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ISTANBUL GEDİK UNIVERSITY
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WATER RESOURCES MANAGEMENT IN MOSUL DAM

MASTER'S THESIS

Ismail Ibrahem Othman SLE

Engineering Management Master in English Program

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Thesis Advisor: Assistant Prof. Dr. Redvan GHASEMLOUNIA

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İSTANBUL GEDİK ÜNİVERSİTESİ

LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜ

Yüksek Lisans Tez Onay Belgesi

Enstitümüz, Engineering Management Department İngilizce Tezli Yüksek Lisans Programı (191281010) numaralı öğrencisi Ismail Ibrahem Othman SLE'nin "Water Resources Management in Mosul Dam" adlı tez çalışması Enstitümüz Yönetim Kurulunun 30.07.2021 tarihli kararıyla oluşturulan jüri tarafından *Oy Birliği* ile Yüksek Lisans tezi olarak *Kabul* edilmiştir.

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DECLARATION

I, Ismail Ibrahem Othman SLE, do hereby declare that this thesis titled as “Artificial Intelligence Utilization in Production Quality Management: Piping Fabrication” is original work done by me for the award of the masters degree in the faculty of Engineering Management. I also declare that this thesis or any part of it has not been submitted and presented for any other degree or research paper in any other university or institution. (30/07/2021)

Ismail Ibrahem Othman SLE

DEDICATION

It is in my pleasure to dedicate my thesis work to the soul of my beloved father, who was my first teacher in this life. He taught me many lessons that become the guide of my life. Even my father passed away, his words and advices still encourage me to work hard and achieve my goals.

I also dedicate my thesis work to my dear, lovely mother. She always stands for me and gives support. I dedicate my thesis work to my amazing brothers and sisters. I feel so greatly privileged to have them in my life.

I dedicate my thesis work to my amazing family (My wife and Kids). Without them, I could not make and progress in my life.

PREFACE

Getting a master's degree was a challenging decision to make. However, having supports from family, friends makes that easy. First, I would thank my supervisor Assistant Prof. Dr. Redvan Ghasemlounia for all support and guidance throughout my research work. It was all fruitful advice during my academic career.

It is in my pleasure to thank my family and friends especially my friend Inam for their help and support. It is my pleasure to thank my mom who stood by me during my study and always offered their love, care and support.

Finally, I would like to thank all participants who took part in the study and enabled this research to be possible.

July 2021 **Ismail Ibrahem Othman SLE**

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ABBREVIATIONS

APP	: Appendix
LRM	: Linear Regression Model
WRM	: Water Resources Management

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ABSTRACT

The rapid increase use of freshwater has enforced decision makers in most countries to pay more attention to water resources managements. Water is used for many daily activities such as drinking, cleaning, agriculture, manufacturing, and others. Therefore, the water scarcity can be a serious problem, and has to be fixed using good WRM plans and strategies. This study was constructed based on some problems. The crucial problem is that Iraq suffer from the lack in the water resources. The lack in water resources is a result of the increase in using water, which happened due to the rapid increase in population. The flow of the Tigris and Euphrates Rivers have decreased for several internal and external reasons. In addition, the climate change has negative and significant impact on the quantity of water. The other problem is related to Mosul Dam which has damaged because of shortage of maintenance and other factors. Therefore, it is important to evaluate the performance of this Dam as part of WRM. The study tests whether this Dam can play a significant role in managing water resources in Iraq. The results of this study show that Mosul Dam still has significant impact on water supply system in Iraq. This result indicates that Mosul Dam has significant impact on WRM in Iraq. In other words, the dam still plays a significant role in the WRM system. The results show that water consumption has negative relationship with water supply, which is expected. However, the impact of water consumption on water supply is not significant. The results show that temperature (climate effect) has positive relationship with water supply, which is not expected. The results show that stored water has negative relationship with water supply, which is expected. This result indicates that water storages in Iraq are very important in the WRM system.

Keywords: *Mosul dam, Water resources management, Water problem*

MUSUL BARAJINDA SU KAYNAKLARI YÖNETİMİ

ÖZET

Tatlı su kullanımının hızla artması, çoğu ülkede karar alıcıları su kaynakları yönetimlerine daha fazla dikkat etmeye zorladı. Su, içme, temizlik, tarım, imalat ve diğerleri gibi birçok günlük faaliyet için kullanılır. Bu nedenle, su kıtlığı ciddi bir sorun olabilir ve iyi WRM planları ve stratejileri kullanılarak düzeltilmesi gerekir. Bu çalışma bazı problemler temel alınarak oluşturulmuştur. Can alıcı sorun, Irak'ın su kaynaklarındaki kıtlıktan bir problemle karşı karşıya olmasıdır. Su kaynaklarındaki eksiklik, nüfusun hızla artması nedeniyle su kullanımındaki artışın bir sonucudur. Dicle ve Fırat Nehirlerinin akışı iç ve dış birçok nedenden dolayı azalmıştır. Ek olarak, iklim değişikliğinin su miktarı üzerinde olumsuz ve önemli etkileri vardır. Diğer sorun ise bakım eksikliği ve diğer etkenler nedeniyle hasar gören Musul Barajı ile ilgili. Bu nedenle, bu Barajın performansını WRM'nin bir parçası olarak değerlendirmek önemlidir. Çalışma, bu Barajın Irak'taki su kaynaklarının yönetiminde önemli bir rol oynayıp oynayamayacağını test ediyor. Bu çalışmanın sonuçları Musul Barajı'nın Irak'taki su temini sistemi üzerinde hala önemli bir etkiye sahip olduğunu göstermektedir. Bu sonuç Musul Barajının Irak'taki WRM üzerinde önemli bir etkiye sahip olduğunu göstermektedir. Diğer bir deyişle, baraj hala WRM sisteminde önemli bir rol oynamaktadır. Sonuçlar, su tüketiminin su temini ile negatif bir ilişkisi olduğunu göstermektedir ki bu da beklenmektedir. Bununla birlikte, su tüketiminin su temini üzerindeki etkisi önemli değildir. Sonuçlar, sıcaklığın (iklim etkisinin) su temini ile beklenmeyen pozitif bir ilişkisi olduğunu göstermektedir. Sonuçlar, depolanmış suyun su temini ile negatif bir ilişkisi olduğunu göstermektedir ki bu da beklenmektedir. Bu sonuç, Irak'taki su depolarının WRM sisteminde çok önemli olduğunu göstermektedir.

Anahtar Kelimeler: *Musul barajı, Su kaynakları yönetimi, Su sorunu*

1. INTRODUCTION

1.1 Overview

Recently, more attention has paid on managing water resources as a response to the increase use of freshwater. Many reasons have led to the increase use of freshwater such as rapid increase in world's population and the climate changes (global warming). It is well known that water is used for many daily activities such as drinking, cleaning, agriculture, manufacturing, and others. Therefore, water resources must be carefully managed to obtain sustainable freshwater. Water resource management (WRM) have become crucial for life and economic survival. However, achieving sustainable water resources needs a lot of work such as monitoring, planning and managing these resources (Loucks 2000).

The WRM is define as a set of decisions and actions that improve the efficiency of using different types of water resources. For example, water policies, water management programs and projects. Most of these actions have done by governments and private sectors under short and long terms plans (Pahl et al. 2007).

It looks like that managing the water resources is easy, or it is just putting roles to follow regarding the use of water. However, managing the water resources faces many difficulties. For example, one of the most challenging issue that makes WRM hard is that water is moving and passing countries boarders. Figure 1.1 shows Tigris River and Euphrates River in Iraq, which both cross over multiple countries. As a result, the politics, or international dimension is included in the process of WRM. The other example, is that water could be available anywhere, but it is hard to control (Pahl et al. 2007).

It is important to indicate that the WRM cannot be identical. That is, the WRM plans and actions can be suitable for one location and one time only. The reason of this is that the water resources are not homogenous.

There are many differences between these sources from one region to another even within same country. In addition, there are many differences between these sources from one season to another (Biswas 2004).

Figure 1.1: The Rivers in Iraq

Source: https://ourworldindata.org/water-use-stress

Recently, the WRM has become more complex, and it has many connections with other development related issues. Todays, WRM is not only managed by water specialists, but by socialist, economists, environmental specialists, and political leaders. The future of WRM is expected to be more complex. It is expected that it will be strongly linked to agriculture, energy, industry, transportation and communication. In addition, it will be linked to the environment, health, and regional development (Biswas 2001).

1.2 The Study Topic

The topic of this study is about managing water resources in Iraq. Several reasons make selecting this topic important.

The first and the most important reason is that most countries around the world, including Iraq, recently suffer from the lack in the water resources. The lack in water resources is a result of the increase in using water, which happened due to the rapid increase in population. In addition, it happened due to the increase in economic activities such as manufacturing and agriculture. Figure 1.2 shows the rates of worldwide quantity of water that used from 1900 to 2014. From this figure, huge increase in using of water resources over time is clear (Al-Ansari & Nadhir 2021).

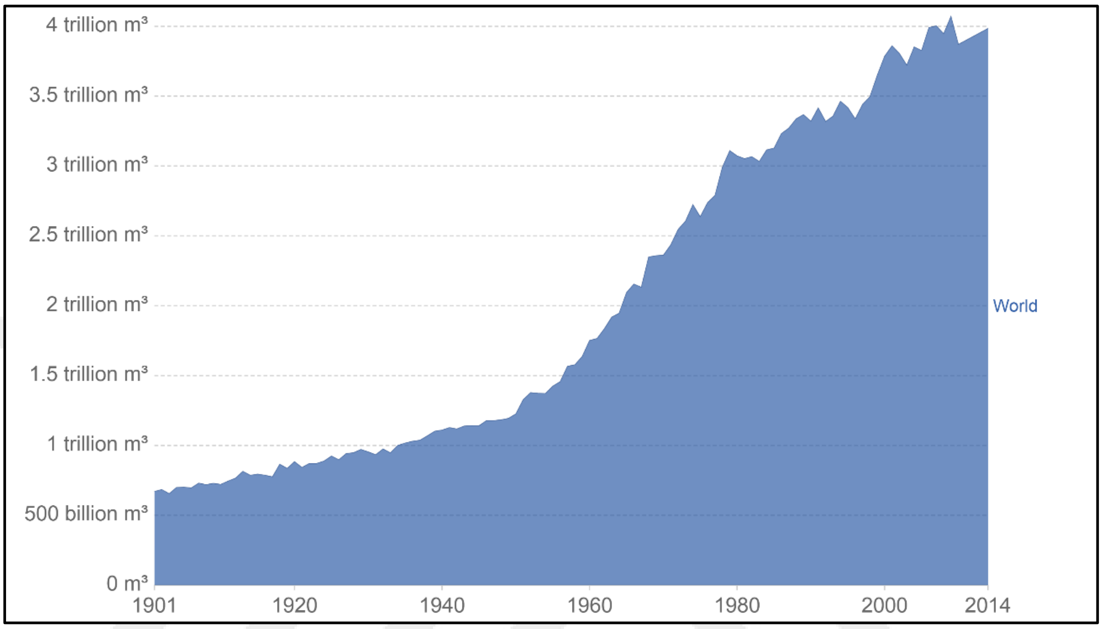

Figure 1.2: Global Freshwater Use Over the Long Run

Source: https:// www.ourworldindata.org

The main water sources in Iraq are the Tigris and Euphrates Rivers. The flow of these rivers have decreased since 1970s because of hydrological projects that built in the countries that these rivers come from. In addition, the climate change has negative and significant impact on the quantity of water in these rivers.

From the other side, the population in Iraq increased in the last two decades, which reaches to around 40 million. This growing in population puts more pressure on water resources. Therefore, WRM in Iraq have become more important to keep things going well (Al-Ansari & Nadhir 2021).

The second reason is the climate change. Even the climate change is a global phenomenon, Iraqi weather has special case. The temperature in Iraq usually reaches very high degrees and for long time during the year. Figure 1.3 shows that the temperature reaches about 45 Degree Celsius, which can negatively influence the water resources. In addition, Iraq suffers from lack of rain even in the rain seasons, which also puts more pressure on the water resources (Salman et al. 2019).

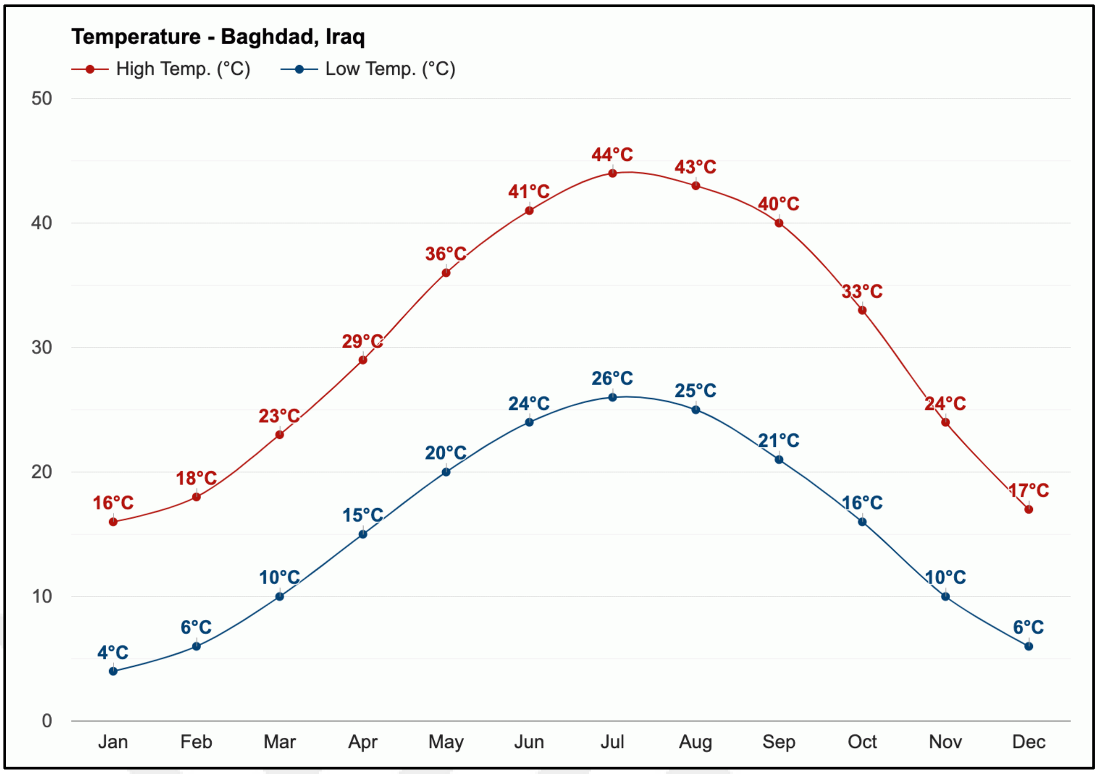

Figure 1.3: Monthly Average Temperature in Iraq

Source: https://www.weather-atlas.com

The third reason is related to Mosul Dam. Mosul Dam is one of the important part of the water resources management system in Iraq. However, this Dam has damaged because of shortage of maintenance and other factors (Adamo & Al-Ansari 2016).

Therefore, it is important to evaluate the performance of this Dam as part of WRM. In other words, it is important to investigate whether or not this Dam still able to store and manage water as required.

Finally, in the last two decades, Iraq has had water crisis, which gave a dangerous sign for Iraqi government (Al-Obaidy & Al-Khateeb 2013). Figure 1.4 shows that the average rainfall in Iraq is decreasing over time.

The water demand in Iraq has increasing over time while water supply has decreasing as shown in Figure 1.5. From this figure, the water supply in Iraq is expected to fall down in the next ten years from 77 to 59 billion cubic meter. That indicates that Iraq has to take actions regarding WRM before getting in bad situation. One of the most expected actions is to evaluate the performance of WRM facilities and tools including Dams (such as Mosul Dam) and others (Alwash et al 2018).

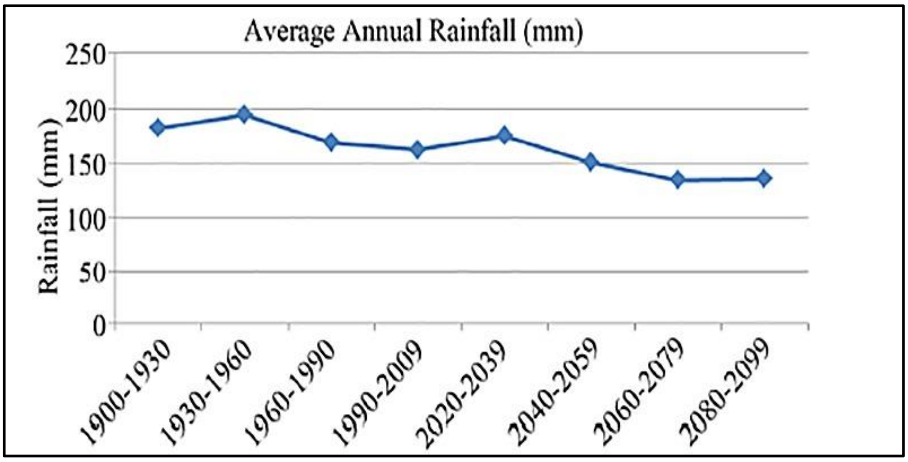

Figure 1.4: The Average Annual Rainfall over Time in Iraq

Source: https://www.1001iraqithoughts.com.

1.3 The Purpose / Importance of the Study

The purpose of the study is to investigate the performance of the WRM system in Iraqi. More specifically, the study investigates the performance of Mosul Dam in Mosul, Iraq. The study tests whether this Dam can play a significant role in managing water resources in Iraq.

The importance of the study is to present statistical results about one of important parts of Iraqi WRM system (Mosul Dam). The results can be used to make decisions regarding to developing this system.

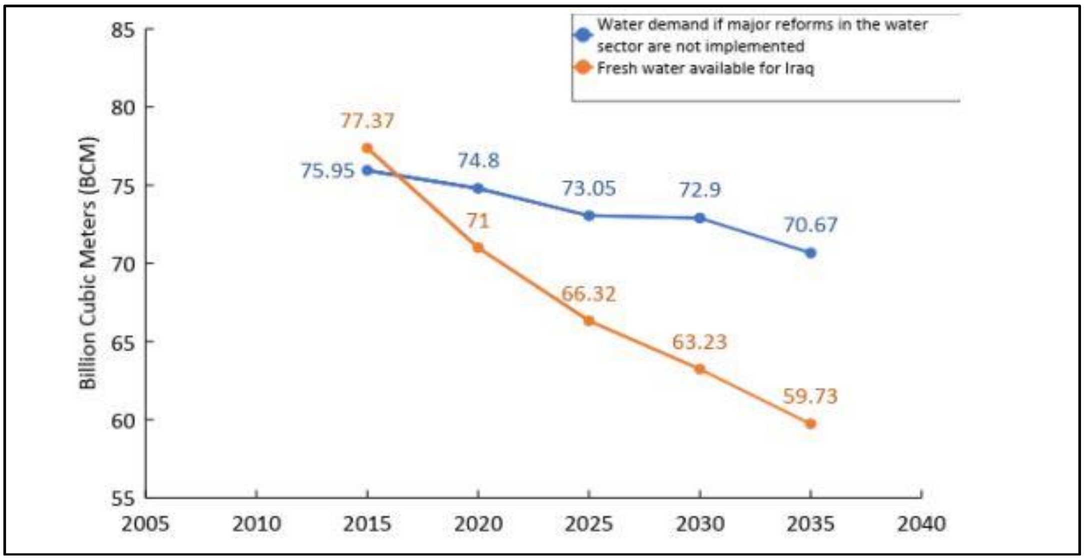

Figure 1.5: Water Demand and Supply in Iraq

Source: (Alwash 2018)

1.4 Literature Review

This section reviews some studies in the literature that tests the performance of WRM. The first example is the study by Biswas (2001). This study indicates that water management considered one of the important issues. The study showed that when adopting WRM system, it is important to take in account all changes that occurred in the past, and the changes that expected to occur in the future (Biswas 2001).

The study showed that WRM have many risks and uncertainties. The study indicates that the WRM in not static. In addition, WRM should take in account all social interests, conflicts, technological changes, economic related issues, and politics. Therefore, all of these factors should be included when testing the performance of WRM systems.

The study by Dhawan (2002). The study presented some economic methods that are part of WRM systems in India.

For example, the study showed that drip and sprinkler irrigation, and submergence method are three economic method that used to save water in India. The study examined the performance of these methods as parts of WRM system. The results of this study indicated that the impact of sprinkler method for each unit water is half of that in drip method. However, the costs of sprinklers is higher by 50% than that of drip systems (Dhawan 2002).

The study conducted by Mollinga (2008) investigated the impact of political dimension on water resources management. The study indicates that the political dimension was presented at the first time in 2004 the Center for Development Research, Bonn, Germany. The study indicates that the politics can play significant roles in WRM (Mollinga 2008).

Butterworth, et al (2010) showed that WRM can be applied in developing, but not only developed countries. This study identifies some ways that can be used to apply WRM in developing countries. For example, the developing countries can adopt long-term policies and reforms. In addition, they can build big water storages to save water (Butterworth, et al. 2010).

Naabil et al (2017) showed that the water resources are very important in economic development of west African countries. The study problem is the lack in information about these resources. This paper used the art hydrological model (WRF-Hydro) to assess these water resources in the Tono basin in Ghana (Naabil et al. 2017).

The study indicated that this model (WRF-Hydro model) can allow simulating the discharge of the river. The simulations were from 1999 to 2003. The results indicate that using the WRF-Hydro model results in Nash-Sutcliff efficiency (NSE) of 0.78 and Pearson's correlation of 0.89. The output from the WRF-Hydro model used as input into a water balance model to find the level of the dam.

Whittington and Sadoff (2005) showed that hard work has done to find opportunities to maximize the benefits from the Nile River's waters (Whittington & Sadoff 2005).

However, until now, there is no clear plan about the economic value of developing the water resources. This research presents the results of the model that used to optimize the water resources of the Nile basin. The results showed that the annual gross benefits of Nile water was 7–11 billion US dollar. This does not account for the costs of building or operating the infrastructure.

The paper by Hipni et al (2013) showed that the WRM is critical to the development. The study used the Support Vector Machine model. This model is used to estimate the daily dam water level of the Klang gate. The results showed that the Support Vector Machine is the best model among others model to estimate the water level (Hipni et al. 2013).

Lai et al (2014) investigated the effects of the Three-Gorges-Dam on lake outflow and water level. The Three-Gorges-Dam is used to control the flow of water to Poyang and Dongting Lakes. These two lakes are the largest freshwater lakes in China (Lai et al. 2014).

The role of the dam is to reduce the river discharge. A hydrodynamic model was used to simulate hydrodynamics in the both lakes and the Yangtze River. The results show that the dam significantly affect the flow in both lakes. The dam dynamically adjusted with the Yangtze River discharge. The results improved the understanding of the dam impacts on the river-lake system.

1.5 Hypothesis of the study

The study has two hypotheses:

1. The Mosul Dam can has significant impact on the Water Resources Management system in Iraq.
2. The Mosul Dam can do the required tasks even with the big damages.

1.6 The Study Plan

This thesis includes four chapters as shown below:

1. Chapter one which is the introduction.
2. Chapter two which is the WRM concepts and theories.
3. Chapter three which is the WRM system in Iraq and the role of Mosul Dam.
4. Chapter four which is the empirical work that includes data, model, methodology, and the results.
5. The last part of the thesis is the conclusion.

2. THE WATER RESOURCES MANAGEMENT

It is well known that getting additional water supplies is a big problem that faces most countries around the world. That is because water sources are not under the control of these countries (they are natural resources). As a result, more attention has paid towards water demand management. That is because managing the water demand expected to increase the efficiency of using water, which by the end will make sufficient savings for future water needs. Increasing the water use efficiency is possible by using less water for each unit of output (Seckler 1996).

It is important to indicate that the economic efficiency can also increase by increasing the efficiency of water using. For example, using water in agriculture consumes about 80 % of the water supplies. However, using new irrigated method in agriculture such as drip system can sufficiently increase the efficiency use of water.

Saving water, using water efficiently, and any other issue related to the used of water depends on understanding the nature of water resources. In addition, it depends on understanding the reasons of using water (water demand), and the possible ways of saving and managing water. Therefore, the next sections discuss the water resources.

2.1 The Water Resources (Water Supply)

In general, there are three main natural types of water resources. These resources are surface water resources, groundwater resources, and the storm water resources. The Surface water resources usually supplies fresh water through rivers, lakes, and streams. The groundwater resources are the sources of water that are underground (Sidle 2000).

Groundwater resources supply water through filling the cracks in rocks and come up to the surface. The storm water or rainwater resources are the sources that come from rain and snow. The next sections view in details these types of water resources.

2.1.1 The headwaters

The headwaters are known as a water original sources where the water initially comes form. Many headwaters supply water, and together make rivers and lakes. Water in headwaters can come from ground and rainfall especially in mountains forests (Sidle 2000). The system of headwaters can be define as the regions where the water come through network of channels. These network channels are known by their interactions between, geomorphic, hydrologic and biological processes (Gomi, 2002). There are many types of headwaters; some of them are shown below (Naiman et al. 2005):

1. Mountain headwaters

- Even mountain have rocks and steep slopes, it is known to be one of important headwaters. Water comes from rain and ice on the top of mountains. Alberta, Canada is one example of regions that has many mountain headwaters, which provide clean water.

2. Valley headwaters

- In this type of headwaters, water flow through large areas valleys. Water moves slowly over the valleys that have many types of plants. Arkansas, USA has this type of headwater that supplies water to the Arkansas River.

3. Springs headwaters

- Springs are small headwaters where water flows through frozen areas. Lake Itasca in southeastern Clearwater County, Minnesota, is an example of the spring headwater

4- Warm rocky headwater

- Rocky headwaters are seasonal sources of water. That is, in the spring season, the melting snow and rainfall provide and fill water to these headwaters.
- Yellowstone’s Mammoth Hot Springs in Wyoming, USA is one example of this type of headwater.

2.1.2 The rivers

A river is one type of water catchments. The water catchment is an area where water is collected by the gravity. That is, the water from rain run down to the catchment to make rivers, and lakes. Water in rivers flows down by the force of gravity. Rivers differ in wide and deep, some of them are small and not deep, while others are wide and deep. If the flowing water was small, this called a stream, or creek. Water in rivers can be seasonal (flow only in specific season usually the rain seasons) or flow all time. Rivers are differ in long. Some rivers can be thousands of miles in long while others can be short (Giller 1998).

The water in all rivers begins its flow from a starting point, which is called (headwater). The water from headwater come from rainfall, snowmelt, and could be from groundwater. The river’s end point is called its mouth. At the river’s end, the river’s water goes to big catchments such as lakes or oceans.

The rivers’ water is usually fresh, and not salted. The rivers’ water can bring and distribute many types of nutrients to support the life of plant and animal. However, at the rivers ends, rivers can form an estuary, which is a place where seawater mixes with fresh water. This mixed water is called (brackish water). For example, the Hudson River in USA has an estuary that forms brackish water along more than 150 miles.

The water flows fast in rivers, but it slows down when the river passes the wetland. Rivers usually carry sediments that form the deltas. The deltas are considered to be perfect agricultural areas. Rivers are used for irrigation in agriculture, drinking water, transportation, electricity production, and for leisure activities (Giller 1998).

There are many famous and important rivers around the words as shown in table 2.1. Most of these rivers are not placed in one country.

Table 2.1: The Famous Rivers in the World

River Name	River Length (km)	Countries in the Drainage Basin
Nile or White Nile	6,650	Ethiopia, Eritrea, Sudan, Uganda, Tanzania, Kenya, Rwanda, Burundi, Egypt, Democratic Republic of the Congo, South Sudan
Amazon	6,400	Brazil, Peru, Bolivia, Colombia, Ecuador, Venezuela, Guyana
Yangtze	3,917	China
Mississippi	6,275	United States, Canada
Congo	4,700	Democratic Republic of the Congo, Central African Republic, Angola, Republic of the Congo, Tanzania, Cameroon, Zambia, Burundi, Rwanda
Amur	4,444	Russia, China, Mongolia
Niger	4,200	Nigeria, Mali, Niger, Algeria, Guinea, Cameroon, Burkina Faso, Côte d'Ivoire, Benin, Chad
Brahmaputra	3,969	India, China, Nepal, Bangladesh, Disputed India/China, Bhutan
Murray	3,672	Australia
Zambezi	2,740	Zambia, Angola, Zimbabwe, Mozambique, Malawi, Tanzania, Namibia, Botswana
Amu Darya	2,620	Uzbekistan, Turkmenistan, Tajikistan, Afghanistan
Pilcomayo	2,500	Paraguay, Argentina, Bolivia
Orange	2,092	South Africa, Namibia, Botswana, Lesotho
Tigris	1,950	Turkey, Iraq, Syria, Iran
Rhine	1,233	Germany, Switzerland, Netherlands, France, Luxembourg, Austria, Belgium, Liechtenstein, Italy
Euphrates	3,596	Iraq, Turkey, Syria, Iran
Mekong	4,350	China, Myanmar, Laos, Thailand, Cambodia, Vietnam
Volga	3,645	Russia
Danube	2,888	Romania, Hungary, Austria, Serbia, Germany, Slovakia, Bulgaria, Croatia, Ukraine

Source: https://www.wikipedia.org

The length of the rivers is the distance between the starting point and river's mouth. The length is often not exact, but it is an approximation because it is hard to measure the exact length. The length of the rivers depends on many factors, and these factors can be changed.

For example, the river's length may depend on the edge of the river, cycles of erosion, flooding, and channels. The length can be changed over time because of the new channels cut narrow the strip of land. The Nile River was considered as the longest river in the world. However, recent statistics showed that the Amazon is the longest river in the world (Giller 1998).

2.1.3 The lakes

Lakes are big catchments of water which are ringed by land. There are too many types of lakes around the world. These lakes can be in very different environment. Some of them are in the mountains while the others in the deserts (Fluet 2017).

Lakes have variety of sizes. The size of some lakes can be a few square meters while others can be around 150,000 square kilometers. The small lakes called ponds, and the big lakes are called seas. The depth of lakes is also vary. Lake Baikal, in Russia is the deepest lake in the world with the depth of 2 kilometers.

It is interesting that lakes can be formed at any elevations. For example, Lake Titicaca, in the Andes Mountains is placed about 3,810 meters above the sea level. However, the Dead Sea in Jordan is placed about 395 meters below sea level (Boehrer & Schultze 2008).

The source of lakes freshwater is usually the rain, snow, ice, streams, and groundwater. Most lakes contain. If the lakes water leaves to an outlet, this lake is called (open lake). However, if lakes water leaves the lakes by evaporation, the lake is called (closed lake). The water in the closed lakes become salty because when the water evaporates, the salts stay. One example of salty lake is the Great Salt Lake, in the Utah, USA. The salt flats that is close to the salty lakes is one source of white salt.

The lake basins can be formed in different ways. The Glaciers formed some lakes. That is, when the ice from the ice age was melted, these lakes were formed.

In addition, Glaciers also formed many valleys and, pebbles, and boulders. These materials worked as dams that trapped water and made lakes (Fluet 2017).

Another way to form lakes is the plate tectonics. When these plates moved, they made earth crust breaks, and deep cracks. These can make natural basins, which when be filled with water become lakes.

The water comes from rainfall and from streams flowing. Sometimes, the plate tectonics movements happen close to the oceans, and part of the oceans' water fill the lake (Boehrer & Schultze 2008).

Volcanoes can be another way to from lakes. When the volcanos becomes inactive, the rain will fill the volcano crater and form the lake. One example of this kind of lakes is the Crater Lake in Oregon, USA. Rivers are the other main sources of lakes water. In some places, during the season of flooding, rivers may create some type of small lakes.

People also can formed some lakes. This type of lakes have used to generate power or to save water. Building dams on rivers is one way of creating artificial lakes. Lake Mead, Arizona in the USA is one example of artificial lakes. The Hoover Dam in Nevada, USA was built to control the water of Colorado River and generate power. Table 2.2 below shows some important lakes in the world.

2.1.4 The groundwater resources

Groundwater is the water that exists underground. It is usually found in the saturated zones under the land surface. The most common types of these sources are the aquifer, which is a geological structure that store water. Water in these sources is stored underground. The water slowly moves through geologic formations that called aquifers. Groundwater can be used for drinking, irrigation, and industrial processes. In addition, it can be an important source of charging water to rivers and lakes (Mandel 2012).

There are several types of groundwater are available, such as (Panabokke & Perera 2005):

1. The shallow aquifers

   Shallow aquifers is formed in the case where the soaked soil is less than one meter from the surface of land.

2. The deep aquifers

   This king of groundwater is formed when water depth is about 9000 meter.

Table 2.2: The Famous Freshwater Lakes in the World

Lake Name	Country	Surface Area (Km^2)	Water Volume(km^3)
Caspian Sea	Azerbaijan, Iran, Kazakhstan, Russia, Turkmenistan	371,000	78,200
Baikal	Russia	31,722	23,600
Tanganyika	Tanzania, DR Congo, Burundi, Zambia	32,900	18,900
Superior	Canada, United States	82,100	11,600
Malawi	Malawi, Mozambique, Tanzania	29,600	7,725
Michigan	United States	58,000	4,920
Huron	Canada, United States	59,600	3,540
Victoria	Tanzania, Uganda, Kenya	68,800	2,700
Great Bear Lake	Canada	31,153	2,236
Ontario	Canada, United States	18,960	1,710
Ladoga	Russia	17,700	908
Titicaca	Bolivia, Peru	8,372	893
Van	Turkey	3,755	607
Toba	Indonesia	1,130	240
Argentino Lake	Argentina	1,466	216
Vänern	Sweden	5,653	153
Dead Sea	Jordan, Israel, West Bank	810	147
Therthar	Iraq	2,710	120
Milh	Iraq	1,562	305
Nicaragua	Nicaragua	8,264	108

Source: https://www.wikipedia.org.

3. The sand coastal aquifers

The coastal aquifers are formed close to the ocean boundaries.

4. The silt aquifers

The alluvial aquifer is usually formed very close to rivers and buried channels.

5. The shallow aquifers in the rocks

This king of groundwater is formed when water enter and stay inside the spaces between the rocks.

6. The laterite formation aquifers

The laterite formation aquifers can be formed by the deterioration of rocks. That can happen under specific environmental conditions.

Even groundwater is considered as one of important freshwater sources, there are many difficulties and challenges facing people when using them. The most important difficulties or challenges are that groundwater cannot be easily controlled. In addition, groundwater resources are usually have not good quality water, which can cause health problems. However, with the negative expectations about the availability of freshwater around the world, the managing and developing groundwater resources have become more attractive (Villholth & Rajasooriyar 2010).

2.1.5 The storm water resources

The storm water resources are the places where water comes from rain, snow and melted ice. Storm water can fill and be stored in ponds and puddles creating water resources on land surface. In most cases, the water from rain and snow move to closest rivers or water bodies without any treatment. Storm water is considered as one of important water resource that can cover part of the increased demand for water. In some cases, Storm water can completely provide water to some urban areas, so they do not need any other water sources (National Research Council, 2009).

The storm water resources are most likely created in the forests where heavy rain is happening continuously. In some cases, the plants can also create storm water by drain. It is important to indicate that storm water can cause major problems especially in the developed areas. That is, it can cause flooding if it was heavy which by the end negatively affects people's properties.

The other problem is that storm water can bring pollution. Therefore, storm water management can provide many advantages such preventing the baring of agricultural land. In addition, it can prevent flooding of urban areas (Adams 2000).

Figure 2.1 shows how storm water resources be created from the water cycle. As shown in figure 2.1 the water evaporate from rivers, lakes, oceans and other water catchments on land surface. The water vapor goes up creating clods, then return to the land as rain or snow creating the storm water resources.

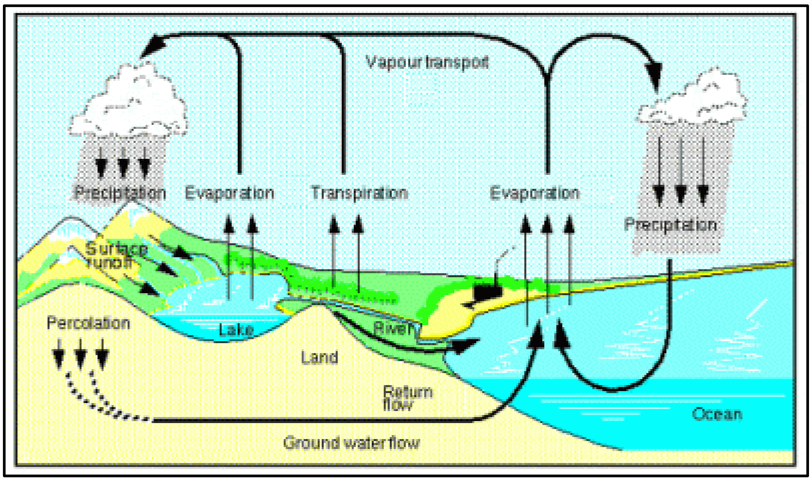

Figure 2.1: Hydrological Cycle (Water Cycle).
Source: https://www.deeptrekker.com/resources/storm-water.

2.2 The Use of Water (Water Demand)

This section presents the ways, fields, and reasons of using water from any water resources. The use of water is wide aspect since water can be used in any part of life on earth.

2.2.1 The use of water for drinking purpose

It is known that almost every live creature on this earth needs water to stay alive. This fact can be very important and very difficult. It is important to keep the lives especially human lives, and it is hard because it needs huge amount of water with high quality. That require more and more plans and water management systems (Zogorski 2006).

The recent statistics showed that about half the people in the third world countries have suffered from lack of drinking water supply. The other problem is that the available drinking water in these countries has not sufficient standards of quality, which has caused many health problems such as Diarrhea, Hookworm, and others (Gadgil 1998).

Drinking water is not only water coming from rivers or other water sources and use directly for drinking. However, many processes must be done on water to be ready for drinking or to be safe and healthy.

Countries use different definitions of drinking water. However, the World Health Organization, which is the international health organization, recommended guidelines for requirements of drinking water (Aryal 2012).

The World Health Organization issued the first guidelines in 1985. The revised guidelines were in 1993, which reflect many year of work by experts from about 40 countries. The recommendations presented in the first volume guidelines indicated the maximum values for water contaminants. The second volume indicated the health criteria, such as discusses related to drinking water. The third volume of guidelines was published in 1998. This volume presents processes for setting national targets to provide drinking water with specific quality standards.

In general, drinking water can be defined as the water that has acceptable quality. The acceptable quality must be in water physical, chemical, and bacteriological parameters. Having water with the required quality can make it safe and ready for drinking.

According to the World Health Organization (WHO), the daily use of water for drinking and cooking is about 2 liters for each person. The WHO statistics for 2017 showed that 71% of earth population uses safe drinking water. In addition, about 785 million people do not drink save water. About 144 million of them use water without any treatments for drinking and other uses. The WHO expectation is that in 2025, half earth population will suffer from lack of water. Figure 2.2 shows the distribution of people how have limited access to clean water.

It is clear that the high increase in the population can put more pressure on water supply especially in the third world countries (Asia, and Africa).

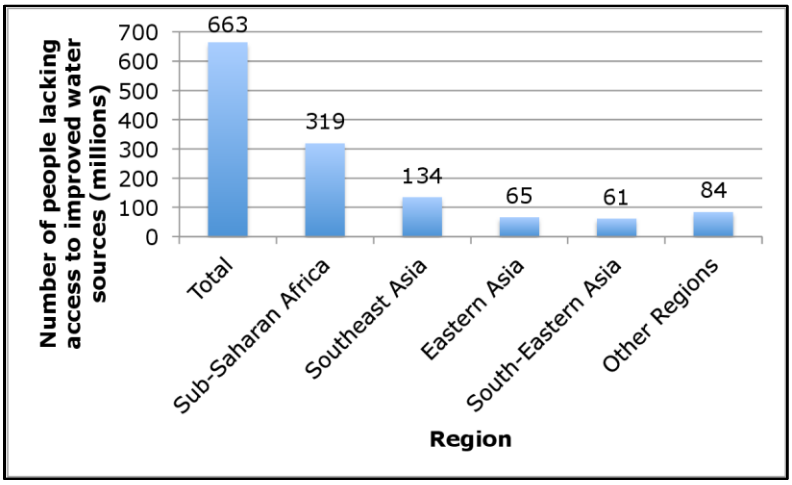

Figure 2.2: The Distribution of People Lacking Safe Drinking Water
Source: https://www.semanticscholar.org.

These regions as shown in figure 2.2 are now suffering from the lack of water, so it is expected that they will have more difficulties getting freshwater in the future.

Therefore, adopting good water management policies can help provide the required amount of water for the future generations.

2.2.2 The use of water for agricultural purposes

The agricultural or agricultural production is the process of using lands to produce plants and animals. These plants and animals are used to produce many products such as food, clothing and other industrial things.

People use agricultural products in every part of their lives such as at home, at work and anywhere. Therefore, agricultural production is very important even it consumes big amount of freshwater (Debertin 2012).

Agricultural production is one of the main economic activities since it has costs spent to produces agricultural goods, sell them, and get profits.

As agricultural is an economic activity, the main goals of farmers or agricultural managers is usually to maximizing the profits. That is, farmers have to reduce the costs of crops and livestock and increase the returns of selling them.

However, the process is not that easy because agricultural production is strongly related to many uncontrolled factors. One of these important factors is the availability of water for irrigation. Making a choice of agricultural outputs to be produced should be carefully viewed. Farmers have to decide what to produce based on available land, water, workers, and tools. However, in this part, the interest is only on available water.

Using water for agricultural production is not open; it is often restricted by authority roles. In most cases, governments put roles and regulations that are differ from place to place to organize and control the use of water in farming (Ward & Michelsen 2002).

Most governments established institutions that are specialized in managing and controlling the use of water in agriculture. The main goal of these institutions is to maximize the water's benefits and balance the growing demands for water. These institutions are collecting information and data on water supply and demand. They use these information or data to make decisions and polices on water uses.

One of the most common water use polices is called water saving in agricultural. For example, the agricultural in China uses water amount that reached 70% of total water usage. China's government applied a policy to save water in agriculture. This policy has four parts. The first part is rational utilization of water. The second is saving water when irrigation. The third is agronomic water saving. Finally, the agricultural management (Wang et al. 2002).

The rapid growth in world's population has put more pressure on agriculture products to meet the needs of these products. As a result, this motivates farmers to increase their corps, which increases the use of water. Therefore, it is important to adopt suitable water management policies to reduce the possibility of losing water. Recently, innovators present new systems of using water and other tools of farming. These systems called smart agriculture systems. Their goal is to keep same size of production with less amount of water, or increase the production using same amount of water (Sushanth & Sujatha 2018).

Smart agriculture uses most recent technologies such as laser technology, wireless technology, and smart sensors. These technologies can help monitoring the environmental conditions, water use, and others, which are the most important factors to get good crops. The system has communication tools that allow farmers to collect data on irrigation using some computer application. These systems cheap and they are useful in the areas where water is limited.

Figure 2.3 shows the growth in world's use of water. Figure 2.3 shows that the main percent of the water usage is in the agriculture, which enforce decision makers to focus more on this sector in term of water management policies.

2.2.3 The use of water for industrial purposes

Water is not only used for life of people, animals, and plants, it is also an important material for manufacturing and industries. Water is used in the production process for many purposes. For example, water can be part of the products' material such as juice or other drinking products. In addition, water can be used as part of the production process such as cooling equipment (Dupont & Renzetti 2001).

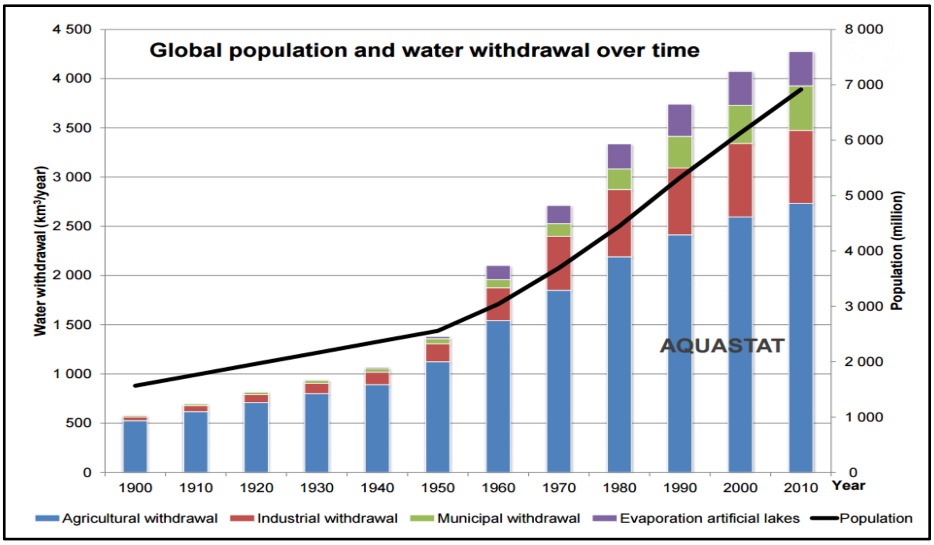

Figure 2.3: The Growth in World's Use of Water.
Source: https://www.fao.org.

Water can be used in several industrial production process. It can be used for washing, cooling, and fabricating. In addition, it is used in petroleum refineries, for chemical products, and food products. Chemical and paper industries are known to consume the most water for industrial use. The developed countries use about 59% of their available water in industrial production. However, 8% only of available water is used in developing countries (Renzetti 1992).

The other important use of water in industrial is to generate electricity. The electricity generation has a significant impact on regional water resources especially in the USA and some other developed countries. For example, the USA uses about 41% of freshwater for the electricity generation in 2005, which is big number (Macknick et al. 2012).

The high consumption of water for electricity generation expected to have significant and negative impacts on the relationship between water resources and power provided. That can be worse in the areas that have low water availability and high temperatures. For example, in 2007 the shortage of available water lead the Browns Ferry nuclear plant to shut downs because of high temperatures of its water cooling system.

From the other side, the power generators can also affect the quantity and the quality of water. They can affect the amount of water taken from different water sources. They can affect the amount of water that evaporated from immediate water in the environment. In addition, electrical generators can negatively affect the quality of water because of high carbon pollution.

One solution to these problems is using new and advance technologies in power generation that can reduces the water consumed and produce less pollution. For example, the low carbon energy technology in power generation can reduce the impacts on water consumption. In addition, the renewable energy sources such as solar photovoltaics and wind generators can be great solution to save water and reduce pollution.

2.3 The Problem of Water (Water Scarcity)

There are important questions to ask related to this issue, why are people scared of water? Is the water problem in the supply side or in the demand side? Answering these questions needs to know much about water. Many reasons that led people to be scared of water, some of them are related to the current situation while others are related to the future. For example, about 1.2 billion people have limited access to safe water for daily use. In addition, more than 900 million of poor people living in rural areas have limited access to safe water. Having limited access to water can impact people's health and productivity (Rijsberman 2006).

In general, water scarcity can be defined as having no or very limited access to safe and water to meet the individuals daily needs of water. These needs are drinking, washing, and others. People who have no or very limited access to safe water are called insecure people. If the number of the insecure people was large and they were insecure for long time, the area where they live in is called water scarce area.

The degree of water scarcity depends on some factors. For example, the environment of the water scarcity area, the available or could be available water resource, and the period being water scarcity area. In addition, the size of countries, the number of people, the water quality, and others are also factors that affect water scarcity (Seckler et al. 1999).

It is important to indicate that changing the conditions that made an area to be water scarcity area can change the situation. For example, building a dam to control the floodwater in the flooding season and use it in the dry season can change the situation. Water will be available in the dry period, and the people in that area will not be living in water scarcity area. Therefore, dams and other water infrastructures that manage and control water can significantly affect the water scarcity.

In large countries like China, water scarcity is more likely because of the country size and number of people. However, that is not always the case; some small countries have the same problem. As a result, the country size and number of people should be account when determine water scarcity, but they are not sufficient to make that decision (Jiang 2009).

The quality of water is another important factor of measuring water scarcity. Table 2.3 shows the water quality standards table of the World Health Organization.

The water quality must meet these standards to be safe and healthy. That is because freshwater could be polluted which increases the degree of water scarcity in the polluted area. The degree of pollution in water can affect the availability of water resources in specific area.

Table 2.3: Water Quality Standards of WHO

Parameters*	WHO Standards
pH	6.5 – 9.2
Total Hardness	300
Total Dissolved Solid	500
Electrical Conductivity	300
Total Coliform Count (100ml)	0
Sulphate	200
Sodium	200
Ammonium	1.5
Zinc	5
Iron	0.3
Lead	0.05
Cadmium	0.01

*All values in mg/L, except pH, EC (µS/cm) and total coliform count (CFU/ml)
Source: https://www.researchgate.net/figure/Drinking-water-quality-standards.

Determining water scarcity can be done by analyzing how much water is demanded and how much water is available with required quality in a specific area and specific time. Determining water scarcity is important because it can help water policy makers addressing the possible water crisis, and find good solutions.

Water scarcity is not local problem, but it can affect any area in the world. Water scarcity is global problem especially after the increase impact of climate change on earth. The recent statistics showed that more than two thirds of global population would suffer from water scarcity in the near future.

The rapid population grow is expected to cause less available water per capita. Climate change, which has led to less rainfall, is another reason of reducing available water (Mekonnen & Hoekstra 2016).

Some countries in central and west Asia, and North Africa have daily available water below 1000 liters/capita. This part of the world is more likely to be water scarce areas. The people in these countries have also limited access to water resources. Table 2.4 showed the countries in Asia and Africa that expected to be water scarcity area in 2030 (Rijsberman 2006).

Table 2.4: The Countries In Asia and Africa That Will Have Water Scarcity in 2030.

List of Countries in Asia and Africa				
Afghanistan	Egypt	Kenya	Niger	Tanzania
Algeria	Eritrea	Korea	Republic	Nigeria
Togo	Burkina	Burkina Faso	Ethiopia	Lebanon
Pakistan	Tunisia	Burundi	India	Libya
Rwanda	Uganda	Iran	Iraq	Malawi
Saudi Arabia	Emirates	Israel	Maldives	Somalia
Yemen	Jordan	Morocco	South Africa	Zimbabwe

Source: (Rijsberman 2006).

The important question here is how people can solve the problem of water scarcity. One of the traditional solutions presented by engineering is by constructing water infrastructures.

The most common example is building dams that used to control water resources. In addition, they can save and provide larger part of total available water for human use. Sanitation systems are another example of saving water and solve in part the water scarcity problem (Mekonnen & Hoekstra 2016).

The modern solution to the water scarcity is happen when policy makers shift their thinking from water supply management to water demand management. That new method of managing water resources is called (the integrated water resources management).

The integrated water resources management has three main methods, which are:

1. Water users must be involved more in the water management usually by water user associations.

2. Pricing water. That is, using water is not free, each unit measurement of water has a price, and people have to pay for each unit of water they use.

3. Constricting the river basin to be under authority's control.

These three methods can be theoretically effective. However, they are not always effective. The results of applying these three methods showed that they can be successful in some areas but not in other areas. For example, pricing water is highly debatable. Some people cannot pay, while some other use corruption to not pay. As a result, these actions can play roles in solving the problem but they are not enough.

The study conducted by Postel (2001) proposed new method of water management. This method focuses on high water productivity. The basic idea of this method is to use micro irrigation that can increase the water productivity. In Addition, it can and increase the output of goods and services per unit of used water (Postel 2001). The study conducted by Narayanamoorthy (2004) presented the drip irrigation method. This method can to help solve the water scarcity crisis in India (Narayanamoorthy 2004).

In general, too many ways have been used to solve water scarcity problem. However, all of them are under the title of water resources management which will be presented in the next section.

2.4 Water Resources Management's Theory

2.4.1 The water resources management's concepts

Water can play an important role in different fields of our life. Water is essential for life, industrial, agricultural, and many other economic activities. These facts have led to develop many water management strategies to achieve the efficient use of water. These strategies were formed depending on the principles of integrated water resources management (IWRM). This section reviews in details the concepts of IWRM.

Until now, IWRM has considered as the best tool that can gather many conflicting and competing uses of water resources. The IWRM has become more effective when political issues between countries became extremely complex (Jeffrey & Gearey 2006).

The IWRM is defined as a process in which people can develop and manage water and other related resources. The goal of IWRM is to maximize the economic and social outcomes using ways that do not threat other people lives. In other words, the IWRM's main goal is to address at the same time two problems. The first problem is the sustainable development and the second is the overlapping sectoral planning.

The IWRM indicates that water development and management should depend on sharing idea. In addition, its concept focuses on involving users and planners in the process and at all levels. The IWRM is viewed now as the best solution to water problems, and it is the only available one even with some limitations. One example of IWRM was applied in 1930s, in Tennessee, USA. The program led to improve public health, water control, electricity generation, and others. Another successful example of applying IWRM was close to the Ruhr River in Germany.The IWRM strategies have developed to provide the right responses to water scarcity.

That is, they focus more on increase the water resources by getting high water supply efficiency.

Some IWRM strategies focus on reducing the water leakage, and increasing the recycling water. In addition, some IWRM strategies work on reducing the water demand by changing the water unit's price, and the water use license structures. Furthermore, some IWRM strategies encourage the use of technology and education for all users and in all sectors (Mayer & Munoz 2009).

It is important to indicate that IWRM principles that take in account both national and regional strategies. That can to successful joined planning across economic sectors development and the use of natural resource. Below are a set of IWRM principles:

1. The IWRM is applied at the water resources level.
2. The IWRM can integrate water management with the environmental management.

3. Workers, Users, and the community are involved in the IWRM system.
4. The social dimensions is an important part of IWRM.
5. One of the main goals of IWRM is to build capacity.
6. Costs and pricing are taken in account.
7. Governments support is part of the system.
8. Adoption the newest and best related technologies.
9. Water allocation must be fair.
10. Water is dealt as an economic good.
11. Women should have significant role in water management.

2.4.2 The water resources management's approaches

The central idea of water resources management's approaches is that these approaches have to involve some important elements. They have to involve the development of water policies at the national level. They have to consider the equity and efficient use of water allocation without hurting the environment. The IWRM approaches must consider the development of human resources, and the development of new institutions. There are several IWRM approaches, which can be discussed as following (Al Radif 1999).

1. Water supply management approach

This approach was first introduces as a respond to the rapid growth of the world population. That growth in population was expected to increase the needs for water especially in daily human use, agriculture, and industrial uses.

Policy makers believed that the available water resources would not be enough to cover all these increased needs. Therefore, the first and traditional approach that was adopted is by manage the water supply.

The idea of this approach is that the governments and water resources managers try to maximize the water supply. In other words, they try to maximize the available amount of water that can be directly used. They usually do that by transfer the water from its original storages to new storages. The other way is by changing the water pathways from its original pathways to a new one.

Water specialists recognized that this approach put more stress on water resources. In addition, they found that water quality has negatively influenced.

2. Water demand approach (Integrated water resources management)

Integrated water resource management or water demand approach is the way of managing water resources with more focus on the water demand side. In this approach, all water related issues including users, society's development, and any environmental concerns are involved.

The approach goal is to get the sustainability of water resources. The central idea of this approach is by applying water policies that lead to an integrated water management.

The integrated means, adopting water polices that take in account the local and international levels. In addition, this approach integrates the different related technological, different economic related aspects, and health aspects.

3. The strategic approach

The strategic approach is a way that can applied at in the natural ecosystems. For example, forests, rain zones, wetlands and coastal areas. The idea of this approach is by supporting the different types of ecosystems to keep their functioning. That is because these ecosystems can provide services that can be used in water resources management.

They can provide assessment of water resources, which is important to adopt good water management strategy. They can help in training at management levels. They can help transferring the related technology to local water managers. They can help improving communication by creating partnerships.

Finally, they can help adopt good water policies and planning that improve the water and reduce the economic costs.

2.5 The Future of Water Allocation

The traditional methods of water allocation aim to maximize the benefits of using water. That is, they allocate water efficiently between the use for domestic, agriculture, and industrial. These traditional methods focus more on maximizing the quantity of water for direct use. In addition, they focus only on costs and benefits.

However, the new strategies of water allocation take in account bot social and the economic benefits. In addition, they consider the sustainability of water resources for future generations (Speed et al. 2013).

Water allocation can be in different forms. For example, the national level water allocation. In this type, the authorities decide how water be shared between provinces or states inside a country.

Another type of water allocation is called the regional water allocation. This type is formed based on regional level water management. The other water allocation methods can be related to flood management, the protection of water resources, and others.

From one side, it is expected that in the future the competition between water users will continue and be more aggressive. From the other side, the population growth will also keep growing which put more pressure on water resources. Therefore, it is important for governments, and other international organization to have fair agreement on using water resources. They have to consider the environmental concerns when they design their strategies (Wang & Hipel 2003).

3. THE WATER SUPPLY, WATER DEMAND, AND WATER PROBLEM IN IRAQ

Before explaining the water resources management, and role of Mosul dam in managing water resources in Iraq, it is important to present information about water supply, water demand, and water management system in Iraq. That can help better understanding the role of this dam in Iraqi WRM.

3.1 The Water Resources in Iraq (Water Supply)

In general, Iraq was considered as one of the countries that has surplus in water supply. Iraq has two main rivers, which are the Tigris and the Euphrates Rivers. In addition, it has a good level of rainfall, big natural catchments, and moderate climate. However, many changes have happened and led to shortage in Iraqi water supply (Abd-El-Mooty et al. 2016).

For example, in the 1970s, both Syria and Turkey began building dams on the start points of Iraqi rivers. That caused a significant decrease in the rivers water levels. The wars and the climate changes are other reasons that cause the shortage in water supply in Iraq.

The next section presents different types of water supply resources in Iraq. There are three types or groups of water resources in Iraq, which are surface water, groundwater, and non-traditional sources.

3.1.1 The surface water resources

The surfaces water resources in Iraq takes four shapes as discussed below:

1. The big rivers:

The main surface water resources in Iraq are the two rivers (the Tigris and the Euphrates). These rivers with their tributaries provide around 90% of the country's surface water. The water from these rivers is used mainly for drinking, for industrial processing, and for irrigating large areas of agricultural land (Issa et al. 2014).

The Tigris and Euphrates rivers are originate in Turkey and Syria. They meet at their ends at the Shatt al-Arab. Shatt al-Arab is a big water channel that gathers the water from the two rivers. Shatt al-Arab is located in the south of Iraq, in the city of al-Qurnah in Basrah (Al-Ansari & Knutsson 2015).

The Euphrates River is the longest river in this area. Its main headwaters are located in Turkey and Syria. The length of the Euphrates River from its start point to the point where it meets Tigris River is 3,000 kilometers. The Euphrates River's length is distributed along three countries. About 1,230 kilometers of its length is in Turkey, 710 kilometers in Syria, and 1,060 kilometers in Iraq.

Most water of the Euphrates is coming form of rainfall and melting snow. The peak water volumes usually reached during the spring season (April through May) of each year. In these two months, the water discharge is accounts for 36% of the total annual discharge of the Euphrates. The average natural annual flow of the Euphrates is estimated to be from a 15.3 Km^3 to 42.7 Km^3 (Al-Rijabo & Salih 2013).

The water discharge of the Euphrates has changed since Syria, Turkey, and Iraq starts the construction of the dams in the 1970s. In 1990, the collected data on Euphrates discharge show that dams and withdrawal of water for irrigation negatively impact the water discharge of Euphrates. The average discharge after 1990 has dropped to 11.2 cubic kilometers per year.

The Euphrates enters Iraq at Al-Qaim city, and it passes many provinces in Iraq as shown in figure 3.1. The Euphrates River is the main source of irrigated agriculture since about 12,000 years ago. People who are living on this river mostly work in agriculture, and do other activities such as fishing, river transport, and trade.

The economic activities continued and thousands of cities and villages were built on this river over time. Recently, investments are rapidly increased on this river with the help of many dams and the large number of farms (Sissakian et al. 2018).

Figure 3.1: The rivers in Iraq
Source: https://www.worldatlas.com/maps/iraq.

The Tigris River is the other main river In Iraq that has a length of 1,900 km. Its Yearly discharge of water is about 41.2 to 58.3 billion m3. The Tigris river headwater is located in the city of Elazig, Turkey. The Elazin city is located about 30 km from the headwaters of the Euphrates.

The river flows for 400 km in turkey, and then enters Syria. After 44 km in Syria, the river enters Iraq and passes many provinces (such as the capital, Baghdad). The Tigris River meets the Euphrates at Shatt al-Arab as shown in figure 3.1.

In Iraq, the Tigris splits into several channels and small rivers. Some of these branches are natural, while the other are made to serve agriculture. The Tigris joins the Euphrates near al-Qurnah to form the Shatt-al-Arab. Historically, many of the great cities was built on or close to the Tigris (Al-Ansari et al. 2018).

Its water is used for the needs in agricultural activities. In addition, the Tigris has been an important transport route that used to transport people and goods between cities.

It is important to indicate that there are many dams placed on the Tigris River. These dams including the Mosul Dam, which is the biggest one, are used to control and allocate water resources in Iraq.

Even Euphrates River the Tigris River flows for more than 1000 km in Iraq, The fact that these rivers do not originate in the country creates some problems. Beside the political problems with Iraq neighbor’s countries, the shortage in water supplied puts Iraq in a difficult position when planning and managing its water resources (Al-Ansari 2016).

This natural contribution of the two rivers in Iraq is changing rapidly. For example, it is recognized that the amount of surface flow of these rivers decreased due to the reduction in the flow of their sources by 30%. This effect is expected to increase in the next twenty years. It is expected that the water available from these rivers will be decreased by up to 60%. Therefore, the policy makers in Iraq have to adopt urgent plans to manage the big shortage in water supply.

2. The small rivers (the tributaries):

In addition to these major rivers in Iraq, there are many other small rivers or tributaries. These tributaries are (Issa et al. 2014):

- The Great Zab River (which originates in Turkey).
- The Little Zab River (which originates from Iran).
- The Diyala River (which originates from Iran).
- Al-Azim River, which occupies an area of about 13,000 km^2, all within Iraqi territory.
- Al-Shehaby Rivers, which occupies an area more than 8,000 km^2 in southern Iraq.
- The Karkh River, which its main course lies in Iran, has an area of more than 50,000 km^2 and flows into the Hawizeh Marsh, where it connects at the downstream with the Tigris and Euphrates rivers systems.

- The Karun River, which occupies an area about 67,000 km^2. This river started from the Zagros Mountains of western Iran. This river has a major impact on salt-water infiltration along the Shatt al-Arab.

3. The lakes

Iraq has many lakes that are located in different places in the country, and considered as important storages of water. Some of these lakes are natural made, while the other are manmade. These lakes are listed below (Dawood et al. 2018):

a. Tharthar Lake

Tharthar Lake is a manmade lake that established in 1956 in Al Anbar Province. This lake is located about 100 km northwest of Baghdad, the capital of Iraq. It is located on the area between the Tigris and the Euphrates rivers. Tharthar Lake has an area of about 2,050 km^2. The lake capacity is about 83 billion km^3 water volume. The lake was made originally to safe people who are living in this area from the threats of floodwater of Tigris River. Then, it becomes as one of the most important freshwater storage in Iraq.

The lake collects floodwaters of the Tigris River through the Tharthar Canal, which is an artificial inlet canal. The canal transfer the surplus water to the lake by the help of Samarra Dam. The lake has also two artificial outlets. The first one is called Tharthar Taksim. This outlet drains water directly to the Euphrates River in the summer.

The second outlet is called Dhira'a Dijla, which is a channel that returns water back to the Tigris River as needed. The other purpose of the lake is to wash out the salts from the stored water by natural continuous draining of the stored water.

b. Habbaniyah Lake

Habbaniyah Lake is a lake located in Al Habbaniyah city, in Anbar Province, Iraq. The lake was established in 1956. The lake covers an area of about 140 km^2 and stores around 3 billon km^3 of water volume.

The main goal of this lake was to collect the flooding water from the Euphrates River, and safe people who are living in this area. Later, the lake's water was using for irrigation in the dry seasons especially in summer. In addition, the lake is used for tourism. Many tourist cities were built on this lake since 1979.

For several reasons such as the climate changes and the dams that built on Euphrates River in Turkey, the stored water of this lake started decreasing since 2001. Recently, many government programs were applied to return the capacity of this lake to its original level.

c. Milh Lake

Milh Lake, which is also known as Razzaza Lake, is located at the west of Karbala, Iraq. The lake is a manmade lake that constructed during the 1970s to regulate the flood flows in the Euphrates River.

Lake Razaza is considered the second largest freshwater lake in Iraq. The lake covers big part of a wide valley that includes Tharthar, Habaniya, Razaza and Najaf Sea. It is also an important source of water that used for agriculture and fishing.

The water of this lake is coming from eight sources. These sources are the River Euphrates, Lake Habaniya, east of Ramadi, Rashidiya, north of Karbala, groundwater springs in Ayn al-Tamr, west of Karbala, and rainfall and seasonal flows. Lake Milh is mainly getting its water from the excess water of Habbaniyah Lake. The water flows (in and out the lake) through controlled channels. The water level in the lake changes with the seasons. Recently, this lake lost its stock of fish, and only a few recreational areas around the lake still exist.

The lake area is about 1810 km^2, and its elevation is about 40 m above the sea level. The lake water volume is estimated to be 26 billion m^3 when it is completely full of water.

d. Qadisiyah Lake

Qadisiyah Lake is a manmade reservoir that is located in Al-Anbar province, Iraq. This lake is placed on the north side of the Haditha Dam. The building dams on the Euphrates River above Haditha city, Iraq, constructed Qadisiyah Lake.

Its total area is about 500 Km^2, and provides water for irrigation to nearby fields. Its water volume is estimated to be 8 billion m^3.

e. Najaf Lake

Najaf Lake or Najaf Sea is a lake that located at Najaf city, Iraq. Historically, this lake was an important source of fresh water. The lake gets its water from the Euphrates River. However, many factors including the climate changes and building dams on Euphrates River have led to dry this lake. Recently, the lake is in its lowest volume of water that used in irrigation of small farms around the lake.

The water surface area of the lake is about 450 km^2, and the lakes water volume is about 6 billion m^3. Many local and international civil organizations have been trying to help return the water to this natural lake, which have a variety of creatures.

f. Dukan Lake

Dukan Lake is a lake located at the city of Ranya, North part of Iraq. The construction of the Dukan Dam creates this lake. The lake is a manmade lake that constructed to store water from the Little Zab River. The lake was created between 1954 and 1959, which is the same time of building the Dukan Dam.

The area of the water surface of this lake is about 270 km^2 when it is at maximum capacity. The capacity of the lake is about7 billion m^3. The surface elevation is 515 m above sea level. The lake is used for irrigation and energy generation or hydroelectric power plant.

G.Darbandikhan Lake

Darbandikhan Lake is a lake located at southeast of Sulaymaniyah, Iraq. The lake's capacity is about 3 billion m^3. Around 70% of the lake water is coming from Iran through the Sirwan River and other tributaries.

It is expected that the water level in the lake is going to declining. This is because Iran has built several dams over the tributaries that supply water to the lake.

Recently, in the spring season, the discharge about 95 cubic meter per second enter the lake. However, that is small amount compared to the last century. Many interested organizations indicate that the low water levels can has negative impacts on the life in these areas.

h. Mosul Dam Lake

Mosul Dam Lake is a manmade lake that was constructed with the Mosul Dam. It was built before the Mosul Dam to store water. Its locations is at the north of the Mosul city in the Nineveh, Iraq. The lake gets its water from the Tigris River. The amount of water storage in the lake is about 6,250 km^3. The water surface of the lake covers an area about 380 km^2.

The lake is one of the important freshwater sources that provides water for irrigation and power generation. It irrigates more than 25000 hectares of agricultural land. In addition, it was designed to provide 50 megawatts of electric power.

i. Sawa Lake

Sawa Lake is a natural closed lake. That is, there are no inlet or outlet water channels. The water depth in this lake is ranged from 1-4 meters. The lake is salty lake that located in Muthanna province, south of Iraq near the Euphrates River.

Lake Sawa gets its water from the underground water that infiltrates into it from the Euphrates River through faults and cracks. The lake is a unique lake because of its high level of salinity compared to the other lakes in Iraq.

The lake area is 12.5 km^2, and the depth of the water in the lake is about five meters. The water color varies from dark green to blue. The water level in the lake changed based on the season. However, the lake does not totally dry. That is because of the balance between the supplied amount of groundwater and the evaporated amount of water. The water of this lake cannot be used for irrigation, but it is a good source of salt.

j. Hamrin Lake

The Hamrin Lake is a manmade lake that is located at the northeast of the Baqubah, in Diyala provione, Iraq. The Hamrin town is a small town placed on the shore of the lake close to the Hamrin Mountains.

The lake was constructed in 1981 with an area of 340 km^2. The main goal of using this lake is to hold more than 2 billion m^3 of water. The water of this lake is used in irrigation of nearby farms, and for fishing.

The lake had lost around 80% of its capacity because of dams that constructed by Iran on Alwand River, which is the main source of the lake water.

k. Delmaj Lake

Delmaj Lake is a natural lake that is located between Wasit and Diwaniyah provinces, southern Iraq. The lake is located in the area between the Tigris and Euphrates Rivers. The important role of the lake is keeping the water flowing in the artificial river called (the third river). The lake is also used for natural drainage, and for the irrigation.

i. Azim Lake

Azim Lake is a manmade lake located on the Azim Dam. The lake is placed on the north of Baquba city, Diyala province, Iraq. The lake is considered to be the second largest lake in Diyala. The lake has a capacity of 1.4 billion m^3. The lake's water is coming from the Azim River, which is one tributary of the Tigris River. The water of this lake is mostly used for irrigation.

In addition to all lakes that listed above, Iraq has many other big and small lakes. These lakes are also used as water storages, for agriculture, and some of them for industrial. Table 3.1 shows the other lakes in Iraq with their locations. Figure 3.2 shows the distribution of lakes in Iraq. It shows that lakes in Iraq are almost in every part except the southwest part (the dry part).

4. The Marshes

The marshes in Iraq are located in the south part of the country, and some of them are shared with Iran. They are natural wetland areas that have very long history. The biggest marshes in Iraq are Hawizeh and Hammar Marshes (Richardson et al. 2005).

In general, marshes in Iraq are considered as important sources of water storage that provide water for the life of many people and for many different animals. The Iraqi government had a plan started in 1950 and stopped in 1970s to drain part of these marshes to use it for agriculture and for finding oil. In the 1980s and 1990s, the Iraqi government drained most of these marshes areas for some political problems. As a result, the marshes drained to about 10% of its original sizes, which was led to the big negative changes.

Table 3.1: The Lakes in Iraq.

Lake Name	Location
Dohuk Lake	Dohuk Province, Iraq
Picodian Lake	Erbil Province, Iraq
Amerli Lake	Salahaddin Province, Iraq
Jadriya lake	Baghdad Province, Iraq
Knau Lake	Sulaymaniyah Province, Iraq
Samarra Lake	Samarra city, Salahaddin Province, Iraq
Anah Lake	Anbar Province, Iraq
Alwand Dam Lake	Diyala Province, Iraq
Shuweija Lake	Wasit Province, Iraq
Sugar Lake	Maysan Province, Iraq
Shereen Lake	Kirkuk Province, Iraq

Source: https://ar.wikipedia.org.

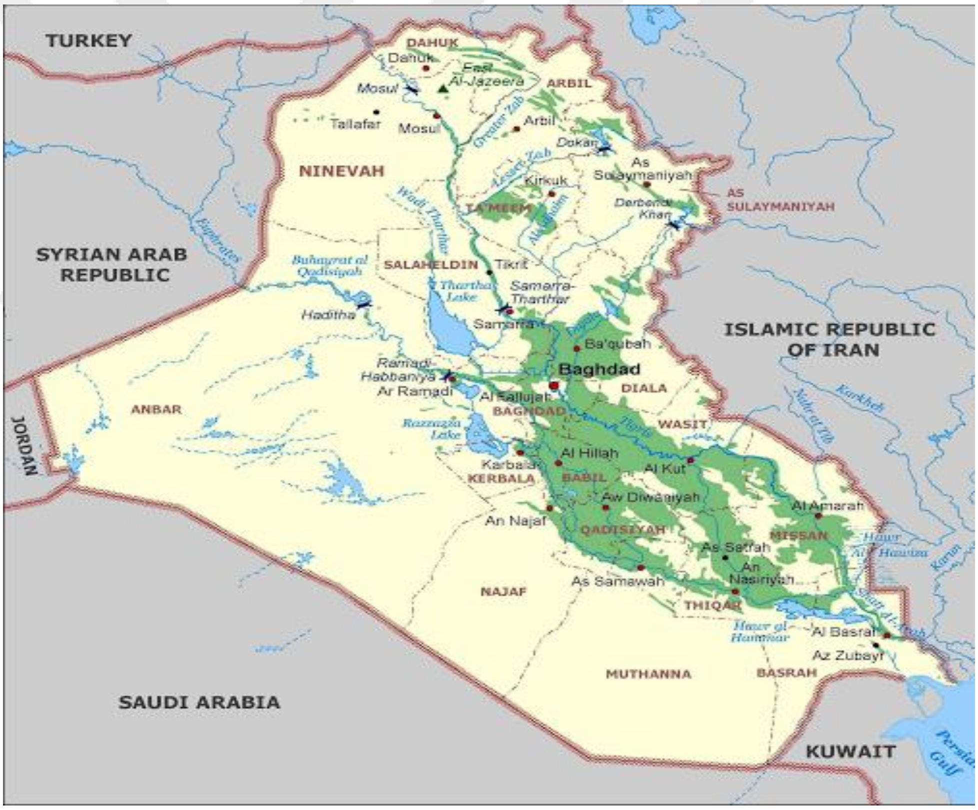

Figure 3.2: The Distribution of Lakes in Iraq.
Source: http://iraqieconomists.net.

After 2003, more attention has paid on these important areas from different local and international organizations. They all have worked on recovering the life in these marshes. Until now, the recovering process is not sufficient because of water shortage in Iraq. However, the work is continued on returning the amazing life in these areas (Al-Ansari et al. 2012).

There are many marshes in different locations of Iraq, which can be presented as following (Al-Zaidy et al. 2019):

a. Hammar Marsh

The Hammar Marsh is one of the biggest marshes in the south part of Iraq. It receives its water from the Euphrates River.

It is located in the area between both Nasiriyah and Basrah provinces. The area of Hammar marsh varies depending on the season. It varies between 2,800 to 4,500 km^2 in the flooding season. The flooding water usually comes from the Central Marsh, which gets its water from the Tigris River. The Hammar marsh has also the Hammar Lake. This lake has an area of 30000 km^2 with water depths reached 3m in the flooding season. In the dry season (usually in summer), big part of the marsh and the lake dry, and used for agriculture.

b. Hawizeh Marsh

The Hawizeh Marsh is located in the area between Maysan and Basrah provinces. It gets its water from the Tigris River. Iraq shares the marsh with Iran. The marsh inlets, in Iraq side, are the Tigris distributaries (Al-Musharrah and Al-Kahla).

The marsh outlet is the Al-Kassarah River. This river is very important since it is keeping the water flow system in the marshes and keeping it as an open basin. The marsh has an area of 3000 km^2. The Hawizeh Marsh is one of water sources that provide water for many people, for agriculture, and for fishing.

c. Central Marsh

The Central Marsh is located in south of maysan. The marsh is located in the area between the Tigris River on eastern boundary and the Euphrates River on southern boundary. It gets its water from the Shatt al-Muminah and the Majar al-Kabir, which are the Tigris's distributaries.

The Central Marsh has an area of 3,000 km^2. The marshes has many lakes such as Umm al Binni lake and Al-Zikri lakes.

d. Chibayish Marsh

The Chibayish Marshes is located at the east of the Nasiriyah, south of Iraq. The Marsh gets its water from the Euphrates River and the Tigris River. The marsh area is about 2600km2. The marsh is organized to have many different wildlife animals and fishes. Its water is used for living, agriculture, and fishing.

e. Umm Niaj Marsh

The Umm Niaj Marsh is located Maysan, south of Iraq. The marsh gets its water from Al-Kahla River and Al-Mashrah River inside Iraq. In addition, it gets some water from outside Iraq through Al-Tayyib, Al-Duwaireej, Al-Karkh, Nissan and Khafajia rivers. The marsh area is about 750 km^2. Its area is distributed between Iraq and Iran.

Part of the marshes was dried. However, the water returned to it after 2003 because of the Marshes recovering programs. The marsh's water is used for living, and agriculture.

In addition to the above list marshes, Iraq has many other marshes that are located in different places. Table 3.2 shows these marshes and their locations in Iraq.

All of these marshes, which cover an area about 40,000 Km2, are used as water storages, and they provider water for people, agriculture, and fishing in the middle and south part of Iraq. Figure 3.3 shows the important marshes in Iraq.

3.1.2 Underground water

Even Iraq has many underground water resources that are currently used, the information about underground water system in Iraq still not enough. In other words, the annual active aquifer recharge rate in Iraq is not fully understood. The Iraqi government and the UNESCO are currently trying to collect and analyze any information to better understand the groundwater systems (Stevanovic & Iurkiewicz 2009).

Table 3.2: The Marshes and Their Locations in Iraq

The Marsh Name	The Marsh Location
Shuweijah	Wasit Province
Al Dalmaj	Wasit and Diwaniya Provinces
Shamia	Diwaniya Province
Ibn Najm	Diwaniya and Karbala Provinces
Afak	Diwaniya Province
Abi Debs	Karbala Province
Al-Shenafiya	Karbala Province

Table 3.2: Continue

The Marsh Name	The Marsh Location
Qurna	Nasiriyahand Basrah Provinces
Alsnaf	Nasiriyah Province
Abu Zark	Nasiriyah Province
Adel	Nasiriyah Province
Alfhod	Nasiriyah Province
Ghammouka	Nasiriyah Province
Sunni	Maysan Province
Odeh	Maysan Province
Al-Soda	Maysan Province
Adaim	Maysan Province
Al-Maleh	Maysan Province
Al Sahin	Maysan Province
Abi Kalam	Maysan Province

Source: https://ar.wikipedia.org.

In general, Iraq is divided into seven hydrogeological regions as shown in figure 3.4. The division was specified according to Iraqi different physical, structural, geological and hydrogeological characteristics.

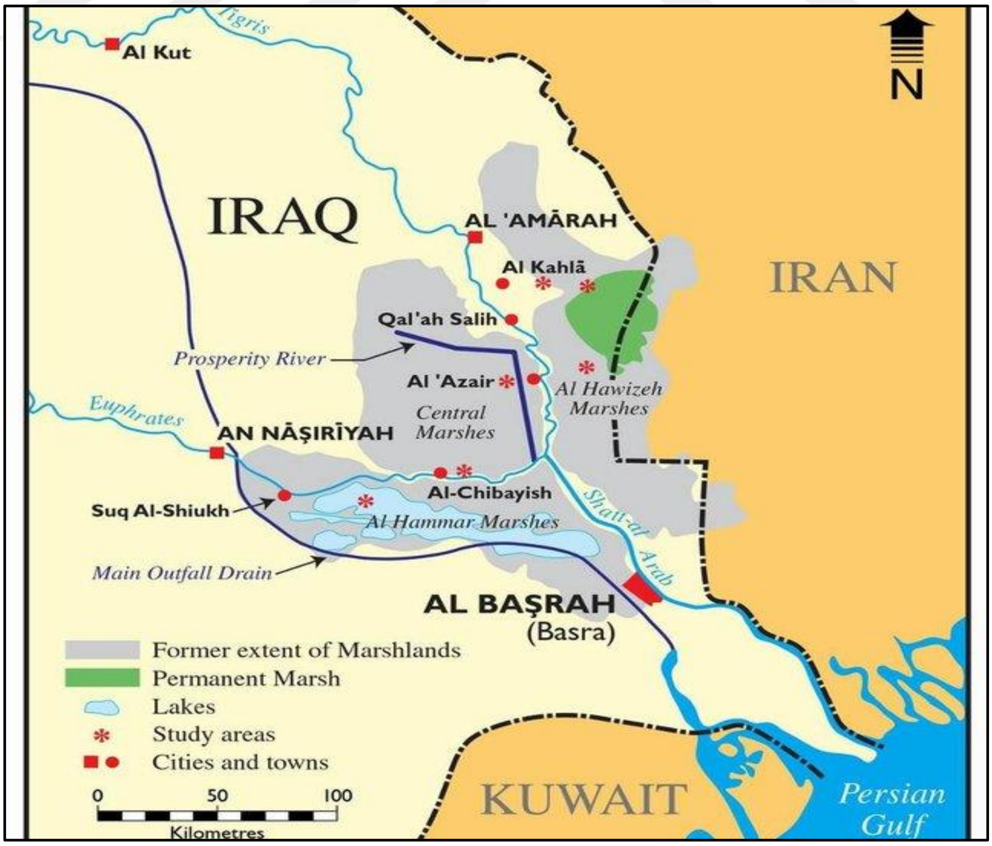

Figure 3.3: The marshes in Iraq.
Source: https://www.researchgate.net/figure/Map-of-southern-Iraq-showing.

These regions are expected to have different groundwater resources. Therefore, this regional classification can help better investigating the groundwater resources in Iraq.

The Mesopotamia region is the area between rivers. The name Mesopotamia is a historical name that comes from the Greek. The name, in Iraq case, is pointing the land between the Tigris River and the Euphrates River. It is expected that this region have many groundwater resources that get their water from the rivers.

Figure 3.4: The Seven Hydrogeological Regions in Iraq.
Source: https://water.fanack.com/ar/iraq/water-uses-in-iraq.

The availability of groundwater is strongly related to the availability of surface water. Therefore, when changes level of rivers water change, the amount of available groundwater will be changed.

The low and the high folded zone are located in the north part of Iraq. These zones have mostly mountains. The rocks reflect most of the lands in these zones. The surface of these zones has complicated water drainage system. They drain water towards the main streams and rivers such as the Tigris River, Greater Zab, and the Lower Zab rivers.

Al-jazera zone is mostly located in the Anbar province. The Euphrates River is passing this area, so it is expected to have groundwater close to the river (Varoujan et al. 2014).

The western desert zone and the southern desert zone are all dry areas in Iraq. They are located mostly in Anbar, Samoa, and Najaf provinces. Some groundwater sources are founded in these areas, but their water is very limited.

3.1.3 Other water sources

Iraq has two other freshwater resources, which are not natural resources. The first one is the water coming from water desalination process. Even this type of water sources still very limited, the Iraqi government has a plan to establish a desalination plant in southern Iraq because the water over there has high level of salt. This project is under processing, and it is expected to supply freshwater to 400,000 people in Basra province (Khalifa 2011).

The second non-natural source of water is the water coming from sewage water treatment. The technology of sewage water treatment in Iraq is still old and not enough to treat all sewage water. Therefore, most of the sewage water drained into rivers, while a portion is collected and recycled. The main use of the treated water is to re-inject oil fields with water, create green environment, and to increase the available water in southern Iraq (Al- Ghazali & Al- azawi 1986).

Based on all the types of Iraqi water resources that discussed, people may think that Iraq does not suffer from any water supply problems. However, in the past 50 years, the situation has changed. Many factors that affect the water resources have changed, and most of them have had negative impacts on water supply.

These factors are (Procházka 2018):

- Wars, which in some cases, led to drain all the water from some rivers and marshes.
- No or bad water resources managements and plans.

- Many political problems with the neighbor countries, which have affected the water supplies in Iraq.
- Great climate change, which makes the consumption of water very high, and very hard to save water.

To understand the water management system in Iraq, there is a need to review the uses of water in Iraq (water demand), which will be in the next section.

3.2 The Uses of Water in Iraq (Water Demand)

In general, Iraq is one of the countries that known in agriculture production. The agriculture in Iraq represents one of the main economic activities. Therefore, the big part of water consumption in Iraq is used for agriculture. Water is also used for industry, livestock and fish farms. Figure 3.3 shows the distribution of water usage in Iraq.

3.2.1 Water use in agriculture

The agriculture system in Iraq still uses the traditional ways of irrigation. In other words, farms in Iraq still have limited use of technology, which leads to more water consumption.

As shown in figure 3.5, the agricultural sector consumes about 70% of the water resources in Iraq, in 2008, which is very big amount. Figure 3.5 also shows that the consumption of water in industrial sector (including factories and power generation) was about 10%. In addition, about 17% of freshwater is going to the marshes and to Persian Gulf (Al fahad & Razaq 2004).

These statistics indicate some problems in water managements in Iraq such as limited use of irrigation technology and limited water saving.

The agriculture in Iraq has very long history, but it became as formal economic activity in the beginning of the last century. When Iraq was a colony of the Great Brittan, the agriculture lands in Iraq were distributed to some people. The UK government gave those people the power to become the official owner and managers of these lands. At that time, the agriculture was the only economic activity in Iraq (Jaradat 2003).

This situation ends in the 1960s, when the new independent Iraqi government destroyed the old system, and lands were re-distributed. Even this process reduced the agriculture production, the government kept its reform system. In the 1970s, many industrial factories were built as part of the government reform.

These factories are mostly uses agriculture raw materials. For example, the textile factories, and the food Industry were almost everywhere in Iraq.

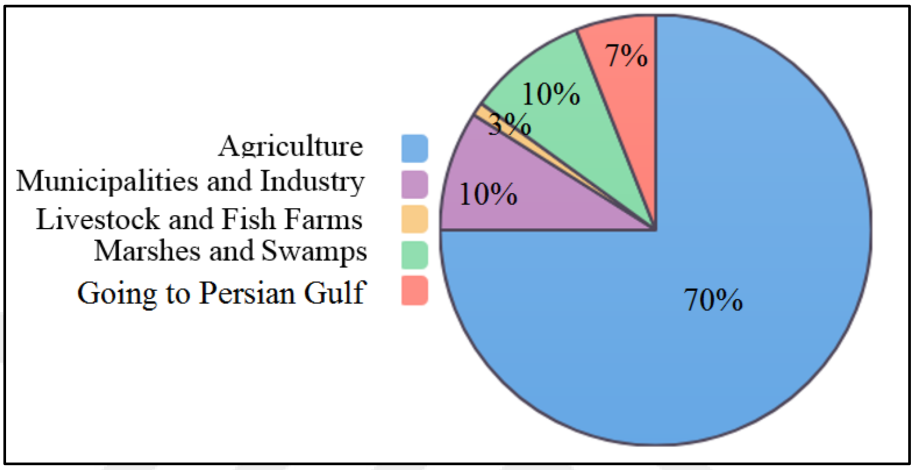

Figure 3.5: The Distribution of Water Usage in Iraq.
Source: https://water.fanack.com/ar/iraq/water-uses-in-iraq.

As a result, the demand for agricultural products has rapidly increased. In addition, more demand for agricultural products was because of the population growth, migration, and changes in food patterns. Therefore, the traditional ways of agriculture production has changed. Policy makers started thinking about using the new technological in the agricultural production (Al fahad & Razaq 2004).

The official plans to change the way of agricultural production in Iraq faced many difficulties over time.

For example, the wars, shortage in financial resources, climate changes, and many other economic problems. Therefore, the agricultural production is still using traditional ways, which by the end increases the waste of freshwater.

The area that can be suitable for agriculture in Iraq is estimated to be about 12.9 million hectares, which represents about 28% of the total Iraqi lands. About 8.12 million hectares of this land use irrigated system in agriculture. This area is located in the middle and southern of Iraq. About 4.6 million hectares depends on the rain in agriculture. This area is located in the north part of Iraq (Al-Ansari et al 2021).

The main water sources that provide water to these lands are the Tigris River, the Euphrates River. Even the groundwater and rainfall are other water sources, but they irrigate only small portion of total agriculture lands.

That fact that most of the water of the Tigris River and the Euphrates River comes from outside of Iraq can arise some difficulties. That is, water supply to these rivers is expected to be negatively affected by the politic and economic plans of various countries. That can lead to water security in the next years.

In Iraq, the Ministry of Agriculture is the only institution that is responsible for development the agricultural. They have guiding farmers and teaching them how to use the application of the best agricultural methods and techniques. This educational program in agricultural supposed to support the plans of water management. However, most farmers in Iraq are still far away from using the new technologies in irrigation. That is because new technologies are expensive and hard to use (Schnepf 2004).

Some strict regulations were applied on farmers to enforce them to change their irrigation methods. For example, the government specified a monetary fine on each farmer who consumes water more than his/her share.

However, these regulations did not work. That is, when the farmers face these regulations, they stop working in agriculture and start searching for another job. That has created many problems such as the shortage in food supply and increase the unemployment rate.

Therefore, the Iraqi government should reconsider many agricultural policies that can make balance between the agricultural sector development and the water resources managements.

3.2.2 Water use in industry

The industrial in Iraq started in the late 1960s. Most of the factories do not use water as part of their products. In addition, Iraq has only little number of small power generators that use water. Therefore, the use of water in Iraq was not big to scare water policy maker. After the war of 1990 with the USA, most of the factories, which are almost all of them owned by government, increased their production.

That is because Iraq was put under the international punishment program, and they tried to cover the market needs of different products. This led to increase the water use in industry (Abd-El-Mooty et al. 2016).

After 2003, Iraqi government has adopted many reform programs that focus more on private sector. These programs negatively affect the public sector, which have most of big companies. As a result, the use of water for industry in Iraq has reduced. In general, the use of water in Iraq does not consider as a serious problem. Table 3.3 shows the water use in industry in Iraq from 1979 to 2000.

Table 3.3: The Water Use for Industry in Iraq from 1979 to 2000

Year	Industrial water withdrawal (Million m^3/year)	Industrial water withdrawal as % of total water withdrawal
1975	450	1.11
1980	310	0.76
1985	170	0.41
1990	2140	5
1995	5920	10.88
2000	9700	14.7
2015	5930	9

Source: (Abd-El-Mooty et al. 2016).

3.2.3Water use for drinking

This type of water use is strongly related to the population growth. The population of Iraq was about 14 million in the 1980s. In 2010, the population of Iraq was estimated to be about 31 million. The estimated line indicated that the expected population would reach 71 million in 2050 if no changes happened. This rate of population growth is considered very high and can led to high consumption of water (Abd-El-Mooty et al. 2016).

Table 3.4 show the expected population growth in Iraq and the change in stake of water of person per year. Table 3.4 shows that the individual water share per year will be decreased over time as a respond to the high population growth in Iraq.

For example, the individual water share per year is expected to be reduced from 1829 m^3 in 2015 to 336 m^3 in 2100.

In other words, in the year of 2100, the Iraqi individual will get about 18% of what he/she was consumed of water in 2015. Therefore, Iraqi authority must take actions to eliminate this problem. One of the possible solutions is to adopt good water management strategies.

Table 3.4: The Expected Population Growth and Individual Water Share per Year.

Year	Population Growth (%)	The individual water share per year (m^3)
2015	2.89	1829
2025	2.4	1475
2035	1.92	1237
2045	1.6	1067
2065	1.45	932
2075	1.95	780
2085	2.45	626
2095	2.95	484
2100	3.2	336

Source: (Abd-El-Mooty et al. 2016).

3.3 The Water Problem in Iraq (Water Scarcity)

As mentioned in the previous sections of this chapter, the water shortage or water scarcity in Iraq is expected because of the below reasons:

1. High population growth rate.
2. Big climate change (high temperature for long time).
3. The pollution of some water sources.
4. The water resources policies of neighbor countries that supply water to Iraq.
5. Limited water resources managements in Iraq.

The problem of water scarcity is usually happened in dry areas. The climate change resulting from global warming has increased this problem.

Since Iraq is one of the countries that are located in dry areas, it is more likely to have the water scarcity problem.

In fact, in the recent years, many signs of the water scarcity problem in Iraq were identified. For example, the lack of water supply due to the behavior of neighboring countries. In addition, there are very old and limited water management strategies were used in Iraq. Therefore, Iraqi authority must respond seriously and immediately to these challenges to obtain sustainable water availability (Rijsberman 2006).

4. THE WATER RESOURCES MANAGEMENT IN IRAQ

This chapter has two parts. The first part reviews the water resources management, and the role of Mosul dam in managing water resources in Iraq. The second part is the empirical work that tests the impact of Mosul dam on WRM in Iraq.

4.1 The Water Resources Management in Iraq

Iraq is one of the countries that are located in a region that face water scarcity problem. That is because; these countries do not have good WRM systems and strategies. Despite the many advanced innovations and technologies in the field of WRM, Iraq and some other countries in this still do not use them (Sulaiman et al. 2019).

Iraq still uses only traditional techniques such as artificial lakes and dams to manage it water resources. As discussed in the previous chapters, the Tigris River and the Euphrates River are the main water resources in Iraq. Most of the WRM applications and tools are related to these rivers. That is, most of water storages in Iraq get their water from these rivers. In addition, most of the important dams in Iraq, including Mosul Dam, are placed on these rivers.

Iraq was considered as one of the rich countries in water resources until the seventies of the last current. At that time, Syria and Turkey began building dams on Tigris River and the Euphrates River. That has caused a significant decrease in the drainage of rivers coming into Iraq. This situation has led Iraqi governments to pay more attention to WRM system and strategies (Sissakian et al. 2018).

Iraq has many regions that are differ in their climatic conditions and geographical terrain. That makes many differences in the availability and diversity of water resources and their quality. Therefore, plans to manage water resources and strategies to manage water supply and demand needs more analyzing (Abbas et al 2018).

Iraq can be divided into three distinct regions. The first region is the northern and northeastern part of Iraq. This region has much mountainous terrain, and it has high rainfall rate with about 1400 mm per year. It also has groundwater resources that have good water quality. These groundwater resources are renewable and suitable for various uses. This region has moderate temperatures relative to the rest parts of Iraq.

The second region is the western region. This region of Iraq is distinguished by its hot and dry desert climate. The average rainfall is between (50-150) mm per year. Its geographical terrain mostly has wave to flat shapes. It has salty groundwater resources, and there is no surface water sources.

The third region is the central region. This region is located between and around the Tigris River and Euphrates River and the southern region. This region is characterized by its flat land. Its climate is less hot than the western region and warmer than the northern region. The Tigris and Euphrates rivers represent its surface waters, and it has salty groundwater resources.

Most of the agricultural projects and cultivated lands that are needs irrigation are located in the central region, which is located between the Tigris and the Euphrates. In addition, some of agricultural areas and agricultural projects that depend on irrigation methods and rain are located in the northern region. Irrigated agriculture consumes more than (80%) of the total water resources of the Tigris and Euphrates and their tributaries.

Most of the industrial projects, especially the oil ones need large quantities of water to extract oil and other operations. Most of the oil fields are located in southern Iraq, with some fields in the northern region (Jaradat 2003).

Most of the population in Iraq resides in the cities located on the Tigris and Euphrates rivers and their tributaries or near them. They represent about 90% of the total population, which put more pressure on water resources (Al-Ansari 2015).

Based on the above information, the strategies of managing supply and demand of Iraqi water resources should take into account the differences between the regions of Iraq.

From this point, it is necessary to identify the existing WRM techniques and tools that Iraqi government has used to face the water scarcity problem.

In addition, it is necessary to evaluate the roles of these techniques and tools of WRM in Iraq. The good evaluation of the roles of these techniques and tools can lead to more improvements and adjustment in the WRM system. As a result, the improvements and adjustment in the WRM system is expected to overcome the problem of water scarcity in Iraq.

4.1.1 The WRM techniques and tools in Iraqi

In general, there are several techniques and tools that Iraq use them in its WRM system. The goal of using these techniques is to collect the water that is coming from different sources and save it for future use. Iraq uses three main existing techniques in its WRM system. These techniques are the following (Abdullah et al. 2019):

1. Water harvesting:

This technique has two types as follow:

a. Rain water harvesting

It is very basic technique of collecting water, usually used to collect or direct water to specific storages. For example, in the rainfall season, the water from rain is collected and directed to the specific storages to be used in the dry season.

There are many ways of water harvesting. The first example of the rainwater harvesting is called the micro catchments. This method has several characteristics. The harvested water is coming from the overland flow. The catchment length is about 1 and 30 meter. The water is stored in soil profile, and there is no possibility of overflow. Examples of rainwater harvesting are contour bunds, contour ridges, and semi-circular bunds.

The second example of rainwater harvesting is called the external catchment systems. This method has several characteristics. It depends on the overland flow harvested. The water is stored in soil profile using catchment with about 30 - 200 meters length.

b. The floodwater harvesting

This type depends on the flooded water that flow in turbulent channel. The water harvested diversion spreading within the valley floor. The water stored in soil profile with catchment length reached some kilometers.

In Iraq, rainwater harvesting is used especially in the north part, but it is very limited.

The floodwater harvesting is mostly used in the middle and south part especially in the flood season. Flooded water is directed to the natural catchments or to the rivers. This way still needs more improvement in the channels that direct water to its final basins.

Figure 4.1 shows an example of water harvesting system. Figure 4.2 shows an example of the floodwater harvesting system.

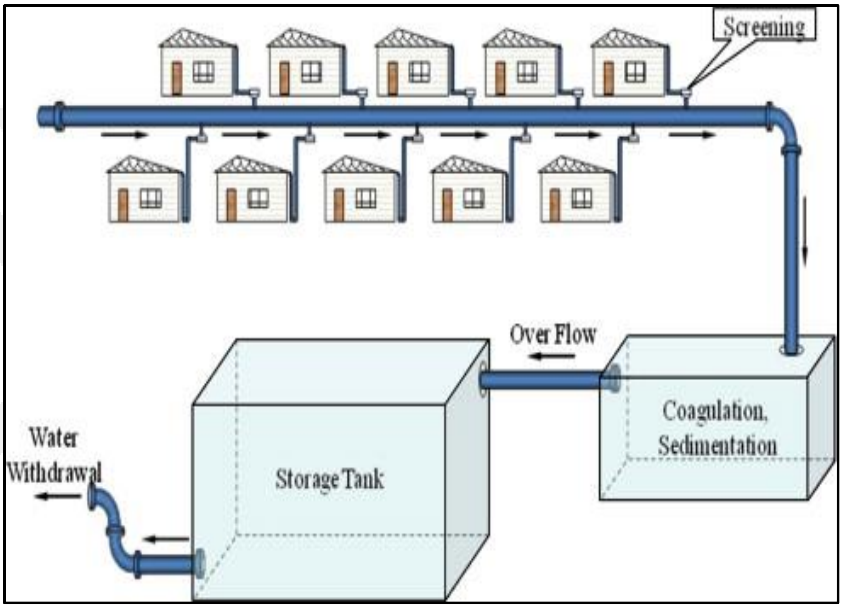

Figure 4.1: The Water Harvesting System
Source: https://www.toppr.com

2. Small and big Basins

Basins are a natural or artificial slip in the land surface. The most known types of basins are the river drainage basins. The river drainage basin is a depression area that filled with water drained by a river or its tributaries. Figure 4.2 shows an example of water basin.

Iraq has many small and big natural and artificial basins. The Tigris River and Euphrates River and their tributaries are the main Iraqi water basins. These basins are important part of the Iraqi WRM since they are used as water storages. These basins provide an important amount of water that used for irrigation, industry, and other uses in different locations of Iraq.

Figure 4.2: The Floodwater Harvesting System
Source: http://www.jkuat.ac.ke.

3. Lakes and Marshes

The natural and artificial lakes and the marshes are considered as important part of Iraqi WRM. The details about these lakes and marshes discussed in chapter two of this study.

They are mainly used to store the extra water in the flood season to be used in the dry season. Even these water storages can play significant roles in WRM, Iraq have not built new ones since the 1970s. That is because of the wars, bad strategies, and many other factors. The shortage in water storages has led to negative impact on the water supply in Iraq.

4. Dams

The dams in Iraq are the most common tools of WRM. Even the dams in Iraq are old and there is no new dams added, they still play the main role in Iraqi WRM. The hydrological situation in Iraq is characterized by the fluctuation in seasonal and annual revenues of water. That can negatively affects the agricultural plans especially in summer season when the water is in its lowest level. Therefore, the dams can be used to cover the shortage in water supply.

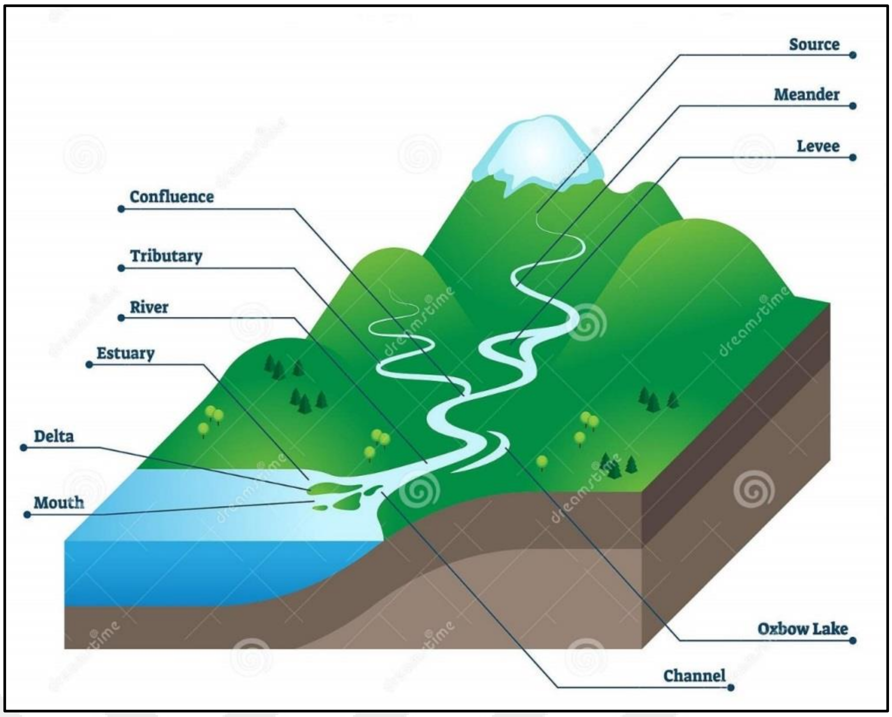

Figure 4.3: Example of Water Basin (River System)
Source: https://www.dreamstime.com/river-systems

4.1.2 The dams system in Iraq

In general, the dams system in Iraq is used to achieve the following goals (Abdullah et al. 2019):

a- Irrigation

The main objective of establishing Iraqi dams is to secure and regulate the water needed for irrigation. The dams system is working based on central operating policy to meet the water needs throughout the year for all sectors in Iraq. The policy focuses more on the agricultural sector, which consumes about 85% of the available water.

The dams system in Iraq is also used to store water when the rain season is good, and use that water in the bad seasons. In general, the dams system in Iraq is used to increase the degree of control over water resources.

b- Electric power generation

Another use of dams system in Iraq is to generate power. The energy generated by dams is considered clean electrical energy that does not cause pollution to the environment. Only two or three dams in Iraq are used to generate power, which is still very limited.

c- Fish wealth production

Dam lakes are considered suitable areas for fish production. Many project of fish farming have established on dams' lakes to produce fish for local consumption.

d- Tourism development

Dam lakes are very suitable areas for the development of tourism in Iraq. They provide attractive and comfortable sites for residents and citizens.

e- Water quality

Iraqi dam system contributes to improving water quality by storing good water quality in the rainy season. Then, it releases that good quality water from the dam reservoir in following seasons. The new incoming water mixes with the water of the lake which in less quality. The new water mix can improve the quality of the lakes' water.

f- Flood control

In the past three decades, the issue of flood control was considered the first goal of building dams in Iraq. That is because flood water from the main rivers in Iraq was very dangerous and cause many damages.

However, after increasing in the number of dams implemented in the countries of the upper Tigris and Euphrates, the possibility of flooding began to decrease in Iraq.

The reduction in the probability of flooding does not mean it will not happen. It is hard to predict that the flood cycle will not return. If the floods do occur, their impact will be very dangerous. Therefore, the dams system is now working as a safety tools that can face any flood.

g- Improving the environment and other benefits

Dams also contribute to improving environmental conditions and climate in the areas surrounding their lakes. In addition, they can improve the living conditions of the people through providing job opportunities in these projects.

Iraq has many dams that are placed on both the Tigris and Euphrates rivers. Some of these dams are very important for Iraqi WRM, such as Mosul Dam, while the others have limited roles.

This study aims to test the impact of Mosul Dam on the WRM in Iraq. Therefore, it is important to provide information about the dams system in Iraq with more focus on the Mosul Dam.

That can help better understand the role of these dams in WRM. Table 4.1 shows the dams that are placed on Tigris and Euphrates rivers.

Table 4.1: The Important Dams on the Tigris and Euphrates Rivers

Dam	River Basin	Reservoir Capacity (km^3)	Year of Construction	Type of the dam	Dam's Height (M)
Al-Mosul	Tigris	11.11	1986	Earth fill dam	113
Dokan	Tigris	6.8	1959	Cylindrical arch	116.5
Darbandikhan	Tigris	2.8	1961	Rock-fill embankment	128
Hemrin	Tigris	2.4	1981	Hydro power plant	53
Dohuk	Tigris	0.48	1988	Earth-fill embankment	60
Al-Udhaim	Tigris	1.5	1999	Earth-fill embankment	76.5
Haditha	Euphrates	8.2	1987	Earth-fill embankment	57
Kufa	Euphrates	4.2	1988	Concrete	100

Source: (Abdullah et al. 2019)

The Mosul Dam is located about 50 km north of the Mosul city, northern Iraq. The dam is the largest dam in Iraq. The dam is placed on the Tigris River.

The dam started working in 1986. The reservoir of the dam is 3.2 km in long and the body of the dam has 131meters height (Adamo & Al-Ansari 2016).

The first plan to build the Mosul Dam was in 1950s, and the location was determined in 1953. In 1956, the Iraqi government started the process of building the dam. Many specialist companies were involved in the process of building the dam. However, The Swiss consortium of Consultants became the official consultants for the construction of the dam.

The construction work on the dam began in 1981 and completed in 1984. In the spring of 1985, the Mosul Dam began working. The dam is flooding the Tigris River area, filling the reservoir that flooded many of the archaeological sites in the area. The power plant began generating power in 1986.

Because of the important structural stability issues associated with the Mosul Dam, the process of filling, restoration, and additional repairs must continue.

In other words, the dam was built on soils of a non-tolerant nature, so the concrete had to be injected periodically to ensure that it did not collapse. This process began in the mid-eighties.

After the war of 2003, the dam was threatened of collapse because of the failure to reinforce its concrete. If it collapsed, about 100 m high flood will happen and inundate the city of Mosul and the cities of the Tigris Valley. That may put about ten million residents under high dangerous.

In order to avoid the collapse of the dam, several solutions were suggested. For example, cutting off the water from the Turkish side and then changing the course of the Tigris River by digging a canal to the Tal Afar desert. The other example is leading water to desert valleys to drain the water of the dam lake into the desert, and then demolishing the dam. However, until now there is no series solution to the dam problem. Therefore, this study aims to test whether this dam can do its job in Iraqi WRM.

4.2 The Empirical Work

This section presents the empirical work of this study including the methodology, the data, the model and variables, and the results.

4.2.1 Methodology

This study tests the impact of Mosul dam on the Iraqi water supply. More specifically, it test whether the changes in the water stored at the dam has significant impact on water supply.

The study estimates the effects of factors that can affect water supply including Mosul dam, water consumption, climate, and stored water (Valipour 2013). The study uses the regression method as a statistical estimation tool. The study uses R programming to do the estimation.

The regression method is statistical method to modeling the relationship between two or more variables. One of them is the response variables (dependent variable). The other variables are the explanatory variables (independent variables). If the regression has one explanatory variable, it is called simple regression. If the regression has more than one explanatory variable, it is called multiple regression (Barten 1968).

4.2.2 The model and the variables

The model used in this study is the linear regression model (LRM). In this model, the relationships between variables are modeled using linear predictor functions whose unknown model parameters are estimated from the data. The LRM is used here because its unknown parameters are easier to fit than non-linearly models. In addition, using this model can help easily determine the statistical properties of the resulting estimators.

The goal of using LRM is for prediction, forecasting, and error reduction. In addition, it can be used to fit a predictive model to an observed data set of the response and explanatory variables (Barten 1968).

Equation (1) shows the elements of the LRM that is used in this study.

$$Y=\beta i + \alpha i\ Xi + \gamma i\ Zi + \epsilon i \qquad (1)$$

Where, the variable (Y) is the variable that represents the water supply (dependent variable). The water supply measure in this case is the amount of available water from different resources including the stored water.

The variable (X) represents one of the independent variables. The variable (X) in this case is the water level in Mosul dam. The water level represents the average change in the level of water before the Mosul dam. The water level is used because it is linearly changed, and its movement reflects the discharge of water from the dam.

The variable (Z) is the set of other factors, or independent variables, such as (water consumption, climate change, and stored water). The water consumption (Z1) is measured by the average change in the water level of rivers' basins. The climate change (Z2) or the evaporation is measured by the average whether temperatures. Finally, the stored water (Z3) is measured by the average change in the water level of water storages. The (β, α, and ɣ) represent the model parameters that will be estimated when running the regression. The (ϵi) represents the error.

It is important to indicate that the water level used in this case is measured from the top surface towards the bottom of the basins. That is if the basin is filled, the water level is at zero point. However, if the water was reduced one meter below, the water level is at one-meter point. The water level in this case is the linear reduction of water in the basins (Ranković et al 2014).

4.2.3 The data

All the data were taken from the ministry of water resources in Iraq. This study uses weekly time series data for two periods. The first period is from 2000-2014. The second period is from 2018-2020. The data is collected from the month May to the month September of each year. That is, the data is coming only from five months of each year, which by the end be 320 observation.

The reason of selecting these months is that these months represent the summer season in Iraq when the temperature is in its maximum value. In these months, there is no rain or snow, so there is no new water added to the water supply system.

The water demand in these months is in its maximum range. Finally, the stored water is used during these months to cover the increased demand.

Since this study aims to analyze the role of Mosul dam in WRM after it had some damages, the data started from 2000. That is because the damages in Mosul dam started in 1999. Therefore, it is expected that the role of Mosul Dam in WRM have changed. The data has four years missing because of the war against ISIS which started 2014 to 2018. Most of the data is in average form. Example of dataset is in appendix A. Table 4.2 shows the descriptive statistics of the data.

The data set was organized using Excel sheet, so that each variable was put in one column. Using R programing codes, the data was imported and defined to the software as the model's variables. Then, the software runs the model using these variables. Finally, the software provided the regression results. The R programing codes are shown in the appendix B.

Table 4.2: The Descriptive Statistics of the Data

Variable description	Water supply (billion Cubic meter)	Average weekly water level before the Mosul dam (meter)	Water consumption, the average weekly level of rivers' basins (meter)	Evaporation, Average weekly temperature (Celsius degree)	The average weekly level of stored water (meter)
Variable symbol	Y	X	Z1	Z2	Z3
Max value	55	10	15	50	7
Min value	15	1	2	20	1
Mean	37	4	8	35	3
Total Observations	320	320	320	320	320

4.2.4 The study results

The results of this study are shown in table 4.3, and table 4.4. Table 4.3 shows the results of the regression model. More specifically, it shows the estimated parameters of the liner regression model. In addition, it shows whether these estimated parameters are significant or not. In other words, the results indicate the magnitude (parameter value), and the direction of the relation between the dependent and the independent variables. In addition, they indicate the significant of the impact of independent variables on the dependent variables.

Table 4.3: The Results of Regression Model

Variable	Estimated parameter	P value
Intercept	47.87***	2e-16
X	-0.62**	0.00754
Z1	-0.19	0.22062
Z2	0.05	0.35800
Z3	-2.75***	0.00044

Significant code: 1% ***, 5% **, 10% *

Table 4.4 shows the correlation coefficients between variables. The value and sign of these coefficients indicate how strong the relation between variables in the model is. If the value of these coefficients were close to (1), it means that the two variables are highly correlated.

Table 4.4: The Pearson Correlation Coefficients

	y	x	z1	z2	z3
y	1.000	-0.246**	-0.249**	0.037	-0.486**
x		1.000	0.112*	0.038	0.246**
z1			1.000	-0.041	0.391**
z2				1.000	0.012
z3					1.000

Significant code: 1% ***, 5% **, 10% *

4.2.5 The results discussion

The results of this study indicate that the Mosul Dam still has significant impact on water supply system in Iraq. The value and sign of the variable X's coefficient, which is -0.62 show that. In other words, when the reduction in water level at the Mosul Dam increases by one unit, the water supply reduces by 0.62. This result indicate that Mosul Dam has significant impact on WRM in Iraq. In other words, the dam still plays a significant role in the WRM system.

The results show that water consumption has negative relationship with water supply, which is expected. The value and sign of the variable Z1's coefficient is -0.19, and it is not significant.

That is, when the water consumption increases by one unit, the water supply decreases by 0.19. However, the impact of water consumption on water supply is not significant.

The results show the positive relation between temperature (climate effect) and water supply, which is not expected. The value and sign of the variable Z2's coefficient is -0.05, and it is not significant. That is, when the weather temperature increases by one unit, the water supply increases by 0.05. One possible explanation to this issue is that when temperature increases, the stored water is used, which increases the water supply. However, the impact of temperature on water supply is not significant.

The results show that stored water has negative relationship with water supply, which is expected. The value and sign of the variable Z3's coefficient is -2.75, and it is significant. In other words, when the water level at the water storages reduces by one unit, the water supply reduces by 2.57. This result indicates that water storages in Iraq are very important in the WRM system.

Table 4.4 confirms the results of liner regression model. Table 4.4 indicates that The Pearson correlation coefficients (PCC) between water supply (Y) and water level at Mosul dam (X) is -0.246, and it is statistically significant at 5% confidant level. The table also shows that water supply (Y) is correlated to all other variables water consumption (Z1), temperature (Z2), and storage water (Z3). Table 4.4 indicates that highest correlation is between water supply (Y) and storage water (Z3), which is -0.486.

In general, the results of this study are in line with the theory. The results confirm the importance of Mosul Dam and the water storages in the WRM in Iraq. Based on these results, Iraqi policy maker should take action to fix any problem in the Mosul Dam and adopt strategic plan to build more water storages in Iraq.

5. CONCLUSION

As a response to the rapid increase use of freshwater, more attention has paid on managing water resources. It is well known that water is used for many daily activities such as drinking, cleaning, agriculture, manufacturing, and others. Therefore, water resource management has become crucial for life and economic survival.

Managing the water resources usually faces many difficulties because water is moving and passing different countries boarders. As a result, the politics, or international dimension is included.

Recently, the WRM has become more complex, and it has many connections with other development related issues. It is not only managed by water specialists, but by socialist, economists, environmental specialists, and political leaders. The future of WRM is expected to be more complex. It is expected that it will be strongly linked to agriculture, energy, industry, transportation and communication. In addition, it will be linked to the environment, health, and regional development.

This study was constructed based on three problems. The crucial problem is that most countries around the world, including Iraq, suffer from is the lack in the water resources. The lack in water resources is a result of the increase in using water, which happened due to the rapid increase in population. In addition, it happened due to the increase in economic activities such as manufacturing and agriculture. That has led to focus more on WRM.

Iraq has two main water sources which are the Tigris and Euphrates Rivers. The discharges of these rivers have decreased since 1970s for several internal and external reasons. In addition, the climate change has negative and significant impact on the quantity of water of these rivers.

From the other side, the population in Iraq increased in the last two decades, which reaches to around 40 million. This growing in population puts more pressure on water resources. Therefore, WRM in Iraq have become more important to keep things going well.

The third problem is related to Mosul Dam. Mosul Dam is one of the important parts of the water resources management system in Iraq. However, this Dam has damaged because of shortage of maintenance and other factors. Therefore, it is important to evaluate the performance of this Dam as part of WRM. In other words, it is important to investigate whether or not this Dam still able to store and manage water as required.

The purpose of the study is to investigate the performance of Mosul Dam in Mosul, Iraq. The study tests whether this Dam can play a significant role in managing water resources in Iraq. The importance of the study is to present statistical results about one of important parts of Iraqi WRM system (Mosul Dam). The results can be used to make decisions regarding to developing this system.

The results of this study show that Mosul Dam still has significant impact on water supply system in Iraq. This result indicates that Mosul Dam has significant impact on WRM in Iraq. In other words, the dam still plays a significant role in the WRM system.

The results show that water consumption has negative relationship with water supply, which is expected. However, the impact of water consumption on water supply is not significant.

The results show that temperature (climate effect) has positive relationship with water supply, which is not expected. That is, when the weather temperature increases, the water supply increases. The results show that stored water has negative relationship with water supply, which is expected. This result indicates that water storages in Iraq are very important in the WRM system.

In general, the results of this study are in line with the theory. The results confirm the importance of Mosul Dam and the water storages in the WRM in Iraq. Based on these results, Iraqi policy maker should take action to fix any problem in the Mosul Dam and adopt strategic plan to build more water storages in Iraq.

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APPENDICES

Appendix A: Data Set

Table A.1: Example of Data Set

Water supply in Tigris River (billion Cubic meter)	**Water level before the Mosul dam (meter)**	**Total water consumption from Tigris River, the level of Tigris river basin (meter)**	**Evaporation, temperature (Celsius degree)**	**The level of stored water (meter)**
y	x	z1	z2	z3
33	2	5	38	1
46	4	9	38	3
33	4	3	45	3
41	5	9	34	1
34	1	8	46	4
54	3	5	43	1
43	6	7	48	1
44	1	7	24	4
41	6	5	42	4
33	1	2	33	2
35	5	4	27	2
40	3	4	26	2
51	2	4	25	1
30	3	5	25	4
31	3	2	47	3
46	6	5	35	1

Appendix B: The Regression Programing Codes

Table B.1: The R Programing Codes and Their Functions

The R Code	The Action
> data <- read.delim ("C:/Users/ /Desktop/Ismail/Data/data.txt")	Reading the data file
> View(data)	Checking the data
> attach (data)	Preparing the data for use
> regression <- lm (Y ~ X+Z1+Z2+Z3)	Running Linear Regression Model Y is the dependent variable X, Z1, Z2, and Z3 are the independent variables
> summary (regression)	View the results of the regression

RESUME

EDUCATION:

- BA in civil engineer from Mosul University at Civil Department 1987-1992
- Multiple courses in planning
- Multiple courses in concrete-reinforcement works
- Multiple courses in computer programs
- Languages: English-Arabic-Turkish

PROFESSIONAL EXPERIENCE AND REWARDS:

- Al-Rafidain Company for Dams Construction/Management of Nineveh Projects
- From March 1993-2019
- 2019 Planning Department Officer in Adit Joint Repair Project of Mosul Dam
- 2019-2017 Planning Department Officer in Dentates Project of Mosul Dam
- 2016-2017 Planning Department Officer in Mosul Projects
- 2012-2014 Deputy Director of Al-Entasar Sewerage Project in Ninawa
- 2011-2012 Site Engineer Manager of buildings in Ninewa Governorate Building
- Project
- 2007-2011 Manager of the 1st & 2nd pumping stations of the Mosul Water Project
- 2006-2007 Site Engineer in the residential project of Sinjar Hospital
- 2005-2006 Site Engineer in Telafar Hospital building
- 2003-2004 Site engineer manager in pumping station project in Nasiriyah
- 2002-2003 Site engineer manager in East Gharraf project in Nasiriyah
- 2000-2002 Site engineer manager in Alebayed Dam project in Alramade
- 1999-2000 Concrete plant manager in Badosh Dam
- 1998-1999 Site Engineer at Al-Azim Dam
- 1996-1998 Planning Department Officer in Algates Dam Project
- 1995-1996 Planning Department engineer in Dewaniya Irrigation Office
- 1993-1994 Site engineer in Bodoah Dam
- 1992-1993 Site enginner in Nenawa Pharmaceutical Building Project