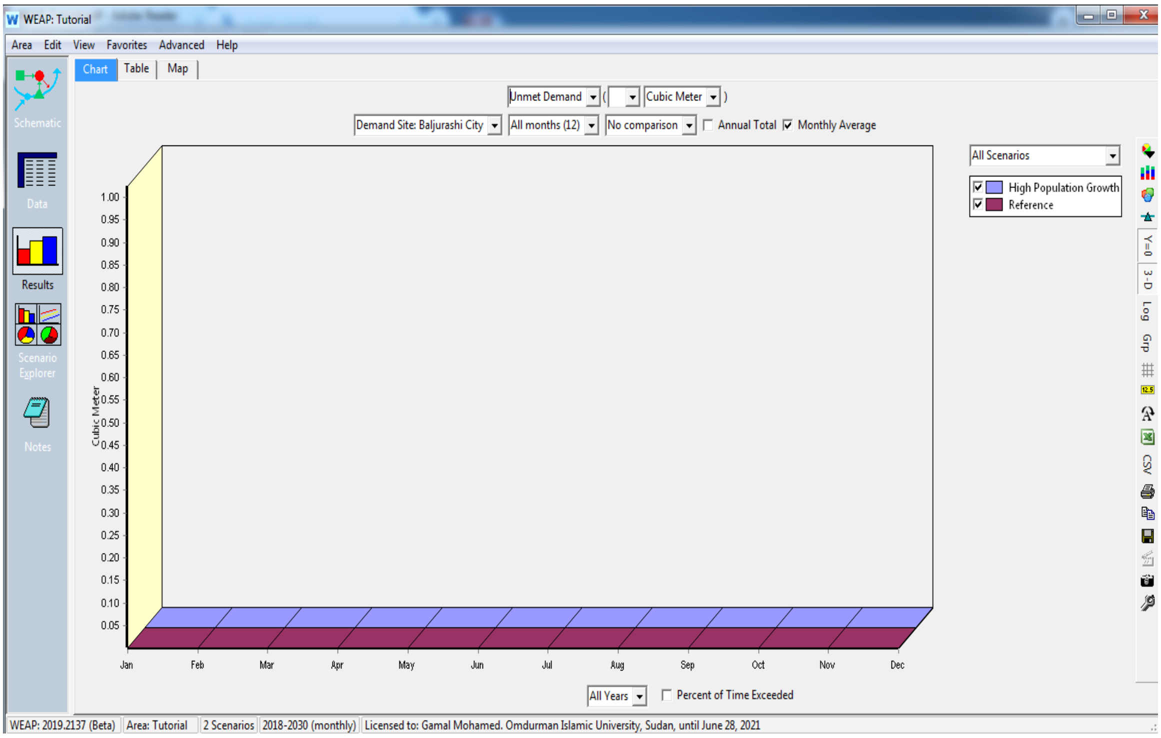


Figure (9): Unmet demand of Baljurashi Governorate

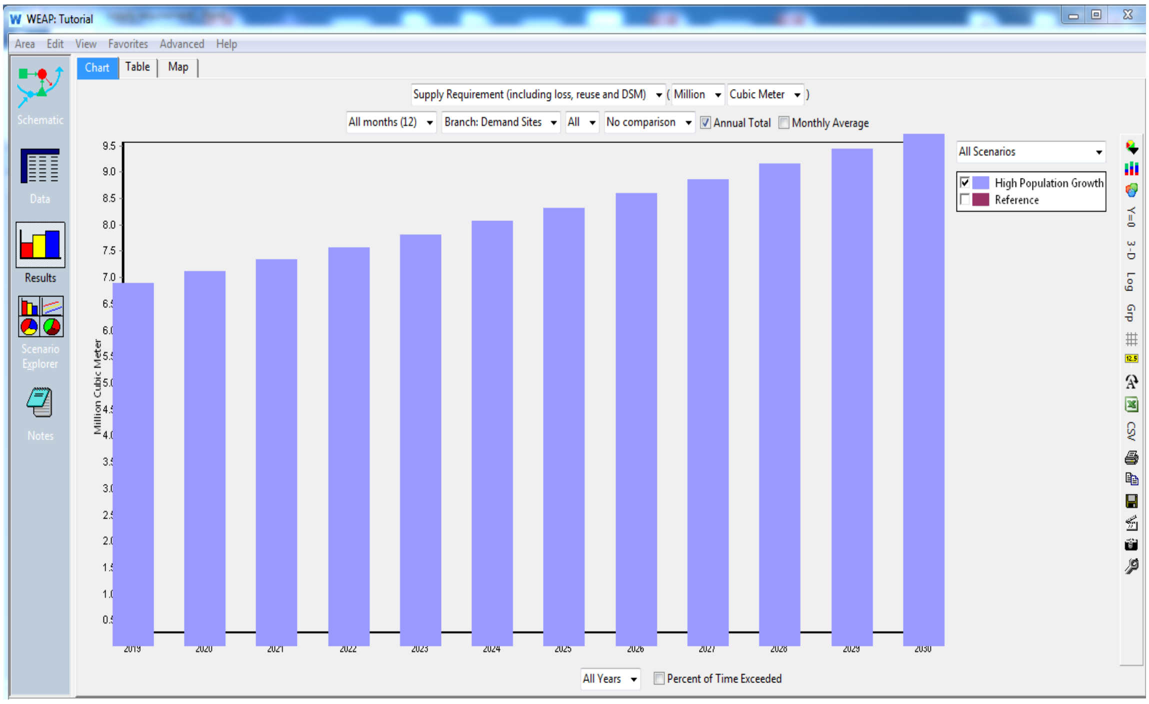


Figure (10): Supply requirement (Scenario 2)

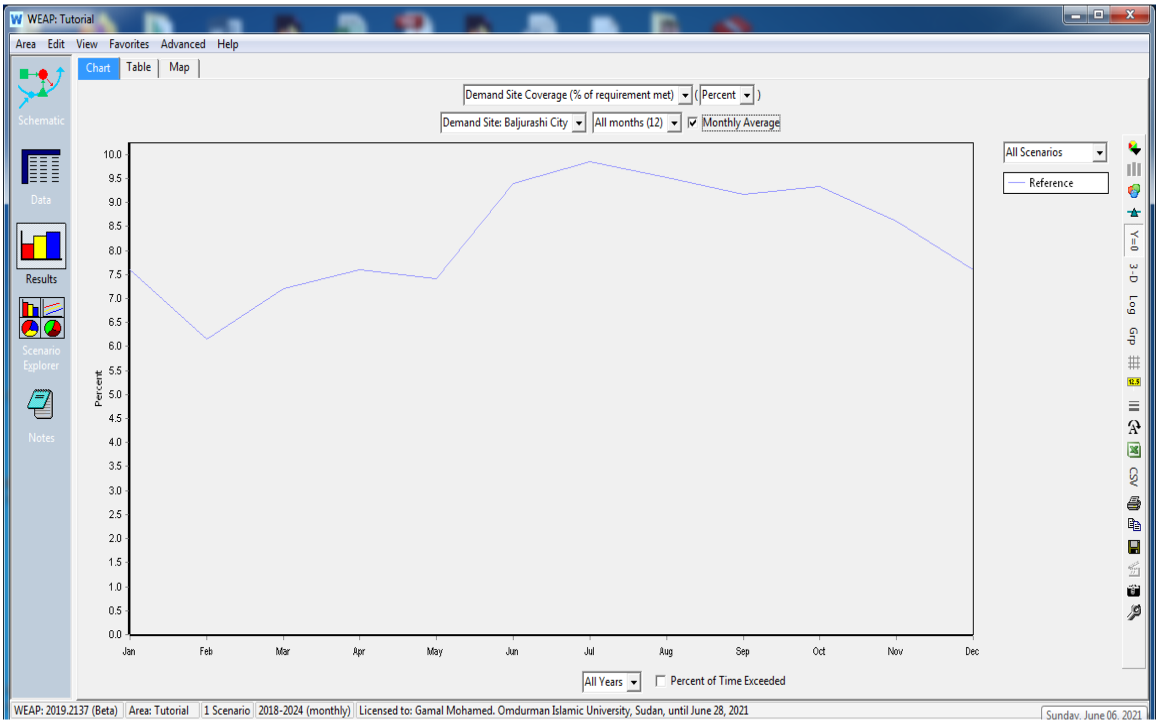


Figure (11): Demand site coverage for Baljurashi Governorate (Scenario 3)

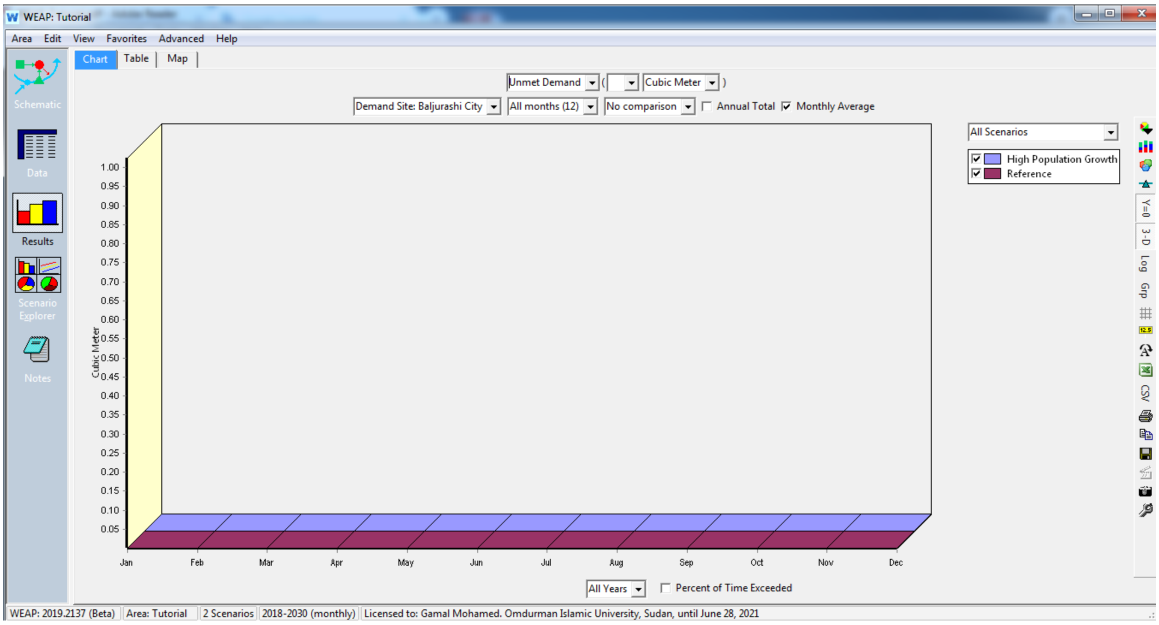


Figure (12): Unmet demand of Baljurashi Governorate (Scenario 3)

Sharef et al. (2021) investigated the management of water resources in Iraq's Kurdistan region using the WEAP model. His conclusions conflict with those of the current study, which concluded that there will be unmet demand in 2021, 2032, and 2046. The variation could be due to the way water is secured in Saudi Arabia.

Presently, systems that strike a better balance between supply and demand and take water demand management into account are more critical than those that place more of an emphasis on water availability or supply. Water demand management aims to meet the demand for water by putting in place necessary and efficient processes as well as financial incentives to ensure equitable and rational water use.

4. Conclusion

This study examined the Baljurashi Governorate's water allocation for the present and future using the Water Demand, Supply Delivered, Unmet Demand, and Demand Site Coverage (WEAP) model. The availability and demand for water were assessed using 2018 reference data. The assessment methodology was designed around three possibilities. The model's results showed that there was no unmet water demand. The produced scenarios are valuable resources for practitioners and policymakers looking for science-based decision support. To develop a comprehensive water consumption rationalization strategy, researchers and water managers must accurately characterize the study area's future water supply and demand, as well as the vulnerabilities of their tools.

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