

ALANA RIVER BASIN MANAGEMENT

Arkhan Jawhar Sharef¹ Rebwar Nasir Dara^{2,3} Ali Rashid Ahmed¹
 Director of Planning, PhD Lecturer, PhD President of Erbil Provincial
 Council, PhD ¹Presidency of Erbil Provincial Council - Erbil, Iraq.

²Department of Geology, College of Science, Salahaddin University-Erbil, , Iraq.

³Department of Petroleum Engineering, College of Engineering, Knowledge University, Erbil, Iraq

*Corresponding author:wrierbil@yahoo.com

ABSTRACT

The main aim of this study is to highlight how the Alana River Basin (ARB) will meet future water needs and optimal monthly water distribution policies. The Water Evaluation and Planning System (WEAP) model was applied in order to determine the ARB and the operation plan policy using data for the past 16 years (2000-2015). The model result determined that the current regulations and practices regarding water use and pollution patterns are inadequate. An ideal scheme has been developed and implemented for various scenarios such as domestic water needs, irrigation water, and tourism. Four scenarios have been considered in this study, which are basic scenarios, a higher population growth scenario, a severe flow requirements scenario, and a scenario of adding dams. Comparisons show that the demand for water from April to September is high due to the agriculture season and the high temperature. The maximum demand for water is 3 million cubic meters, which occurs in August, while the proposed dam provides only 2 million cubic meters. In addition, the maximum demand for domestic water is 0.4733 MCM and the minimum is 0.36978 MCM, which is roughly the same level of water demand for every month. Accordingly, the government should start supplementing the Gali Bale dam. However, it is not a sufficient dam to cover the water demand, so the construction of additional dams is strongly suggested.

Key words: alana river; integrated water resource; water demand; water pollution; WEAP model

شريف وآخرون

مجلة العلوم الزراعية العراقية - 2021: 52(6): 1304-1317

ادارة حوض نهر ألانة

² ريبوار ناصر دارا

¹ علي رشيد احمد

¹ ارخوان جوهر شريف

محاضر دكتورا

رئيس مجلس المحافظة - دكتورا

مدير التخطيط، دكتورا

¹ رئاسة مجلس محافظة أربيل / أربيل - العراق.

² قسم الجيولوجيا، كلية العلوم، جامعة صلاح الدين - أربيل / أربيل - العراق.

³ قسم هندسة النفط، كلية الهندسة، جامعة المعرفة / أربيل - العراق

المستخلص

الهدف الرئيسي من هذه الدراسة هو تسليط الضوء على كيفية تلبية حوض نهر ألانا (ARB) للاحتياجات المائية المستقبلية، وسياسات توزيع المياه الشهرية المثلى. تم تطبيق نموذج نظام تقييم و تحليل وتخطيط المياه (WEAP) من أجل تحديد ARB وسياسة خطة التشغيل باستخدام بيانات السنوات الـ 16 الماضية (2000-2015). حددت نتيجة النموذج أن اللوائح والممارسات الحالية المتعلقة باستخدام المياه وأنماط التلوث غير كافية. تم تطوير وتنفيذ مخطط مثالي لسيناريوهات مختلفة مثل احتياجات المياه المنزلية ومياه الري والسياحة. تم النظر في أربعة سيناريوهات في هذه الدراسة، وهي السيناريوهات الأساسية، سيناريو النمو السكاني الأعلى، سيناريو متطلبات التدفق العالي، وسيناريو إضافة السدود. تظهر المقارنات أن الطلب على المياه من أبريل إلى سبتمبر مرتفع بسبب موسم الزراعة وارتفاع درجة الحرارة. يبلغ الحد الأقصى للطلب على المياه 3 ملايين متر مكعب، والذي يحدث في أغسطس، بينما يوفر السد المقترح 2 مليون متر مكعب فقط. بالإضافة إلى ذلك، يبلغ الحد الأقصى للطلب على المياه المنزلية 0.4733 مليون متر مكعب والحد الأدنى 0.36978 مليون متر مكعب، وهو تقريباً نفس مستوى الطلب على المياه كل شهر. وفقاً لذلك، يجب أن تبدأ الحكومة في استكمال سد وادي بلي. ومع ذلك، فهو ليس سدًا كافيًا لتغطية الطلب على المياه، لذلك يُقترح بشدة إنشاء سدود إضافية.

الكلمات المفتاحية: نهر الانة؛ موارد مائية متكاملة؛ الطلب على المياه؛ تلوث المياه؛ نموذج WEAP.

Received:13/9/2020, Accepted:14/12/2020

INTRODUCTION

Iraq is currently facing a freshwater scarcity due to the rapid growth of population and development in the region (3, 7, 10). Many reasons have led to the water shortages in the region such as neighboring country's policies, those that share water resources with Iraq, climate changes, and mismanagement of water (9). Iraq has limited source of water. With increasing population, it's important to manage the water in a proper way (2). A comprehensive strategy is needed to conserve and develop our water resources (18). To build a strategy, several factors could be considered such as the availability of water, its quality, location, distribution, and variation in its occurrence, climatic conditions, nature of the competing demands, and socio-economic conditions (8). To deal with each of them, every effort is made to optimize the use of water, to make a high level of continuous production possible. Our goal is to increase the agricultural production per unit area. At the same time, provision must take to protect the environment against point and non-point sources of pollution (11). The importance of this study is on one hand, to redistribute the amount of water demand between all water sectors such as agriculture, livestock, tourism and environment and on the other hand is to distribute the river water flows among the irrigation projects for villages that located in this basin. The main aim is to implement strategic plans in the ARB for controlling water shortages and reducing water pollutions as well as creating a water balance for agricultural water use, domestic water use, and environment and tourism purpose. For that, the WEAP model was used to develop different scenarios, which help to the better understanding of integrated water resource management for the future.

MAERIALS AND METHODS

Study area

Alana river basin locates at about 80km to the northeast of Erbil governorate between (N36° 36' 31.88" N) and (44° 24' 28.39" E). It belongs to Khalifan sub district within the Soran district area. The location of the river basin is shown in Figure.1. Generally, Khalifan district is a mountain area with elevations from 650m to 2200m above sea level. Figure 3 shows the digital elevation map of Alana river basin boundary and elevations of the area. The catchment area is approximately about 75000 hector. There are 63 villages in the ARB with a population about 28573 people during 2016, 72% of population gathered in Khalifan, the 10% of the rest distributed in 11 villages of sub-catchment and 18% in 20 villages of main catchment (14). The climate of the region is warm in summer and cold in winter. Generally, rain and snow in north Iraq are changing from year to year; depending on the geographical and climatic conditions. The amount of precipitation has significantly affected the water level in the river and springs (9). The mean annual precipitation for the period of 2000-2016 in the study area is 794 mm (14). The average temperature of ARB in winter is 1.6°C and in summer is 27.8°C. Normally, precipitation is starting from October until the end of April depending on climate change. Precipitation almost is between (600-1000) mm and snow (0.5-1) meter (14). In the summer, maximum temperatures in the lowland areas exceed 40°C and dust storms are a common phenomenon. Evaporation rates are high in summer due to a combination of high temperatures, the absence of clouds (high radiation) and low air humidity. Summer maximum day temperatures reach 42°C in Erbil (average of the months July and August) Relative humidity during the summer months ranges between 20 and 30% in the low lands and is less than 50% even at the highest meteorological stations (1).

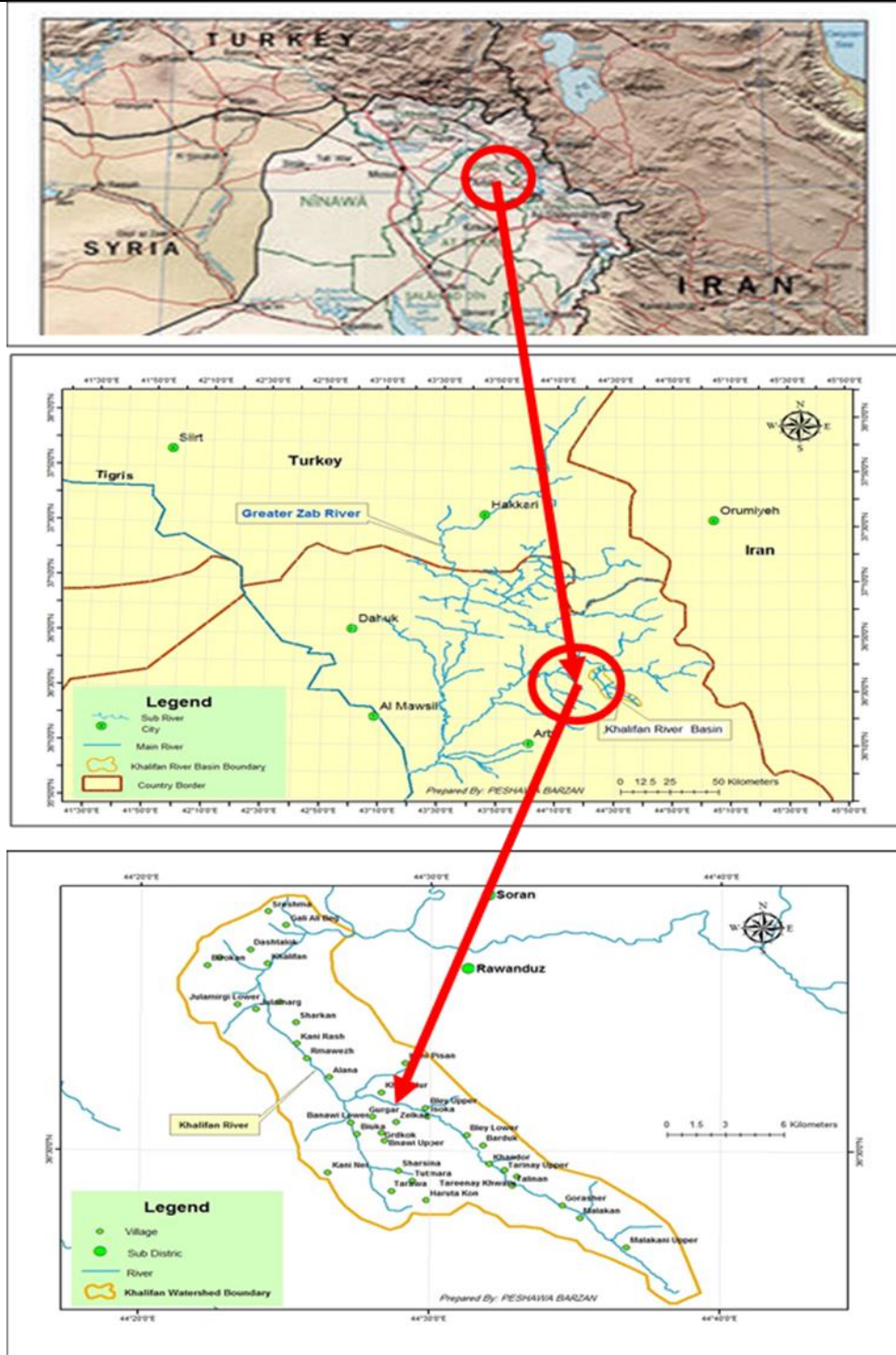


Figure 1. Alana River basin

The source of drinking water in the town of Khalifan is groundwater, which is pumped into the network, and there are also two springs connected to the public water networks (15). In the far south of the city, there are three wells close together and considered as an old wells. Moreover, three wells drilled by the FAO and located at the southern boundary of the town. The Kani Rash and Kanible spring lie in the southeastern part of the town with a distance of approximately 7 and 10.8 km,

respectively (16). Water flows by gravity to the corresponding reservoirs. The spring Kani Rash delivers water to a reservoir in the center of the town. There is a concrete reservoir in the east of the city at a distance of approximately 900 meters, and it is connected to the Kani Ble water network and feeding on it. Also, Kani plnga, Kani Bnawsha, Kani Baran located in Malakan used for different uses. The water system and water supply pump stations is shown in figure 2.

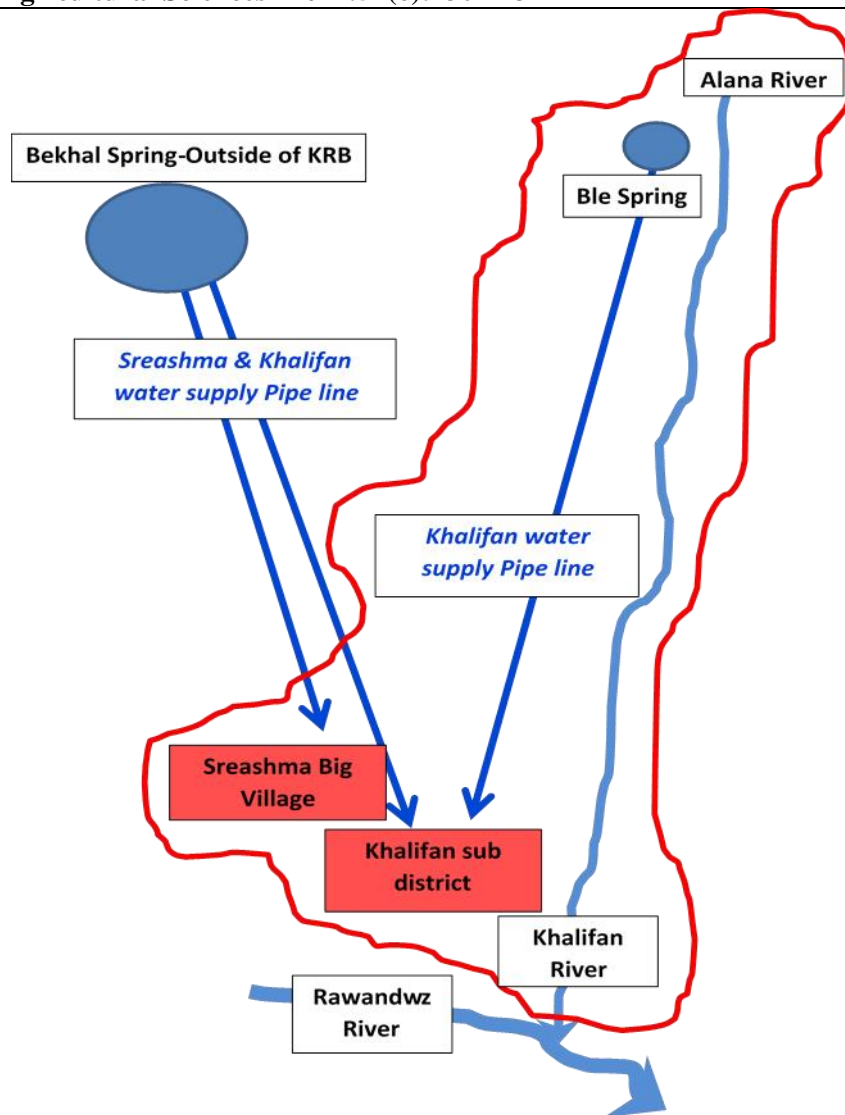


Figure 2. ARB water system and water supply

The shallow part of the soil is characterized by hard rock components in which it is hard for farming purposes. Furthermore, the deeper part of soil is changing from a location to another location (13). In addition, the valley and the plain area is useful for agricultural. The soils are recognized as chestnut soil, dark brown soil, and black soil. Also, in semi-mountainous area and most of the plain area are covered with red soil and brown soil (6). The main crops in Khalifan area are:

1- Field crop: Wheat, barley, chickpea and other legumes.

2- Vegetable crops: Includes dry onion, sunflower, tomato, tobacco, potato, cucumber and other vegetables.

3- Fruit crops: Includes walnut, cherry, pomegranate, apricot, fig and grape.

Agriculture in the Alana basin is produced either by rain or irrigation projects. Furthermore, all land belongs to a farmer means its private agriculture and one important point is there is no security food within the area. The total area irrigated 3100 ha, the year 2016 and Catchment area around 75,000 ha.

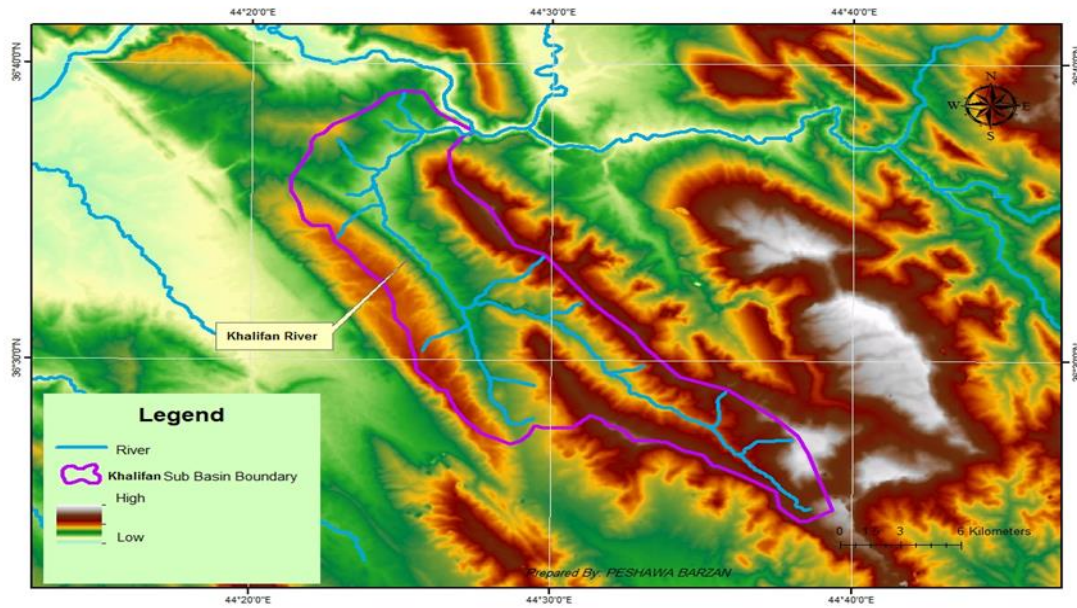


Figure 3. Digital elevation map of ARB badoundary

Methodology

The Water Evaluation Analysis Planning (WEAP) model was used for analysing and evaluating the water resource planning and management for the study area. This system is developed by the Stockholm environment institute for the evaluation of planning and managing of water resources (17). WEAP model could be use in both municipal and agricultural system. Moreover, it can tackle a wide range of issues such as water conservation, water demand, reservoir

operation, ecosystem requirements, and cost-benefit analyses (4). A Digital Elevation Model (DEM) has been prepared using Arc view GIS. First, river basin boundary was outlined as a precondition for hydrological model. Second, create a flow accumulation grid for the study area, it then added to the Alana (DEM) map. Finally, create an outlet point for the catchment area and delineate the watershed (5). Upon completion, the new watershed map will be added to the map document as shown in Figure 4.

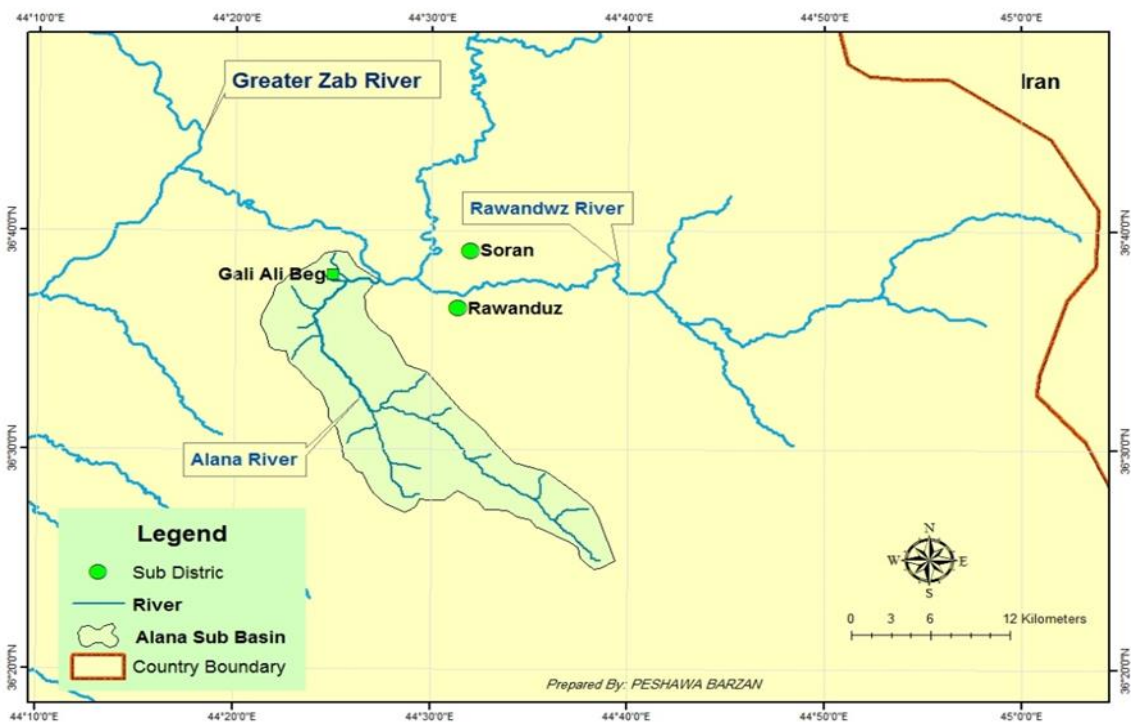


Figure 4. ARB raster geographic digital datasets in (geo-reference)

The map will be imported to WEAP program then water supplies for agriculture, domestic and environment will be delineated. Four scenarios were used for running model such as reference, flow requirement, high population and dam added scenarios. Crop Water Requirements (CROPWAT) are used to calculate water quantities and irrigation

method as shown in Table 1 Preparation of rain data, crop type, soil type and crop pattern is essential to operate the CROPWAT unit. The result will be three calculations (CWR, irrigation schedule, and chart types), the water balance method used to calculate crop schedules in CROPWAT, the incoming and outgoing water flow from the soil type. (12).

Table 1. Illustrates the crop water(CROPWAT) requirement in ARB

Total crop water requirement in mm/ month											
Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1710	534	0	0	0	255	952	3625	6863	8247	6388	3523

RESULT AND DISCUSSION

Agriculture Water Data Use by WEAP

The estimated annual amount of water for agriculture water use sectors in ARB are

summarized in Table 2. In 2010, the irrigation land in ARB was 3100 hectare according to MOA&WR survey (Table 2).The agriculture water demand was 3500m³/ha/year.

Table 2. Illustrates the agriculture land and water demand from (2010-2032).

Year	Land Extend Ratio per 5 Years	Agriculture Water Demand m ³ /ha/ Year	Irrigation Land ha	Annual Total Agriculture Water Requirement MILLION CUBIC METER
2010	0.178	3500	3100	10.850
2015	0.173	3500	3652	12.781
2020	0.167	3400	4284	14.564
2025	0.162	3350	4999	16.746
2030	0.161	3300	5809	19.169
2032	0.0644 / 2 Year	3250	6744	21.918

Table 3 shows the growth ratio, current and future domestic water requirement (15).

Table 3. Population growth and domestic water req. (2010-2032)

Year	Growth Ratio per 5 Years	ARB Population	Indoor Water Demand m ³ /cap/day	Outdoor WR Demand m ³ /cap/day	Total WR Demand m ³ /cap/day	Domestic Water Requirement MILLION CUBIC METER/Year
2010	0.178	22183	0.35	0.11	0.46	3.72
2015	0.173	26021	0.35	0.11	0.46	4.37
2020	0.167	30522	0.3	0.1	0.4	4.46
2025	0.162	35619	0.25	0.1	0.35	4.55
2030	0.161	41390	0.22	0.1	0.32	4.83
2032	0.064 per 2 years	48054	0.2	0.1	0.3	5.26

The Gali Ali Bag waterfall is the outlet point of Alana river basin. Table 4 shows the annual flow of the river. The minimum flow at outlet point was recorded 0.66 m³ / s in August 2010. Therefore, the 0.66 m³ / s could be used as a

base for environmental flow requirement (14). Table 4-6 and figure 5 show average water requirements for different water uses (agriculture, domestic and environment).

Table 4. Annual environment flow in the station of Gali Ali Bag waterfall

Year	Annual Environment flow M ³ /Sec.	MILLION CUBIC METER
2010	0.66	20.814
2015	0.66	20.814
2020	1	31.536
2025	1.5	47.304
2030	2	63.072
2032	2	63.072

Table 5. Water consumption annually

Water consumption MILLION CUBIC METER			
Year	Agriculture	Domestic	Animal
2010	14.564	4.46	0.28
2015	12.781	4.37	0.239
2020	14.564	4.46	0.28
2025	16.746	4.55	0.327
2030	19.169	4.83	0.38
2032	21.918	5.26	0.441

Table 6. Water consumption per day

River Basin	Item	Average water requirement / day
ARB	Population	360 (l/capita/day)
	Cattle	30 (l/animal/day)
	Sheep and goat	10 (l/animal/day)
	Horses	35 (l/animal/day)
	Poultry	0.5 (l/bird/day)

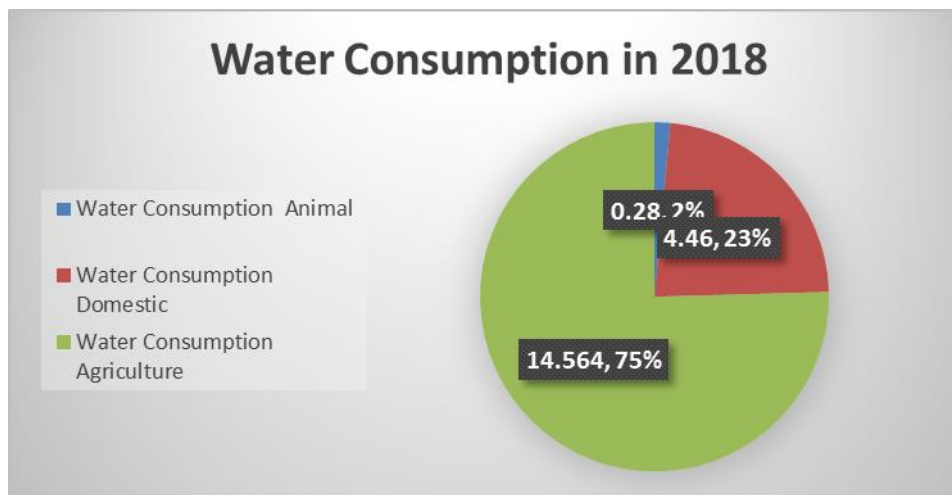


Figure 5. Water consumption chart

Regarding the surface water available are comes from rainfall around 1200 mm/year, the average depth of snowfall around 1 m, there are three mainsprings and 9 small spring in the area, the average water flow around 1m³/sec, as well as the dam, proposed to construction in the ARB with reservoir capacity 2 million cubic meters (MOA&WR, 2016).

Scenarios run model

Figure 6 shows four scenarios for the study site. The model shows that there is water storage about 80 million cubic meters for each month without changing in groundwater storage. This indicated that the groundwater is high in storage during months of a year. From March – May the inflow shows more than 15 million cubic meter (Figure 6). In addition, the

river shows significant flow from January to May and October to December. Moreover, the flow of river water is low during summer months (June- September). In the supply requirement (Figure 6C), in July-September, water supply for different users are more than 3 million meter cube per month due to high water demand. Figure 6D revealed a shortage of water demand which is starting from April to September. The most significant shortage was observed in August for flow requirement scenario. Therefore, each scenario has a shortage in water demand mostly in inflow requirements scenario due to 0.66 million cubic meters per second of environmental water flow to Gali Ali Beg.

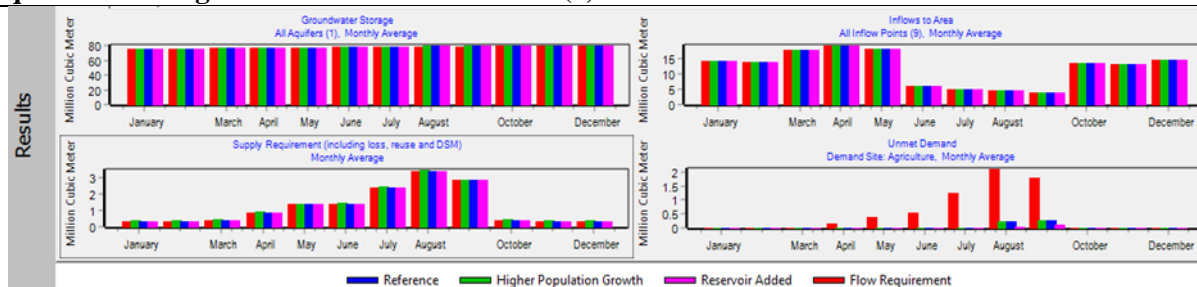


Figure 6. Four scenarios groundwater, inflow, supply req. and unmet demand

The annual of unmet water demand for the flow requirement scenario is 6.268 million cubic meters (Table 7). For high population growth, the annual unmet water demand is 0.55 million cubic meters. Thus, the growth in population resulted in more demand and water

shortage. While in the reference scenario, the unmet demand is 0.55 million cubic meters. Finally, in reservoir added scenario there is annual unmet water demand 0.15 million cubic meters because of having a dam with reservoir capacity of 2 million cubic meters.

Table 7. Four scenarios with unmet demand

Scenario	Unmet demand for all scenarios (million cubic meter)												Sum
	J	F	M	A	M	J	J	A	S	O	N	D	
Flow requirement	0	0	0	0.15	0.39	0.56	1.28	2.1	1.8	0	0	0	6.28
Higher population	0	0	0	0	0	0	0.02	0.25	0.28	0	0	0	0.55
Reference	0	0	0	0	0	0	0.02	0.25	0.28	0	0	0	0.55
Reservoir added	0	0	0	0	0	0	0	0.05	0.1	0	0	0	0.15

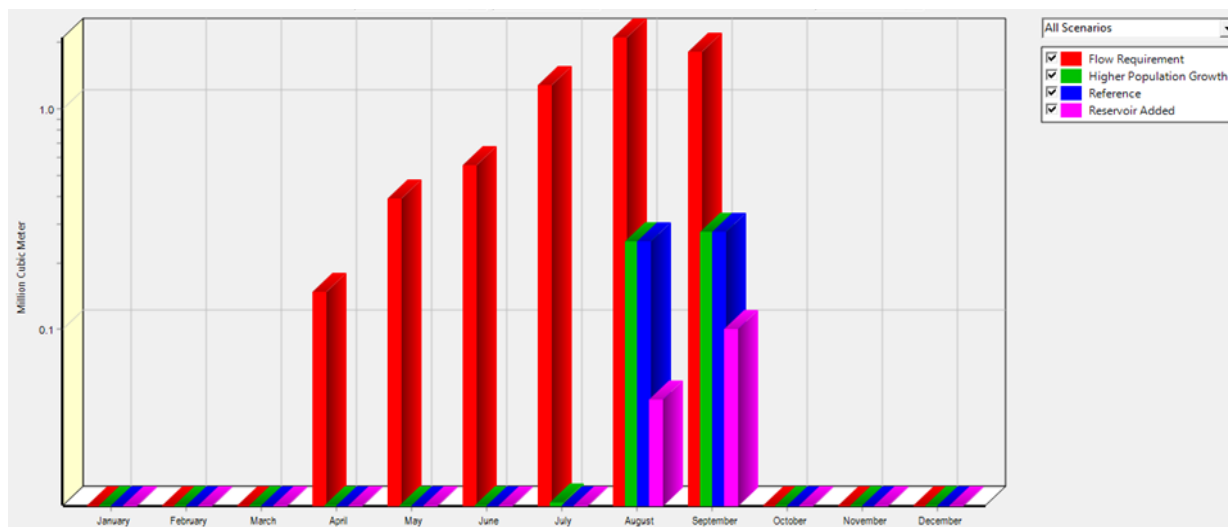


Figure 7. Four scenarios with unmet demand

Scenario reference

In this scenario, the basis for the actual reference data is used as a base for running other scenarios. The annual population growth ratio calculated as a normal case 3.4% after inserting all data required by the software. The output result is the water supply cannot cover the demand for domestic water and agriculture. Figure 8 and 9 show supply delivered for the agriculture sector is 2.8

million cubic meters while for domestic is 3.2 million cubic meters due to the priority of domestic water use. According to Figure 9, in scenario reference, there is a maximum supply requirement 3.42315 Million cubic meters in August and a minimum is 0.36978 Million cubic meters in each from January to March and October to December because of rainy seasons.

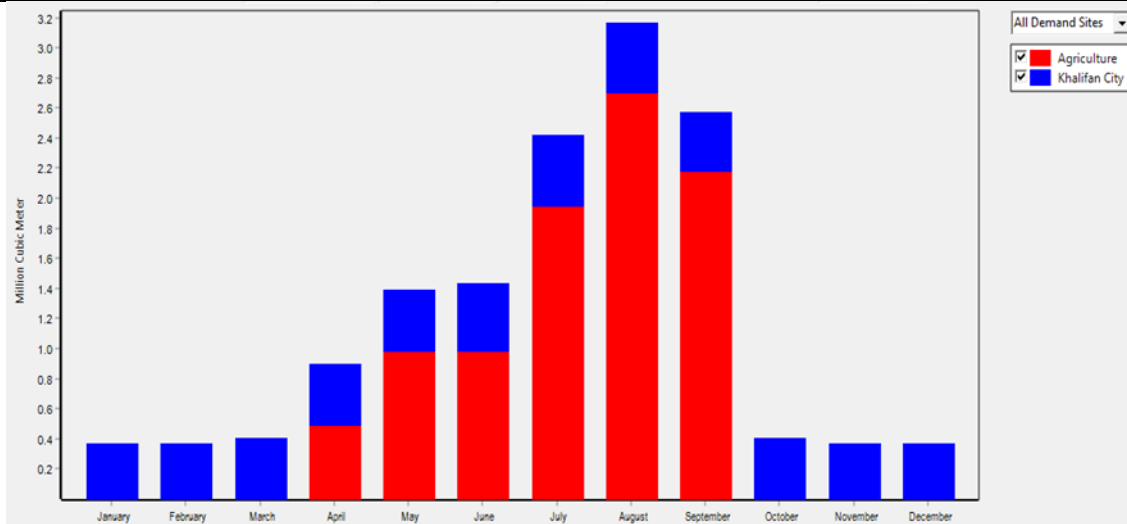


Figure 8. Scenarios reference with supply requirement

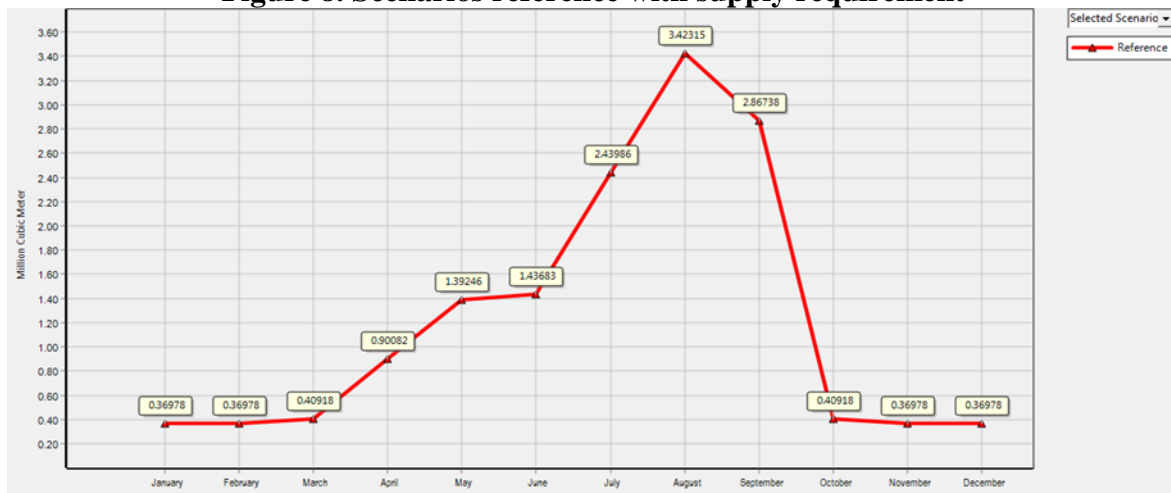


Figure 9. Scenarios reference with supply requirement

Scenario Flow Requirement (SFR)

In the flow requirement Scenario, should consider that the minimum water flow to the Gali Ali Bag waterfall is 0.66 meter cubic per second as environment water flow requirement. Table 8 shows that there is unmet

demand. Meanwhile, water is enough for the domestic purpose, but there is a shortage of water for agriculture. For Khalifan city water demand is enough to all-purpose except agriculture has unmet water approximately is 100 million cubic meter.

Table 8. Flow Requirement Scenarios with Unmet Demand

Scenario flow requirement per year unmet demand (million cubic meter)														
Demand site	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	Sum
Agriculture	6.01	6.87	6.76	7.33	7.32	6.77	6.76	5.91	5.91	6.75	6.76	7.32	6.76	100.29
Khalifan city	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	6.01	6.87	6.76	7.33	7.32	6.77	6.76	5.91	5.91	6.75	6.76	7.32	6.76	100.29

As seen in Figure 10, the water shortage is occurring in agriculture demand. Moreover, for domestic demand water is enough to fit all necessary fully but for agriculture water

demand increase from 1.5 million cubic meters in 2017 to 7.3 million meters cubic in year 2032.

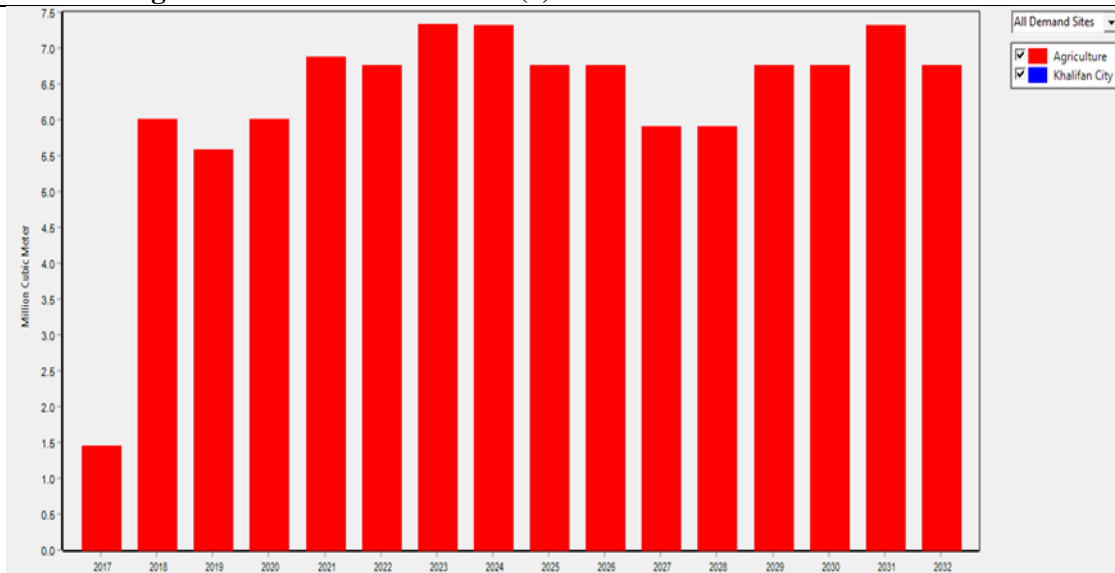


Figure 10. Flow Requirement scenarios with unmet demand yearly

Figure 11 in the flow requirement scenario, shows monthly shortage demand. Also, demand water increase from April to September and other months are zero due to the rainy and snowing season. As seen the

maximum water shortage is in September by the amount of 2.1 million cubic meters. Meanwhile, 2.1 million cubic meters of water reduced for agriculture, but for domestic, the demand is enough for daily life.

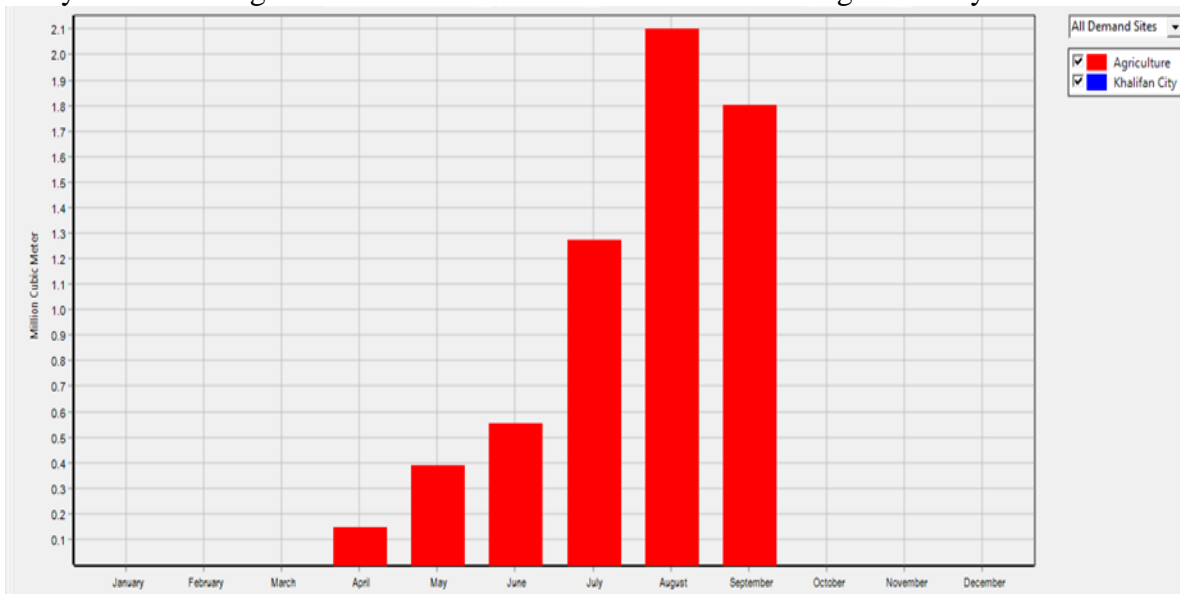


Figure 11. Flow requirement scenarios with unmet demand monthly

High Population Growth Scenario

In this scenario, the rate of growth takes to account 3.4 that are according to the ministry of planning. After running the data, the result gave unmet demand. As seen in the water demand is zero, but there is an 8.707 million cubic meter shortage in the agriculture sector. Also, the water is not enough for supplying water in agriculture. In a high population growth scenario, as shown in Figure 12, there is water unmet for agriculture in each year

2017,2021, 2022, 2023, 2024, and 2031. The maximum shortage will happen in 2023 and 2024. Therefore, the government proposes to construct a dam in 2025 to reduce that shortage which agriculture is facing in. Also in the monthly flow requirement scenario, water shortage showed in July, August, and September. The maximum shortage is 275 thousand meters cubic, which happens in September, and the minimum shortage is 15 thousand meters cubic, which happens in July.

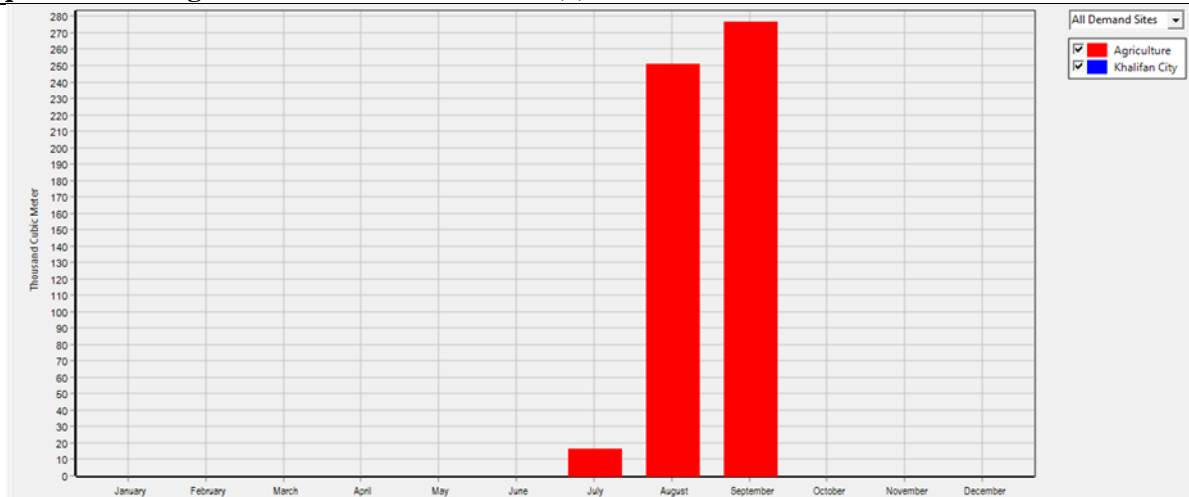


Figure 12. High Population Growth Scenarios with Unmet Demand Monthly Scenario Dam Reservoir added (SDR)

Gali-Ble dam designed by the Ministry of Water Resource, and the final design used in this scenario. Gali-Ble Dam stores 1.8 million

cubic meters at an elevation of 993 m, the height of the dam is 27m, freeboard is 2 m. Table 9 and Figure 13 show (Elevation-Area-Storage).

Table 9. Elevation-Area-Storage for Ble Dam Reservoir

Elevation (m)	Area (m ²)	Storage (m ³)
961	0	0
965	1667	1689
971	18012	56652
977	47648	254160
981	71377	492888
987	115974	1059283
991	140519	1580169
993	151387	1875399

After designing the Ble dam for 2 million cubic meters, there is a shortage of water demand for agriculture in August and

September. Moreover, the capacity of the dam which designed by the ministry of water resource is not enough for agriculture.

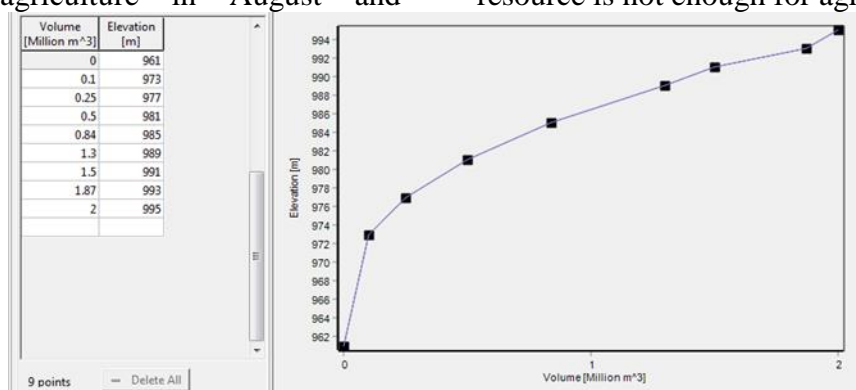


Figure 13. Elevation-area-storage for Ble Da

Figure 14 shows significant water shortage in agriculture demand, there are water shortages in August and September. A maximum shortage occurs in September by the amount of 100 thousand meters cubic due to no rain and use water for agriculture. Moreover, besides the government proposed a dam with a

capacity of around 2 million cubic meters, but there still be a shortage in future in spite of having other sources of water. However, the result shows that the proposed dam capacity is not cover the agriculture need. Therefore, we propose to add an extra dam at least with a capacity of 2 million cubic meter.

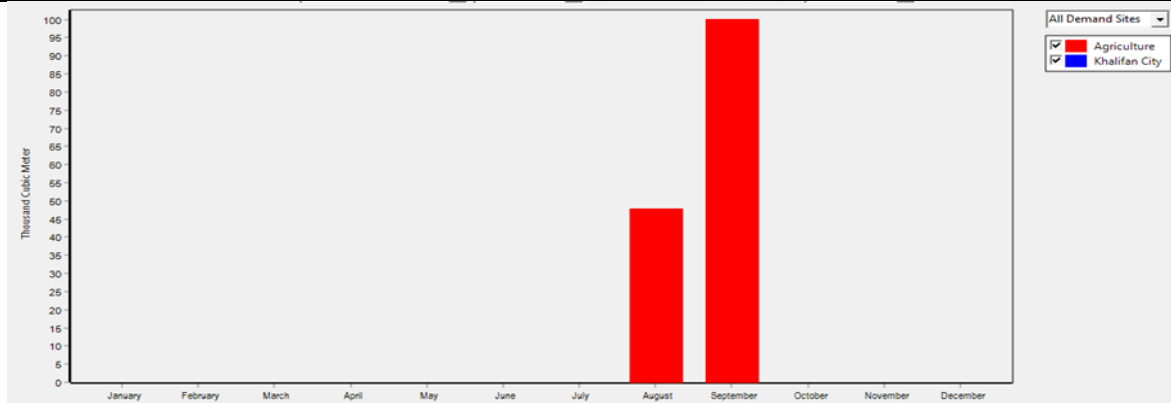


Figure 14. Reservoir added scenario with unmet demand monthly

Figure 15 revealed that there is a water demand for agriculture which is zero from January to March and from October to December zero due to the winter season and using less water for agriculture. Starting from April to September, water demand is high due to agriculture season. The maximum water demand is 2.94984 million cubic meters,

which occurs in August, while the proposed dam only supplied 2 million meters cubic. Also, for domestic water demand maximum is 0.4733 million cubic meters and the minimum is 0.36978 million meters cubic, which almost has the same level of water demand for each month.

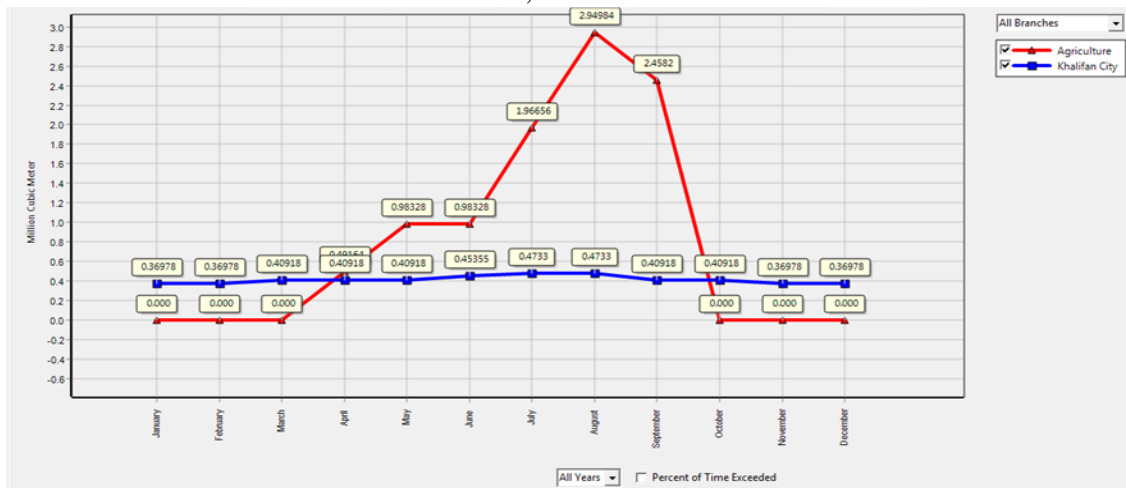


Figure 15. Reservoir added scenario with water demand monthly

The results of the model indicated that the water supply required for the high population growth scenario is much more than other scenarios due to continuing the growing rate of population. Nevertheless, the unmet water demand in inflow requirement scenario is much more than other scenarios due to flowing of water to Gali Ali Bag waterfall continuously and the water flow should be at minimum of 0.66 meter cubic per second. In scenario reference, significant shortages were seen in all sectors because this scenario was relied on the current situation, in which is no availability of reservoirs. In addition, the model of this scenario suggested that the priority was given to the domestic water supply. Thus, the only shortage was seen in agriculture sector with the amount of 540,964

million cubic meters. The area will be faced to water shortages in the years of 2023 and 2024 because the dam will not yet be completed. The WEAP model concluded that, in winter seasons the water is available for all sectors including agriculture, industry, domestic, and animals while in summer seasons, the water is not enough for all sectors. Thus, constructing the dam with a capacity of 5 million cubic meter in villages of Zelakan and Ble, is necessary for integrated water resources management for the basin. The proposed location of dams is shown in figures 16 and 17. The problem of drought is still standing in some villages, especially those situated on high elevation lands and those villages that situated far from the main river.

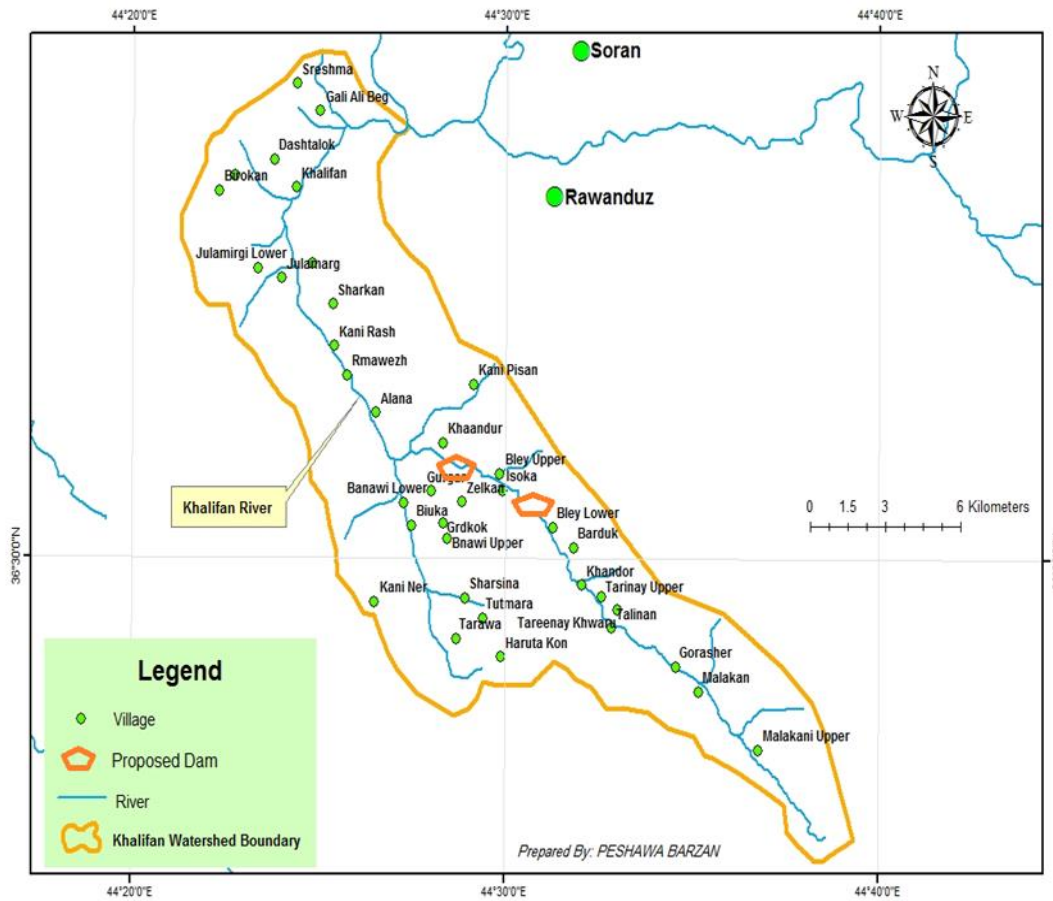


Figure 16. Proposed Dam



Figure 17. Location of planning dams and recommended dams

CONCLUSION

To sum up, the obtained results from WEAP software showed that the Alana river flow was low during July to October in terms of quantity and quality due to climatic and human activity. Hence, this made a significant environmental problem and then would result in a remarkable problem for agriculture, animals and tourism. Furthermore, the results also indicated that the

increasing population leads to extra water demand, expanded agriculture land, water shortages and environmental pollution in the area. The main source of pollution is the direct disposal of humans and animal wastes. No precautions have taken to prevent pollution within the basin boundary. Furthermore, some recommendations are proposed for the area:

a- It is recommended to extend farmer land also tourists should be conscious about the proper use of water and avoiding disposal of wastes into the river.

b- Establishing on-site disposal systems such as septic tanks in the villages upon the main river. Avoid of construction of public buildings such as mosques nearby the bank of the river.

c- Constructing high advanced sewerage water treatment in Khalifan sub-district, which evacuates the wastes of this town to the main river at the lower part of the town.

d- Proper use of nitrogen fertilizers in the area and prevent leaching of these additives with runoff water and water infiltration.

e- Prevent the establishment of animal breeding fields and devoting yards for cattle nearby the banks of the river and near the springs.

f- On the contrary, there is plenty of water for irrigation at most of the villages of Khalifan basin. Accordingly, the lands are intensively cultivated. Some villages also face the problem of water shortage in this valley, such as the upper part of Binawy and the lower Jolamerg.

REFERENCES

1. Abawi, S.A, and M.S., Hassan 1990. Environmental Engineering, water analysis, Dar Alhikma, pp: 296
2. Al-Ansari N, A. Al and, S Knutsson, 2015. Iraq Water Resources Planning: Perspectives and Prognoses. In International Conference on Civil and Construction Engineering: 26/01/2015-27/01/2015
3. Al-Ansari, N. 2013. Management of water resources in Iraq: perspectives and prognoses. Engineering, 5(6), 667-684
4. Arranz R, and M.P. McCartney 2007. Application of the Water Evaluation and Planning (WEAP) model to assess future water demands and resources in the Olifants Catchment, South Africa. IWM
5. Basnyat, P., L.D.Teeter, B.G., Lockaby, , and K.M. Flynn. 2000. The use of remote sensing and GIS in watershed level analyses of non-point source pollution problems. Forest Ecology and Management, 128(1-2 : 65-73

6. DAE. (2016). Agricultural land and product annual report. Directorate of Agriculture-Erbil. Unpublished Report

7. Dara R.N., S. Jirjees, K.K. Fatah, and S. Javadinejad 2021. Climatic Parameters Analysis of Koysinjq Meteorological Station, Kurdistan Region, Northern Iraq. The Iraqi Geological Journal. 54 (1A), 99-109

8. Javadinejad, S., R. Dara, and F. Jafary 2019. Taking Urgent Actions to Combat Climate Change Impacts. Annals of Geographical Studies, 2 (4), 1-13

9. Heshmati A, N.T. Khayyat. 2012. Socio-economic impacts of landmines in Southern Kurdistan. Cambridge Scholars Publishing

10. Karim, S.M. and T. H. Karim 2020. Enhancing furrow irrigation performance and water productivity through better design and water management in a cracked soil. Iraqi Journal of Agricultural Sciences, 51(5):1276-1289

11. Keya, D. R. and T. H. Karim 2020. Multivariate models for predicting rainfall erosivity from annual rainfall and geographic coordinates in a region with a non-uniform pluvial regime. Iraqi Journal of Agricultural Sciences, 51(5): 1249-1261

12. Kuo, S. F., S.S. Ho and C.W. Liu . 2006. Estimation irrigation water requirements with derived crop coefficients for upland and paddy crops in ChiaNan Irrigation Association, Taiwan. Agricultural Water Management, 82(3), 433-451

13. Malczewski, J. 2004. GIS-based land-use suitability analysis: a critical overview. Progress in planning, 62(1), 3-65

14. MOA & WR. 2016. Water resource annual report. Ministry of Agriculture and Water Resource. Unpublished report

15. MOM & T. 2016. Erbil governorate hydrology annual report. Ministry of Municipality and Tourism. Unpublished report

16. MOP. 2017. Statistics of Erbil governorate. Ministry of planning. Unpublished report

17. Stockholm Environment Institute, (SEI). 2005. WEAP: Water evaluation and planning system –user guide. Boston, USA

18. Sharef, A.J., A.R. Ahmed, and R.N. Dara 2011 (in press) Greater Zab River Basin planning (2050). Iraqi Journal of Agricultural Sciences.