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Assessment of sustainability and management for groundwater source in Erbil city

Jwan Sabah Mustafa [a], Salah Farhan A Sharif [b], Shuokr Qarani Aziz [c, #]

[a] Ministry of Agricultural and Water Resources, General Directorate of Dams and Reservoirs, Kurdistan Region, Iraq
[b] Al-Kitab University, College of Engineering, Department of Environmental Engineering and Sustainability, Kirkuk, Iraq
[c] Salahaddin University-Erbil, College of Engineering, Department of Civil Engineering, Kurdistan Region, Iraq

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ABSTRACT

The issue of rationalizing water consumption and preserving it for future generations is one of the most important indicators of sustainable development referred to in the Agenda 21. This study aims to assess the sustainability of water resources for the city of Erbil in terms of quantity and quality. In this study, the amount of water available in the existing water sources was evaluated and compared with the volume of water demand. The reliability of water sources, especially groundwater, in the selected area was evaluated and confirmed. The study also focused on the management of groundwater by the concerned authorities and the identification of factors that help to develop the sustainability of these sources. The problems facing the management of groundwater and the proposed solutions to solve these problems were also identified. Due to the rapid growth of the populations and lack of both water demand and water supply system, Erbil City required a fundamental evaluation of water supply systems and good planning for future. However, in this study, the assessment was conducted based on the existing data and the accurate archived documents as well. As a result, the study concluded that there have been a lot of problems that should be taken into consideration in order to provide good managing of the groundwater system. It was also observed that there was slightly higher depletion in groundwater table due to poor supplying. This study can be used as a fundamental reference for future investigations especially for those areas having the same problems in sustainable management of the subsurface basins.

1. Introduction

Generally, groundwater has a crucial role in water supply system worldwide due to its large percentage as Earth's water. Recently, Erbil City, which is in the northern part of the Kurdistan Region of Iraq and it is rapidly expanding area due to increasing the population growth, has faced economic problems. However, it is necessary to monitor and better manage the sources of water and provide for water in the following years. It can be pointed out that the impact of climate change and sustainability on both groundwater and surface water

Corresponding autor: shoker71@yahoo.com

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resources is important. The requirement for groundwater studies are necessary for providing sustainable management of water resources and its variability for a long period in order to better manage the system (Nanekely et al., 2017). However, in most of the countries, groundwater is a vital source for agricultural, domestic, and industrial purposes. The requirement is to increase water demand due to high population growth, therefore, the problems that the groundwater sources face should be taken into account (Hawez et al., 2020).

Moreover, in Erbil City, due to rapid population growth, the demand for water has increased and the percentage of domestic wells represents 40 % of water supply system in the city. Erbil City mostly uses surface water from Ifraz water treatment plant, which is directly located on the Greater-Zab River. The second source for groundwater is in the area which is used for the irrigation, industrial, and other daily activities as well (Wali and Alwan, 2016). In addition, the groundwater quality depends on the composition of the aquifer recharge and the interactions between both material and the groundwater. It is obvious that clean water is applied for many activities based on World Health Organization (WHO) which states that about 80 % of all the diseases in human beings are caused by water (Toma et al., 2013).

Similarly, there are numerous researchers that work on the sustainability of the water resources. The study of Menon (2007) focused on managing of the groundwater, and Halim et al. (2010) studied the causes of spreading disease through water. Later, Vishwajit et al. (2012) investigated sustainability, and the study of Toma et al. (2013) conducted an investigation into groundwater quality in Erbil City. Jadoon et al. (2015) studied water quality in Erbil City. Miran and Ahmed (2016) explained the sustainability for water sources in their study area.

Moreover, Bapper et al. (2016) evaluated the water quality in Erbil City as well. However, the investigation of Nanekely et al. (2017) was also on sustainability of groundwater management in Erbil City. In addition, there is also the study of Dizayee (2018), which was on groundwater level in Erbil Basin. However, Qurtas (2018) determined the recharge of Erbil groundwater. In spite of this, Mawlood and Omer (2019) used a method to estimate the depth of the Erbil Groundwater. Later, Mawlood (2019) did the investigation on groundwater sustainability for the studied area, and then the study of Mahmood and Omar (2019) investigated the amount of water supplied for population of the selected area.

Hawez et al. (2020) studied quality of the groundwater in Kurdistan Region Provinces. Sustainable water management in Iraq is becoming an urgent matter, despite the political instability in the region with special attention to the Kurdistan Region, and also presents to offer possible changes to the legislative framework (Yousuf et al., 2018). The current research aimed to evaluate the sustainability of water resources in Erbil City in terms of amount and characteristics. In this research, the quantity of water available in the existing water sources was assessed and compared with the volume of demand. The reliability of water sources, especially groundwater, in the selected area was evaluated and confirmed as well. Additionally, the research focused on the groundwater management by the concerned authorities and the identification of issues that assist the development of sustainability of these sources.

2. Study Area Location and Data Collection

Erbil Province is the capital of Kurdistan Region of Iraq, and it is located in the north-east of Iraq, and it covers area of about 197 km^2 with the elevation of the 414 m above sea level (Mahmood and Omar, 2019). It is surrounded by the Greater-Zab River at the north-west and by the Lesser-Zab River at the south-east. However, the sources of water supply depend on both surface water and the groundwater that supply water in the form of wells, Figure 1. Ifraz 1, Ifraz 2, and Ifraz 3 water treatment plants are constructed on the Greater-Zab River and supply drinking water to a big part of Erbil City (Aziz and Mustafa, 2019).

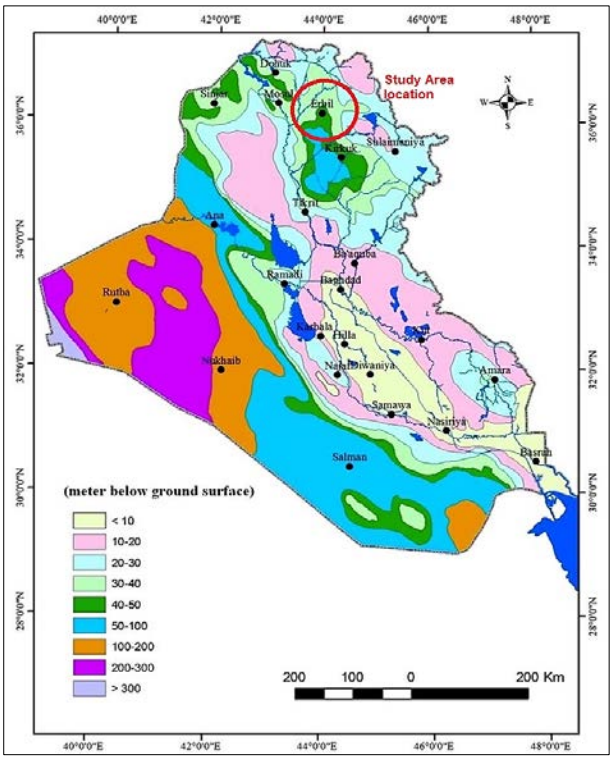

Figure 1. Location of Erbil City

Erbil groundwater basin is divided into three sub-basins, Kapran in the northern part with the area of about 915 km^2, central part is about 1,400 km^2, and Bashtepa area is about 885 km^2, Figure 2. Based on the data on Erbil groundwater, the depletion in Erbil basin is about 100 m. The lowering groundwater in the area refers to

drilling uncontrolled wells in the area. However, the increase in groundwater level mainly depends on the amount of Recharge of the aquifer storage in the recharge area and the velocity of the porous media in the region.

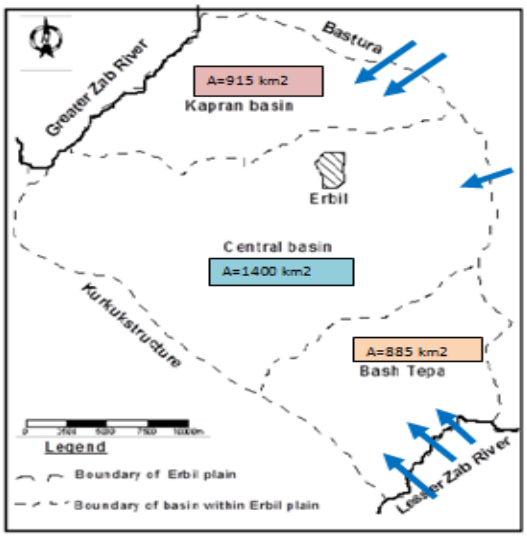

Figure 2. Map of groundwater basins in Erbil City (Abdulnasir, 2011)

During the study the data was collected from the following directorates:

- The data on water quantity were obtained from General Directorate of Water and Sewerage in Kurdistan Region of Iraq (2021);
- The water quality Data were obtained from Erbil Health Laboratory Center (EHLC);
- General Directorate of Health-Erbil, Ministry of Health, Kurdistan Region, Iraq, 2021; and
- Wells data and Monitoring levels were obtained from Directorate of groundwater of Erbil, Kurdistan Region of Iraq (2021).

3. Estimation of Water Quantity

Generally, estimating the quantities of the groundwater mainly depend on production wells. Meanwhile, the collected data of surface water, which include the diverted water form Greater-Zab River, form existing water treatment plants (i.e. Ifraz 1, Ifraz 2, and Ifraz 3) for Erbil City during 2014 up to 2018, Table 1. Table 2 illustrates the details of Ifraz 1, Ifraz 2, and Ifraz 3 Water Treatment Plants.

On the other hand, the estimated amount of groundwater is presented based on the number of populations with wells number and operation time. The current study estimates the approximate quantity of waters based on the data available, number of wells are about 1,200 based on data taken form General Directorate of Water and Sewerage in Kurdistan Region of Iraq (2021).

The estimated rate of well drainage for each well = 25 m^3/hr.

The average number of operating hours for each well = 15 hours.

The produced water from wells = 1200 wells · 25 m^3/hr · 15 hr = 450,000 m^3/day.

The total quantity of water (i.e. Water treatment plants, Table 2, plus groundwater wells) = 34,000 + 44,000 + 216,000 + 450,000 = 744,000 m^3/day.

The rate of losses is about (15 %) (General Directorate of water and Sewerage in Kurdistan Region of Iraq, 2021).

Thus, the remaining net quantity = 744,000 · 85 % = 632,400 m^3/day.

Average daily water consumption in Erbil City is about 380 liters/Capita/day based on the obtained data form Directorate of Water and Sewerage in Kurdistan region of Iraq (2021), Erbil city for water supply depending on 45 % of the groundwater through wells and 55 % of Surface water through water treatment plant units which are three Ifraz projects.

Table 1
The estimated amount of water per year (Mahmood and Omar, 2019)

Year	2014	2015	2016	2017	2018
m^3/year	139,036,720	143,472,095	158,069,446	164,331,177	172,687,525

Table 2
Detail of the Water Treatment Plants on Greater-Zab River (Omar, 2020)

No.	Water treatment plant	Constructed year	Location of Water treatment plant	discharge (m^3/day)	Location of distributions
1	Ifraz 1	1968	Ifraz village	34,000	Erbil city
2	Ifraz 2	1983	Erbil city	44,000	Erbil city
3	Ifraz 3	2007	Ifraz village	216,000	Erbil city

4. Groundwater Water Quality

Physical and chemical characteristics of 265 groundwater wells in Erbil City for the period of January to June of 2021 is given in Table 3, and the Data were obtained from Erbil Health Laboratory Center (EHLC, 2021). It can be noticed from the table that commonly all parameters are within the allowable limits according to Iraqi specification NO. 1974/417. Only, turbidity and nitrate have surpassed the standards. Nitrate value of one well in Ashti location were out of standard range, probably due to seepage of sewerage system into groundwater that caused the increase of the nitrate concentration.

There are a numerous well inside the area, Figure 3. Practically, groundwater is used for water supply in different locations. Groundwater disinfected via chlorine and it is used by consumers for domestic uses. In the past two decades, some groundwater wells were closed in some quarters in Erbil City due to nitrate problems. On the other hand, termination of some groundwater wells in Erbil City and its replacement by Ifraz water treatment plants is regarded as application of sustainable approach and management towards groundwater sources in the city.

Table 3
Characteristics of some wells of Erbil groundwater (EHLC, 2021)

Parameter	Min.	Max.	Standard
pH	7.0	8.2	6.5-8.5
Turbidity (NTU)	0.2	35	0-5
EC (ms/cm)	0.124	0.977	0.5-1.5
Total dissolved solids (mg/L)	27	625	0-1000
Total alkalinity (mg/L)	66	167	0-200
Total hardness (mg/L)	80	376	0-500
Chloride (mg/L)	9.4	21	0-250
Calcium (mg/L)	11	124	0-200
Magnesium (mg/L)	5	62.5	0-150
Sodium (mg/L)	2.8	192	0-200
Potassium (mg/L)	0.14	24	0-250
Nitrate (mg/L)	3	138	0-50
Salphate (mg/L)	41	148	0-500

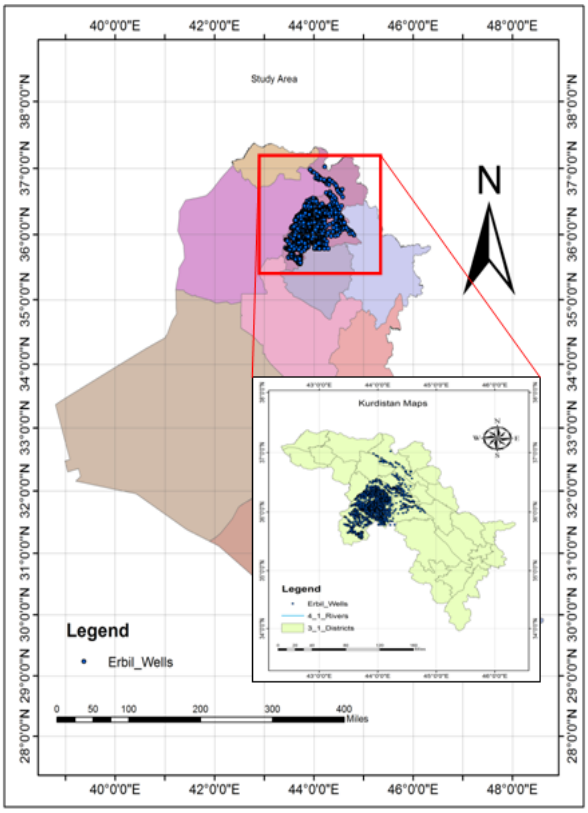

Figure 3. Distribution of the wells in the study area

In addition, for determination of the quality of water in Erbil City is based on the previous study performed by Aziz (2004), who studied the seasonal variation of water and wastewater for the study area. The author collected the samples from well No.3 in Iskan Quarter. Toma et al. (2013) investigated water qualities for the six-wells in various quarters of Erbil City (Ronaky 1, Tayrawa 1, Badawa 13, Azadi 8, Rizgari 1, and Ankawa 9). Their results explained that the quality of water was suitable for drinking purposes. Moreover, the water quality for fifty wells within Erbil city were tested by Daham et al. (1998). In addition, the study observed a high pH, turbidity, total hardness, and alkalinity of water in Erbil City. Similarly, in both Bakhtiari and Ainkawa quarters, five wells were tested by Jadoon et al. (2015). The authors found that the water quality from the wells was also subjected to significant contaminants such as high concentration nitrates and pathogens (Hawez et al., 2020), Figure 4. Aziz and Mawlood (2015) conducted a study on the effect of Erbil Landfill Site on the groundwater contamination by formed landfill leachate.

They found that produced leachate polluted the groundwater close to the landfill area. In another research carried out by Aziz and Fkhrey (2016), the impact of Kawer Gosk Oil Refinery wastewater on the groundwater in the surrounded area was studied. The researchers reported that there was no impact of Kawer Gosk Oil Refinery wastewater on the groundwater in Aghulan village near the refinery in 2016.

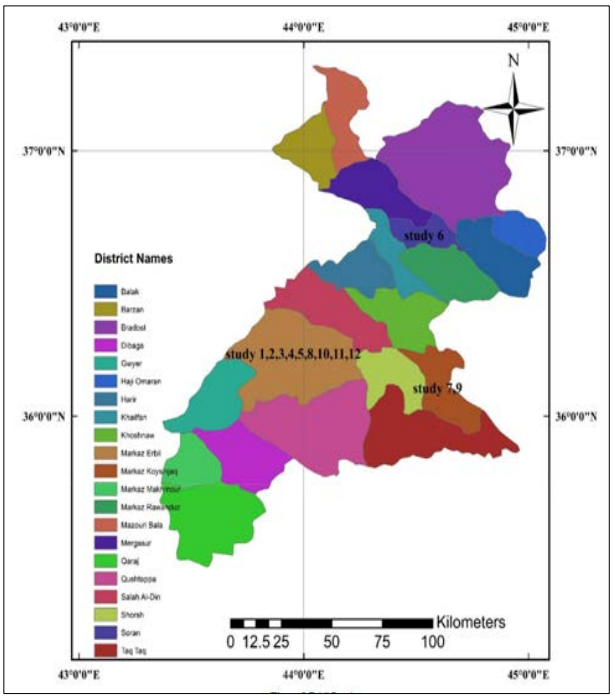

Figure 4. Groundwater quality investigation locations (Hawez et al., 2020)

According to Al Sudani (2019), the groundwater quality was increasingly threatened due to industrial wastes and urban and agricultural wastes that were leaked or injected into the underlying aquifers. However, groundwater was exposed to pollution when pollutants entered from landfills and locations that used to store waste. In addition, the chemical spills and the subsurface storage tanks leakage were also seen as a threat, as well as the sites of the hazardous waste that were improperly managed. Groundwater pollution can also be a result of using fertilizers and pesticides, the disposal of human, animal and the agricultural waste, and the use of chemicals. Additionally, most of the serious effects on water pollution is human infectious disease, especially when sanitation facilities are rarely found. Meanwhile, the safety measures are simpler and fewer costly than remedial measures for groundwater pollution.

5. Evaluation of Erbil Groundwater Sustainability

According to Agenda 21, which addresses the critical issues faced by the global community, this problem will require not only the leadership and funding of governments and business, but also the vision, cooperation and work of every citizen. Sustainable development cannot be achieved without all sectors of society working together. One of the most important points is about protecting and managing water resources and to keep safe drinking water and sanitation, which are the basic requirements for public health and dignity. A cleanup of the most obvious sources of pollution is also needed in order to provide suitable water and sanitation for all in the future. However, according to Vélez et al., (2020) "The concept of sustainability was brought to the forefront by the World Commission on Environment and Development (WCED) held in 1987, and, since then, it has been commonly applied to the whole variety of resources exploited by human society, including groundwater. In fact, the European Water Framework Directive, enacted in December 2000, establishes that it is necessary to promote a sustainable water use". Raouf (2011) stated that the rapid population growth, increase in the number of residential, housing projects, old ways, and methods to manage the resources of water also cause the shortage of water in some areas in Erbil. It also represents one of the reasons that has led to the decrease of Erbil groundwater level. Accordingly, the Kurdistan Region Government should formulate long term strategic policies to develop the water resources management.

The current study states that Erbil groundwater requires the development of sustainability to keep the safe drinking water for future challenges. The detail of the sustainability development of groundwater is explained in Figure 5.

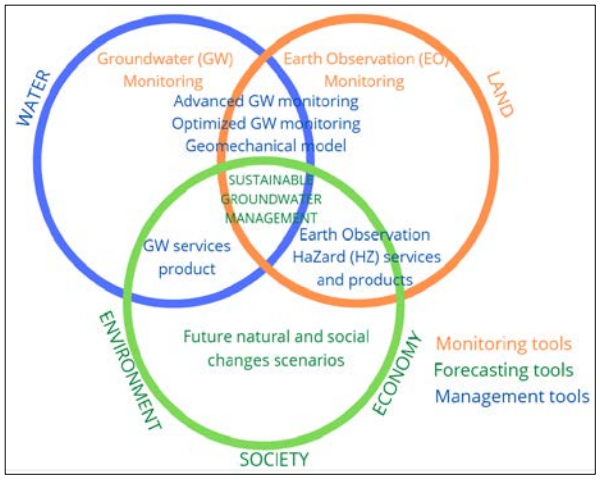

Figure 5. Diagram of Sustainability of Groundwater Management (https://reservoir-prima.org/about-us)

5.1. Sustainability Management of Groundwater in Erbil City

The actual number of drilled wells in Erbil basin is higher than the number of recorded wells which legally drilled, and for these reasons, it is noticed from the previous studies that the ground water table has depleted, and people in this area are facing many problems due to water shortage because several wells have dried in the area as well. This is all due to the increasing number of illegal drilled wells which are located within the selected area and poor water supply and management. The current study highly depends on the available data on the drilling of wells that can be provided from Ministry of Agriculture and Water Resources. Another researcher described that the number of wells in the Central sub-

basin is much higher than the number of wells provided in the data. However, most of the illegal wells are not recorded in the documents. Based on this, other study stated that out of the 650 wells that the author used to conduct the research, 46.6 % (303 wells) were found to be illegal according to Dizayee (2018). Although, the study of Nanekely et al. (2017) determined the conditions of the groundwater levels in area and it was highly declined in the period 2006-2009. However, lots of studies presented that the groundwater pumping intensified during the previous years. It was the same as that the total pumping rates exceeded the recharge rates over large areas, as groundwater tables were declining a negative residual term was found of about 10 mm per year. Moreover, sustainable groundwater should be implemented by management related organizations especially by the regional stakeholders, and also the hydrologists, environmental and political constraints as well. Securing water for future involves many considerations, from those minimizing the net groundwater losses from the aquifer storage, managing groundwater as an integrated part of the hydrologic cycle, developing infrastructure based on an understanding of the natural hydrologic system, and using water based on the required amount and efficiency. In spite of this, Figure 6 shows that there is a large number of wells that exist in the selected area, which caused the depletion in efficiency and the capacity of the production wells, and also caused the production wells to dry in the short period of time and cause drought problems.

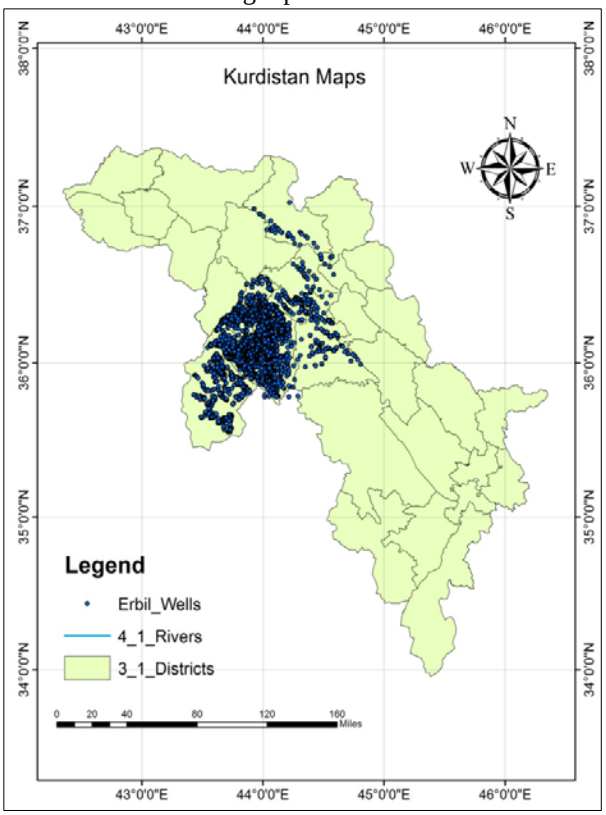

Figure 6. Wells in the study area Created by ArcGIS (Arc Map 10.4)

5.2. Groundwater conditions in Erbil Area

The current study presented the groundwater deletion in the area. The data collected during the study was based on the information obtained from the General directorate of Groundwater in Erbil. There is a number of production wells used for monitoring groundwater fluctuations in the region. Depending on the data available, a large depletion of groundwater reserves has been recorded, which is the worst case of the aquifer system in Erbil basin. However, the paper tried to assess the problems in water resources management in the Erbil Area, as well as, determine the best solutions for water sector problems. For instance, the main problem is groundwater depletion due to the uncontrolled drilling of illegal wells. Consequently, it is required to develop the scientific plan for better management of the groundwater resources in the area. In general, there are a several production wells used for monitoring of the groundwater fluctuations inside all Erbil regions, Figure 7:

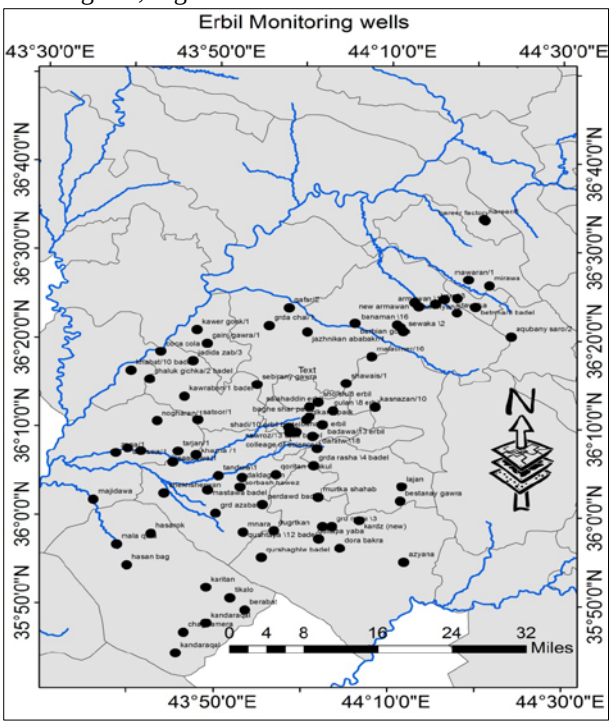

Figure 7. Production wells used for monitoring Groundwater level in the area (ArcGIS 10.4)

Depending on the obtained data from the directorate of Erbil Groundwater, there is a slight depletion in water level, and the details are shown in Figure 8. It is impossible to use production wells for monitoring purposes and it is not allowed within the standard limitations, because inside the production wells there are great losses due to casing. In addition, the sounder may take the error data and spiral with the well pumps. Therefore, it is important to install new observation wells (Unconfined) or piezometric wells (for confined) aquifer

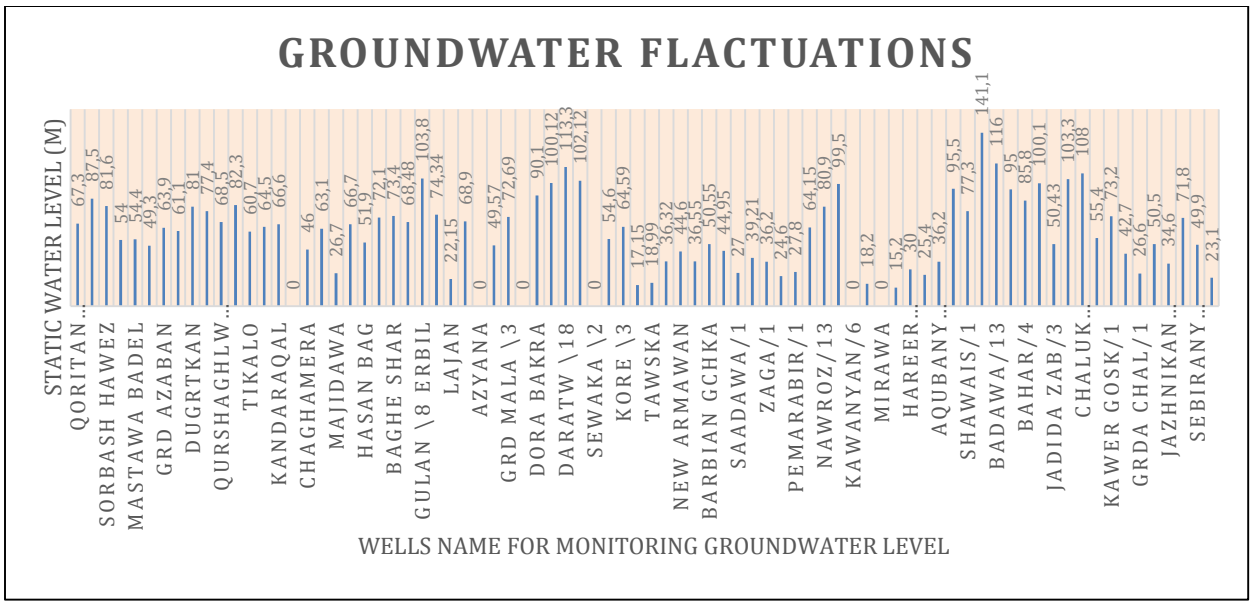

Figure 8. Groundwater Fluctuation in the Erbil Area

for monitoring purpose instead of taking data on the production wells. This is in case if the authority decides to manage water resources in an appropriate way.

6. Proposed Plans for Groundwater in Erbil City

The current study verified that the Erbil City directly provided its required source of water of which about 55 % depends on the Greater-Zab River and 45 % on Groundwater. This water is provided by the water treatment plants, which is responsible for the determining the required amount of supply for each capita. Some of the groundwater pumped out from the wells is subjected to pollutants, such as a high concentration nitrates and pathogens. This water source also has a higher nitrate and E.coli level than the water that comes from the Ifraz. However, when the pathogen (coliform, E.coli) amounts increase, the potential for creating higher levels of disinfection by-products also exist which is also a water quality concern. Meanwhile, Erbil continually imports this treated water by Ifraz water treatment plants. The treated water from water treatment plants is normally disinfected by chlorine gas. Jadoon et al. (2015) stated that chlorine has the effect on the human health. Based on the report of Japan company for the Ministry of Municipalities and Public Works, Iraq, in 2015, the water supply and water demand for Erbil central and surrounding parts are shown in Table 4.

For sustainable management and future plans of the water sources in Erbil City, it is recommended to minimize usage of the groundwater and increase usage of the Greater-Zab River by constructing a new water treatment plant. Additionally, reusing of Erbil municipal wastewater for the irrigation purpose, instead of using groundwater for irrigation, on the other hand, finding other sources for car washing, watering gardens, fish production etc. can be seen as a solution as well. Treated wastewater can be used for recharging groundwater as well. Construction of a proper sewerage system for collection of black water and grey water for avoiding groundwater pollution and treatment purpose is also important. Currently, black water in Erbil City is discharged directly to cesspools which cause groundwater pollution in some old areas in the city.

Table 4
Data of water demand based on (Japan ICA NJS, 2015)

Location	Water supply (m^3/day)	Service population (person)	Water supply per capita (L.pcd)	Service coverage (%)	Water demand (m^3/day)
Erbil/Central	320,680	695,958	461	95 %	338,000
Erbil/periphery	223,675	570,400	392	54 %	414,000

Municipal wastewater is discharged directly to the environment or is used for irrigation without treatment.

Based on the study of Al-Ansari et al. (2015), Iraq is suffering from water shortage problems, due to several factors, which include global warming. However, based on the study, the water supply and the demand are predicted to be 17.61 and 77 Billion m^3 in 2025 respectively. Correspondingly, based on the future prediction, the Tigris and Euphrates Rivers will be completely dry in 2040.

Consequently, in order to avoid this big problem, an appropriate water management policy should be planned, which involve the strategic water management, irrigation techniques development, water losses reduction, use of scientific water resources, research and water development planning. Whereas, the study of Costa et al. (2019) stated that the water management may involve the seasonal storage of surface water in region of low recharge potential or modification of the irrigation methods, protection of the vegetation is also recommended because these locations were considered as the groundwater recharge.

7. Conclusion

The current study concluded that the sustainability of the groundwater management can play a major role to control managing of water for Erbil City future, which partially depends on drilling wells. The rapid growth of the population and their additional exploitation of wells causes the depletion in the aquifer storage and decrease the capacity of the wells within the selected site. The groundwater source faces the pollution in some areas. In spite of this, there is a number of illegal wells that are drilled inside the study region and this should be avoided. It was also observed that most of the consumers spent large quantities of water without any control, which was far from water conservation rules, due to the lack of awareness among people. Using raw river water or treated wastewater for car washing, irrigation, construction etc. is recommended, instead of using groundwater source. At the end of the study it should be noted that if this irresponsible behavior continues, the groundwater will face high depletion and drought in the near future.

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Procena održivosti i upravljanja izvorima podzemne vode u gradu Erbilu

Jwan Sabah Mustafa [a], Salah Farhan A Sharif [b], , Shuokr Qarani Aziz [c, #]

[a] Ministarstvo poljoprivrede i vodenih resursa, Generalna direkcija za brane i rezervoare, okrug Kurdistan-Irak
[b] Univerzitet Al-Kitab, Inženjerski fakultet, Odeljenje za ekološko inženjerstvo i održivost, Kirkuk, Irak
[c] Salahadin univerzitet u Erbilu, Fakultet inženjerskih nauka, Odsek za građevinarstvo, okrug Kurdistan-Irak

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I Z V O D

Pitanje racionalizacije potrošnje vode i njenog očuvanja za buduće generacije je jedan od najvažnijih pokazatelja održivog razvoja koji se pominje u Agendi 21. Ovaj rad ima za cilj da proceni održivost resursa vode u Erbilu sa fokusom na količinu i kvalitet. Procenjena je količina vode koja je dostupna u postojećim izvorima, a zatim je upoređena sa količinom koja se potražuje. Ocenjena je i potvrđena i pouzdanost izvora vode, posebno izvora podzemnih voda na ispitanom području. Rad je takođe ispitao i upravljanje izvorima podzemnih voda koje sprovode nadležne vlasti, kao i identifikaciju faktora koji pomažu u razvoju održivosti ovih izvora. Identifikovani su i problemi sa kojima se suočavaju prilikom upravljanja podzemnim vodama i predložena su rešenja za ove probleme. Zbog brzog rasta broja stanovnika i lošeg odnosa između potražnje i potrošnje vode, potrebno je uraditi temeljnu procenu sistema vodosnabdevanja u Erbilu i isplanirati pouzdan sistem za ubuduće. U ovom radu je sprovedena procena na osnovu postojećih podataka i dostupne arhivirane dokumentacije. Rezultati ispitivanje su pokazali da postoji mnogo problema koje treba uzeti u obzir kako bi se obezbedilo dobro upravljanje sistemom podzemnih voda. Takođe je uočeno da postoji nešto veće iscrpljivanje podzemnih voda zbog lošeg snabdevanja. Ovaj rad se može koristiti kao osnova za buduća istraživanja, posebno za područja koja imaju probleme u održivom upravljanju podzemnim slivovima.