HASAN KALYONCU UNIVERSITY
GRADUATE SCHOOL OF
NATURAL & APPLIED SCIENCES

WATER EVALUATION AND PLANNING SYSTEM FOR GREATER ZAB RIVER BASIN

Ph.D. THESIS
IN
CIVIL ENGINEERING

BY
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Water Evaluation and Planning System for Greater Zab River Basin

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Civil Engineering Department

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Supervisor

Prof. Dr. Mehmet KARPUZCU

By

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ABSTRACT

WATER EVALUATION AND PLANNING SYSTEM FOR GREATER ZAB RIVER BASIN

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Ph.D. in Civil Engineering

Supervisor: Prof. Dr. Mehmet KARPUZCU

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The aim of the thesis is to examine the planning and evaluation of the water resources of the Greater Zab River Basin (GZRB) in North Iraq. In this study, it is aimed to develop a business strategy for the GZRB, and to determine the factors affecting the application. The interactions of water users competing in the basin have also been identified and some action plans and strategies for the solution have been addressed.

The thesis also sheds light on top management issues addressing the obstacles to the implementation of Integrated Water Resources Management (IWRM) policies and includes complementary strategies.

At the same time in this study, it was determined that the existing regulations and practices regarding water usage patterns and water pollution are not sufficient. For this reason, the WEAP model was applied to the basin to determine the optimum GZR planning system and the optimum operating policy of the plan. The main issue of this planning is how the GZR system will meet future water needs. For this reason, the optimal monthly water distribution policies were simulated with the WEAP model using the past 33 years' debts and the performance of the GZRB was re-evaluated. Optimum simulation diagram for different scenarios such as domestic, irrigation water and ecological water needs have been established and implemented. This study was compared with the official figures in the planning works made in the 1980s. As a result of these comparisons, the average annual water supply was 368.1 MCM in August 2032. Accordingly, it is suggested that the construction of Bekhme Dam should be

completed as it is understood that the water requirement cannot be met in the current conditions.

Keywords: Great Zab River, water resource, dynamic programming, WEAP, model, irrigation, domestic, ecological water needs.

ÖZET

BÜYÜK ZAB NEHRİ HAVZASI İÇİN SU DEĞERLENDİRME VE PLANLAMA SİSTEMİ

KHOSHNAW, Ali Rashid Ahmed

Doktora, İnşaat Mühendisliği Bölümü

Danışman: Prof. Dr. Mehmet KARPUZCU

January 2018, 186 sayfa

Tezin amacı Kuzey Iraktaki büyük Zab Nehir havzası su kaynaklarının değerlendirilmesi ve planlamasının incelenmesidir. Bu çalışmada büyük Zab havzası için bir işletme stratejisi geliştirmek, uygulamaya tesir eden etkenlerin belirlenmesi de amaçlanmıştır. Havzada rekabet halinde olan su kullanıcılarının birbirine etkileri de belirlenmiş ve çözüm için bazı eylem planları ve stratejileri ele alınmıştır.

Tez aynı zamanda IWRM politikalarının tatbikini engelleyen etkileri ele alan üst yönetim konularına da ışık tutmakta ve tamamlayıcı stratejileri kapsamaktadır.

Bu çalışmada aynı zamanda su kullanım şekilleri ve suyun kirletilmesi ile ilgili mevcut yönetmeliklerin ve uygulamaların yeterli olmadığı tespit edilmiştir. Bu nedenle büyük Zab nehir planlama sisteminin ve planın optimum işletme politikasının belirlenmesi için WEAP modeli havzaya yönelik olarak uygulanmıştır. Bu planlamanın ana meselesi GZR sisteminin gelecekte artacak olan su ihtiyaçlarının nasıl karşılanacağı ele alınmıştır. Bu nedenle geçmişteki 33 yıllık debiler kullanılarak WEAP modeli ile optimum aylık su dağıtım politikaları simule edilmiş ve GZRB'nin performansı yeniden değerlendirilmiştir. Evsel, sulama suyu, ekolojik su ihtiyaçları farklı senaryolar için optimum simulasyon şeması oluşturulmuş ve uygulanmıştır. Bu çalışmada 1980'li yıllarda yapılmış olan planlama çalışmalarındaki resmi rakamlarla karşılaştırmalar yapılmıştır. Bu karşılaştırmalar sonucunda 2032 Ağustos ayında yıllık ortalama su arzının 368.1 MCM olduğu görülmüştür. Buna göre mevcut şartlarda su ihtiyacının karşılanamayacağı anlaşıldığından, Bekhme Baraj inşaatının tamamlanması önerilmektedir.

Anahtar Kelimeler: Büyük Zab Nehri, su temini, dinamik programlama, WEAP, model, sulama, evsel, ekolojik ihtiyaçlar

To my mother who passed away 1987, my father, brothers and sisters. My family and children (Buzhan, Khalid, Fatima, Sara and Azad) and my grandchildren (Elara and Mir)

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LIST OF SYMBOLS / ABBREVIATIONS

Agr.	Agriculture
Ave.	Average
BAU	Business As Usual
BCM	Billion Cubic Meter
CM	Cubic Meter
CROPWAT	Crop Water Modeling
CRWR	Crop Water Requirement
D.	Director
DEM	Digital Elevation Model
Dem.	Demand
Dom.	Domestic
DSM	Digital Surface Model
DTM	Digital Train Model
ECAFE	Economic Commission for Asia and East
EIA	Environment Impact System
ET_0	Net Evaporation – Transpiration
EU	European Union
EWR	Environment Water Requirement
FAO	Food and Agriculture Organization
G.D	General Directorate
GDP	Gross National Product
IMC	International Meuse Commission
IRC	International Rhine Commission
V&M	Ministry of Transport, Public Works and Water Management (Holland)
VROM	Housing, Spatial Planning and Environment(Holland)
LNV	Ministry of Agriculture, Nature and Food Quality(Holland)

GIS	Geographic Information System
GNP	Gross National Income
Gov.	Government
GWP	Ground Water Program
GZ	Greater Zab
GZR	Greater Zab River
GZRB	Greater Zab River Basin
Ha	Hectare
HKU	Hasan Kalyoncu University
hm^3	hectometer
HPP	Hydro Power Plant
ID	Iraqi Dinar
IHE	Institute of Hydraulic Education
IJJWC	Israel Jordan Joint Water Committee
IMWE	Iraqi Ministry of Water Resource
INBO	International Network of Basin Organization
INRBO	International Network of River Basin Organization
IRBM	International River Basin Management
Irr.	Irrigation
IWL	International Water Law
IWRM	Integrated Water Resource Management
LMB	Lower Mekong Basin
m a. s. l.	Meter above sea level
Max.	Maximum
MCM	Million Cubic Meter
MENA	Medial East North Africa
Min.	Minimum
MOA&WR	Ministry of Agriculture and Water Resource
MOM&T	Ministry of Municipality and Truism
MOP	Ministry of Planning
MRC	Mekong River Countries
NATO	North Atlantic Treaty Organization
NWP	National Water Policy

OECD	Organization for Economic Cooperation and Development
Pop.	Palpation
RBA	River Basin Area
RBM	River Basin Management
RBMP	River Basin Management Plan
Rijkswaterstaat	Ministry of Infrastructure and Environment (Holland)
SB	Sub Basin
SDP	Stochastic Dynamic Programming
SEA	Strategic Environment Assessment
SEF	Scenario Environment Flow
SHPG	Scenario High Population Growth
SR	Scenario Reference
St.	Station
TDS	Total Dissolved Solids in water
Tem.	Temperature
TGDSHW	Turkey General Directorate of State Hydraulic Works
TMFWA	Turkey Ministry of Foreign Affairs
UMB	Upper Mekong Basin
UN	United Nations
UNDP	United Nation Development Program
UNECA	United Nation Economic Commission for Africa and Far East
UNEP	United Nation Environment Program
UTM	Universal Transverse Mercator
WCD	Water Conference Directive
WD	Water Demand
WEAP	Water Evaluation Analyze Planning
WFD	Water Framework Directive
WR	Water Requirement

CHAPTER 1
INTRODUCTION

1.1 Overview

The around 40 % of world population lives in the 263 transboundary watersheds, particularly as those that involve two or more countries. Half of the Earth's land surface covered by these transboundary basins and computed for an estimated 60% of global freshwater flow (UN Water, 2008). The different countries population linked by transboundary basins and for appropriate ecosystem unit for international managing issues for thousands of millions of people, including the use of land, food provision, drought management and floods, and other based services for the watershed. Next, to one of the issue the only action by any country in an international basin is often ineffective (fish ladders only in an upstream country, for example), inefficient (hydropower development in a flat downstream country), or impossible (many developments on boundary stretches). The managing of transboundary cooperation water resources is desirable but can be difficult, often due to unclear and contested property rights. (Mostert, 2005)

Water is a substantial element of life on the earth planet. With increasing world's population, water demand increases and pressure on limited water resource intensifies. It was expected that, by the year 2050, the world populations would reach 9.9 billion. Due to the close tight population's growth to climate change, this could cause major and big pressure on the availability of water resources. There is uncertainty on the exact number of people living on earth in the coming decade, but it is clear that the population will continue growing, this will influence on water availability. (United Nations, 2011)

The Middle East is a region characterized by scarce water resources and a rapid population growth. Water scarcity is increasing and expanding in the region. Accordingly, water is a binding constraint on sustainable future economic and social development in the region, which in turn increases demands, especially for fresh water. Improved efficiency in the water use must be combined with the provision of new and additional water to the region to minimize the shortage of water. There is a prediction that the region's future war will be over water rather than on land or religion conflict based. However, due to interconnected water resources and environmental security, water is likely to be a factor to promote interstate cooperation in the region. Economic, technical and regional water-sharing agreements are sufficient instruments for conflict avoidance. Therefore, governance and the sustainable development of common pool water resources of the Middle East should be given more attention. (Gleick, 1993)

Changes in the structure of urban-rural populations and the urban population's positive and high growth rate have strong implications for the management of water demand and supply across the region. The table 1.1 explains increased urbanization and the annual growth rate of the urban population is 2.4% in the world, while the corresponding figure for the Middle East and North Africa (MENA) region is 3.2%. It is observed that the growth rate is positive but declines over time. Saudi Arabia, Jordan, Turkey, Iran, and Syria show a higher annual growth rate than the average for MENA, while Iraq and Kuwait have lower rates. (Roudi, 2011).

Iraq is currently facing a several water shortage problem also it is one of the Middle East and North African region (MENA region) countries. This problem is predictable to be more severe in the future where the supply is expected to be between 43 and 17.61 Billion Cubic Meters (BCM) in 2015 and 2025 respectively, while current demand is estimated to be between 66.8 and 77 BCM. Tigris and Euphrates River has been forecasted that the river flow will continue to decrease with time, and they will be going to face drier by 2040. Serious, prudent and quick measures need to be taken to control this problem. (Al-Ansari et al., 2015).

Table 1.1 Urban Population Growth of the MENA in Annual. (Roudi, 2011)

Rank	**Country**	**Years**					**Average**
		1981-1985	1986-1990	1991-1995	1996-2000	2001-2006	
1	Saudi	7.8	6.3	3.8	3.6	3.3	5.0
2	Jordan	5.8	5.3	7.2	3.2	2.9	5.0
3	Turkey	6.1	4.6	2.9	2.6	2.3	3.8
4	Iran	5.2	4.0	2.9	2.9	2.4	3.5
5	Syria	4.3	3.9	3.1	2.7	2.6	3.3
6	MENA	4.3	3.5	3.0	2.5	2.5	3.2
7	Iraq	3.9	2.8	2.8	2.7	2.5	3.0
8	World	2.7	2.7	2.4	2.2	2.1	2.4
9	Kuwait	5.1	4.5	**-44.3**	4.0	3.0	1.8

According to the statistics of the Ministry of Planning in the region of three governorates of Iraq, Erbil Province which is the capital of the region shows a substantial increase in population. Years revealed that there will be approximately extra three million people in the next 33 years in Erbil province. This increase in population in Erbil-Iraq leads to the increase in water demand as well as food preparation. Based on the Erbil statistics, the water demand will be triple (MOM&T, 2016). Therefore, the new strategic plan for GZRB is essential.

Table 1.2 Erbil province population growth ratio % per five years.

Year	Growth Ratio per 5 Years	% Growth Ratio Per/Year	Erbil Population
2010	0.178	3.56	1681032
2015	0.173	3.46	1981013
2020	0.167	3.34	2323487
2025	0.162	3.24	2712192
2030	0.161	3.22	3150963
2035	0.161	3.22	3660717
2040	0.161	3.22	4252938
2045	0.161	3.22	4940967
2050	0.161	3.22	5740303

Iraq rebuilding and its economic and demographic growth, especially in Erbil, will result in increasing pressures on the water resources. Guaranteeing a sufficient supply of water quality to meet the needs of the different uses, in a context of overall sustainable development, must become a major aim for local authorities. The extern relations towards upstream countries like Turkey and Iran and the downstream Iraqi government are a second major challenge for Erbil province are the both Turkey and Iran have already the high technical means and the technical knowledge of their resource and they managed water resource better than Iraq.

In general, existing legal framework is too sectorial. There is a lack of sound legal framework, providing an enabling environment for Integrated Water Resources Management (IWRM). There is also a need for water policy and water strategy at Erbil province level. In the meantime, at the same time, there is a lack of enforcement of main existing laws and regulations, as far as water uses and water pollutions are concerned. In the same way, some polluting activities seem to be happening without any previous

Environment Impact Assessment. On another hand, "Environment protection and improvement instructions", as described within Law for Environment 2009 are still not operational.

Some conflicts around water availability (in quantity, quality) and environmental degradation progressively arose during recent years in Erbil, due to, among others:(overexploitation of groundwater in various areas especially in the urban area, urban water pollution that creates some difficulties during dry seasons; sand and gravel mining (take out the sand and gravel from river to the city for construction projects) that damages natural river courses or even some irrigation schemes.

These conflicts mainly result from low-level understanding water resource approaches and lack of integrated water resources management in downstream of the river basin. There is no real operational tool to solve the conflicts. These conflicts can only increase in link with on-going economic development, which generates more and more pressures on the resource: water withdraws, pollutions, environmental degradation. (Mysiak, et al., 2005).

The pilot area selected is main importance for Erbil as the potential for economic growth in this area is real irrigated agriculture, energy, industries but also tourism and recreation will grow in the coming years. Some tasks have already been pointed out regarding the current balance between resources and needs, regarding the institutional and legal aspects and regarding the data management, groundwater level decrease, no sewage disposal, lack of surface water storage. In order to take into account, the main prediction to the future issues for GZRB, the study proposes have to set an action plan for development GZRB for the next 33 years up to the year 2050.

The GZRB exemplifies many of the arguments related to water and dams. On the one hand Iraq and Turkey are emerging economies that want to join the successful nations, but on the other hand nature and people are damaged in the process. Especially in the south of Iraq, the upstream dams without negotiation, have led to droughts, desertification, and salinization. The GZR is largest Tigris tributary that still water flow runs free and uncontrolled.

However, Erbil's water resources are exposed to some risks and threats, in particular:

1. A fast-growing of population means fast growing of demands and caused by urbanization, economic development and in particular the planned extension of irrigated areas.
2. Lack of regulation of groundwater use, resulting in overuse in particular around Erbil;
3. Increased water uses in Turkey country, resulting in reduced inflow.
4. The expected impact of climate change to worst and drier.

Furthermore, Erbil’s water resources are shared, around the 50% of the total annual volume of the GZR surface water resources generated from Turkey, the upstream country and while, water resources management in Erbil directly affects Tigris River water availability and also affects in rest of Iraq. To cope with the mentioned risks and management challenges an (IWRM) approach is required.

The annual flow for the GZR is around 13.3 Billion m^3 (13300 MCM). However, due to the lack of strategic project on the river, the government did not gain remarkable benefits from it. The river flow rate in winter could be more than 2500 m^3/s; this may cause flooding in the area. While in the summer, the discharge may reach to 50 m^3/s. This rate may negatively affect the environment such as water quality deterioration. This, in contrast, it will have a big impact on the sewerage system networks to cities and villages. (MOA&WR, 2016)

The Bekhme dam 17.1 BCM reservoir capacity has been suggested at the begging of 1963 on the Greater Zab River. The main aims of the project are irrigation, hydroelectricity power, domestic’s water supply, and flood control. In the year 1984, Iraqi government redesigned and started the work by the Yugoslavian company. Unfortunately, only %30 of the project was completed, and then the project was stopped in 1991 because of the first Gulf War and UN sanctions. Stopping the project in 1991 had significantly affected the management of the GZR. Nowadays, working on the upstream part of the dam is becoming so difficult due to the development of rural areas and presence of many strategic projects. In the case, this dam construct, around 60 villages (16600 km^2) plus many agricultural areas will be covered by water. (HEN, 1963)

The significant power cut (shortage) and corresponding water needs in the summer season in the study river basin made the Erbil province think about an alternative multi-user method. For instance, building a new dam on the river called Bekhme dam with reservoir capacity 17.1 BCM, which could produce electricity 1500 MGW. This dam can enhance the Greater Zab River flow at downstream of the dam at Ifraz location in summer from 47 m^3/s to 300 m^3/s and transfer a high amount of water to water projects. (DIE, 2016)

1.2 Dissertation Outline

This thesis is divided into 8 chapters. Chapter 1 is a background and introduction to the transboundary river basins and GZR. Chapter 2 provides a literature review of the previous research on transboundary river systems, national rivers and transboundary watersheds, river basin management, and planning. Modelling of water quality and water quantity, where impacted by activities throughout the watershed. Chapter 3 provides and set an overall overview of the study area of the river basin, outlines the topography, exist climate data variability, and surface water resources across the study area. Chapter 4 presents the patterns of water management which are revealed the responsibility of governmental authority and structure of working in the area, for example, how the government managing the water sectors. Chapter 5 include study of water governance and conflicts in transboundary river basins taking samples in the world to show how the cooperation are ongoing between the countries sharing water, also in this chapter showed the example of cooperation agreement between Iraq and Turkey as well as between Iraq and Erbil together with Turkey. Chapter 6 presents the material and methods used to reassess the operating and planning rules of the GZRB. The WEAP model applies for the GZRB and it is given in this chapter together with briefly discussing RB management scenarios. Chapter 7 discusses the simulation results of the studied river basin. Chapter 8 Conclusion and synthesizes of the summary key findings from the research and provide recommendations for future research directions.

1.3 Research Objectives

The goal of this study is to evaluate and plan the water system for GZRB and implications for water resource management and quality within Erbil province, Iraq. The water resources in GZR have faced several problems due to the growing demands and climate change issues. Rainfall rates were reduced around 15% during the last 15 years (from 2000 to 2016). In the meantime, the populations have remarkably increased in the region. Besides that, people from other parts of Iraq and Syrian people were escaped by ISIS and settled down in Erbil. These led to the significant shortage of water compared to the past. Therefore, this study is important for saving water resources for future generations and the objectives are as below:

1. Delineate the catchment area, sub-catchments, and water flows from rainfall (precipitations) to the streams and the main river. In addition, delineate mountainous, hilly and plain areas using Arc Map software.

2. Determine the water balance for the river basin, finding the water supply from river flow and groundwater and water demand for all users up to year 2050, explaining the shortage during the time. Based on this, determine suitable locations for strategic projects (e.g., dams, reservoirs, and Irrigation schemes) for saving water and food security for the future generation.

3. Determine the current and future water needs quantities for all sectors such as domestic, industrial, agriculture, and the environment by using WEAP software.

4. Create a future model for water resources in the river basin for the purpose of analyzing the necessary strategic plan and decreasing water shortage as much as we can.

5. Determine the quantities of agriculture water demands and planting area by different crops, forecasting the Irrigable area and non-irrigable area, during the next 33 years up to 2050.

6. Find the crop water requirements, and monthly irrigation crop water required for current situation and for future (next 33 years).

7. Determine and suggestion irrigation projects for future plan, using new irrigation technology and water saving technology system.

8. Determine optimal future planning for all water users sector in GZRB.

9. Determine and maximize overall benefits obtain from water supply, irrigation, and hydropower productions

10. Reach to the fully implement of IWRM Integrated Water Resource Management in the River basin

1.4 Research Questions

In the end of this study the research will answer the following questions:

1) What are the main instructions and agreements related to the use of GZRB as well as to river basin management?

2) How are these water demands transfer to land use regarding to the planning on a regional level now and in future, especially for the relation for development of river basin plans according to the Water Framework Directive (WFD)?

3) What are the most top conflicts and problems in the GZRB?

4) Are there any popular tools to be utilized in river basin management?

5) How can the distribute information system will done on sustainable river basin planning?

6) What are the principles of the agreement between the riparian countries in the basin of the Tigris and Euphrates rivers, especially between Iraq as a downstream country and Turkey as the upstream country and the main source of water?

7) Are there any previous agreements on the amount of water flow to Iraq, especially the Zab River Basin, to guarantee future coverage of all water users?

1.5 Research Hypotheses

Considering different scenarios for the future prediction (2050) for the study area is important to know how the water balance is will be during next 33 years and for that purpose, this study will include run WEAP model with several data sets as follows:

Scenario High Population Growth (SHPG): Taking into account, the annual growth population at a higher-level factor (5 %) per year. Here, the population of Erbil province in 2015 was 2,018,042 and the population will be 4.1 Million in the year 2030 (MOM&T, 2016). Considering this factor for the study target (2050), the counted population will be more than 10 million people. Thus, the prepared food and water, required for more four and a half million people considered a big challenge for future generations compared to the availability of water resources in the basin.

Scenario Reference (SR): Taking into account, the annual growth population in the GZRB at a proposed level (normal situations) factor (3.4%) years. In this case, the Erbil population in 2015 was 2,018,042 and the population will be 3,150,963 in 2030 (MOM&T, 2016). The same factor has been counted for the study target (2050), in which the population then will be 5,740,303. Therefore, the water supply for more three million and seven hundred thousand people are also considered to be a big challenge for future generations comparing to the availability of water resources in the basin.

Scenario Environment Flow (SEF): Taking into account, the annual growth population in the GZRB at a proposed level (normal situations) factor (3.4%) years and also for high population growth 5 % as well as the mandatory monthly environment river flow release from the river to the Tigris requested amount by the Iraqi government as 50 m^3/Sec.

According to the above scenarios, there are three scenarios for increasing population with the same amount of water has been counted. Hence, the future estimation of quality and quantity of water resources are under threat (challenges). Moreover, it is expected that the climate going to be worse in the future. So that, the future water resources in the Middle East going to be worst, accordingly. Two extra and more scenarios can take into account regarding decreasing water resource for the study area.

CHAPTER 2
LITERATURE REVIEW

2.1 Background

Water - a vital commodity for the survival and socioeconomic development of people - is getting more limited with increasing population, the climate change, and drought conditions worldwide. Especially in those countries located in arid regions. Due to any one of these reasons, a serious and wide-spread water shortage might happen anytime. A water shortage will heighten the threats of conflicts arising from sharing transboundary waters among the countries situated on the banks of a river (riparian countries). The international convention that deals with the subject of transboundary watercourses are the "Convention on the Non-navigational Uses of International Watercourses". This Convention has been signed by only 12 countries since 1997. Although it required approval by 35 countries, and therefore it has not been applied widely. (McCaffrey, 1998).

The "EU Water framework Directive" also deals with transboundary watersheds. In this directive, the transboundary watersheds are referred to as -international water basins", which is an unfortunate choice of words as it appears to allow interference by the countries non-situated on the banks of a river (non- riparian countries). If the word "national" is intended to be used, "multinational" obviously would have been preferable in this context. Here, the "multinational" refers to the riparian countries sharing the transboundary water basins. The proper approach here is to evaluate the entire watershed as a whole for the integrated management of the watershed in a fair and rational manner. The "fair and rational" use of the transboundary waters does not necessarily imply equal share among the riparian countries. Instead, it leads them to collaborative scientific research to determine the fair demand of water for each and the implementation of proper management techniques based on that demand and by focusing on minimization of water losses. (Karpuzcu et al., 2009).

Water issues effect on all parts of society and all saving sectors. Population growth very fast urbanization and industrialization, the extension of agriculture and tourism, and climate change, all put water under growing stress. Given this growing pressure, it is sensible that this vital resource is properly managed. (United Nations, 2011)

Population growth causes increasing economic movements and promotes living standards incorporation with social inequity, economic marginalization and lack of poverty alleviation programs place a growing pressure on the world’s limited freshwater resources (UN Water, 2015). For a sustainable use of freshwater resources, integrated management, often referred to as “integrated water management,” “integrated water resources management” or “integrated river basin management,” has for long been advocated as the solution. (Helmut, 2015)

According to Jakeman et al., (2003), integrated water management may be perceived in at least three ways.

First, it may be the water has several dimensions, such as surface water and groundwater, and quantity, quality of water. The main point of this is that the water has a value of ecological system including of some interdependent components, which required to be managed with regard to their interrelationships. Having this perspective, integration of issues connected to water supply, wastewater treatment and disposal, and water quality may be of concern.

The Second, while water is one system it can be managed as integration and it can also interact with other systems. With this idea, interactions between water, land and the environment in the context of river basins need to be addressed, finding that changes in any of the systems may have consequences for the others. At this level the management issues of concern it may include, for instance, floodplain management, erosion control, and reduction of diffuse pollution and preservation of wetlands and fish habitats.

The Third and wide performance of integrated water management indicates to the interrelationships between water and social and economic development. At this level, the scope to which water is both an opportunity for and a barrier against economic development is of concern. To ensure that water is managed and used is another matter, so that the sustainable development may be over the long term. Interest at this level may be related to the role of water in producing hydroelectricity, in facilitating transportation of goods and in serving as an input to industrial production

2.2 Transboundary River System

The aquifers, lakes, rivers, large marine ecosystems, and open oceans are the water systems of the world; it has supported the economic development and prosperity of humanity and is home to a high part of the world's ecosystem. Many of these systems are shared by two or more countries, and these transboundary resources are related by a complex web of political, economic, environmental and security interrelations. The interrelations extend across national borders and between the different water systems, underlining the required for integrated management of these resources. (Salman, 2007).

During the nineteenth century, agreements and international treaties concerning the progress investment and keeping of transboundary Rivers were exclusives mainly to navigational issues. Called "Waters of International Concern," Trans-boundary Rivers historically have been seen as navigational conduits for thriving market interests, particularly for imperial states like Great Britain, which controlled and relied heavily upon foreign trade with its colonial protectorates. (Mark et al., 2013)

In the twentieth century, the scope of international management of Transboundary Rivers has evolved substantially in order to accommodate increasing conflicts of demand for trans-boundary flows. Increasing competition from various classes of stakeholders (irrigation, hydroelectric, flood control, environmental and recreational uses, as well as traditional needs of navigation), have expanded the scope of international attention beyond navigation to include the more general allocation of use. (Timothy Riley, 2003).

The 1966 Helsinki Rules expanded this scope further, introducing for the first time the term drainage basin. With the advent of the drainage basin, resource managers and policymakers began to think beyond the riverbank and into a broader understanding of a trans-boundary river's hydrological environment. A drainage basin could be associated with a river, lake, drainage channel, groundwater, open and closed canals, perennial and passing streams, estuaries, floodplains, erosional areas, and riparian flora and fauna. And, in the last several decades, with increased economic activity in developing nations, water quality has become an important component of water resource management. As a result, water pollution was integrated into the definition of a drainage basin as early as the late 1960s. (Timothy Riley, 2003).

There are different characteristics of each trans-boundary river and resource management demands, it is serious to reflect all vectors that either benefit or reduce the best use and protection of the overall drainage basin. As such, geographical and hydrological boundaries, as well as, geopolitical demarcations play an important role in evaluating the potential value of trans-boundary flows. The services provided by a drainage basin are a function of geomorphologic conditions, yet the management of transboundary Rivers is often dependent upon political boundaries. The nexus between these two types of boundaries defines the sociopolitical and economic potential of trans-boundary water resources. Additionally, water quality and quantity are impacted by activities throughout the watershed, not just along the main stem of the river. Upland activities, such as deforestation, urbanization, and pollutant discharges into smaller-order tributaries can, directly and indirectly, affect the overall service capacity of transboundary rivers. Water supply, water demand, and population growth. (Mant & Janes, 2005)

2.3 Methods

Unfortunately, many existing projects such as reservoir operational policies fail to consider a multi-facility system with completely integrated methods, but rather ensure operations for individual projects. However, the operational strategies are needed to be integrated and faced with system managers with a difficult task. Development the scope of the working system for more integrated analysis highly multiplies the potential number of alternative operational strategies. The large-scale water resources management, for example, multipurpose reservoirs, has traditionally been carried out by public administration. The motivation for a public management are both political and financial: to get equity and arbitrate conflicts among water users, to maintain ownership on a strategic infrastructure, to ensure that certain water services viewed as public goods are preserved, and to promote the development of water resources. (Sharma et al., 2007).

Water resource systems should be managed efficiently taking into accounts all operating objectives and constraints. Such management is complicated because of varying demands, uncertain stream flows, and multi-objective and multi-institutional characteristics of water supply. Dams, the subject of this thesis, allow controlling rivers and can provide crucial benefits such as irrigation and energy generation (Kularathna et al., 2017).

Also, construction dams cause some disadvantages such as displacement of people, disrupt the ecosystem and harm the environment. Dams have becoming a controversial issue because of those negative impacts but remain prevalent in manifesting economies countries, such as Turkey and Iran.

More specifically, release decisions and demands will be determined by a stochastic dynamic programming (SDP) formulation. The main advantage of SDP is that it can handle the hydrological uncertainty and nonlinear objective functions such as hydropower production. Reservoir operating policies will then be used in simulation over a hydrologic period of interest (Tejada et al., 1993).

For a river basin operation problem, the main decision variables are the releases and demands. The allocation of river basin services among the water uses requires both a river basin management and planning model an economic objective function. The optimization model will determine an optimal river basin operation policy for the river basin system in the Greater Zab river basin.

The objective is to maximize the overall benefits obtained from the water supply, hydropower production, irrigation and flood control. Optimal river basin operating policies will be simulated over the 2000-2016 period, which is the normal period with historical flow records.

2.4 Logical and Key Messages

Agricultural, human, and environmental water stress often happen in the same transboundary catchments, resulting in competition for water between countries and sectors.

The relative risk for any of these stresses is high or very high in 41 out of 286 basins; greater Zab river basin is one of them. Actions to mitigate water stress need to be planned in an integrated, cooperative framework to take careful consideration of all sectors in each country sharing a basin. (Rao and Aliyar, 2017)

In the many transboundary river basins, the pollution risks are high and extended to increase. The relative risk for either nutrient pollution or wastewater pollution is high or very high in most of the transboundary river basins; wastewater treatment and nutrient management in agriculture are needed in most basins. The threat to freshwater biodiversity is global. The transboundary river basins extinction risk is moderate to very high in 70%. However, local-level, tailored solutions are needed to address species extinction risks.

In many transboundary river basins, the construction of reservoirs, dams, and water diversions is in progress or planned, sometimes without adequate cooperation instruments of international water. While many exist, transboundary agreements, more powers are needed to update them to reflect modern principles of transboundary water management, such as the obligation not to cause significant harm and the principles of cooperation and exchange information. (Rao and Aliyar, 2017)

To improve guidelines for siting new dams is needed continuing commitment, dam designing for multiple purposes, and optimizing the operation of dams to maximize advantages and minimize disadvantages impacts and sediment trapping. This is particularly relevant in transboundary river basins, where often dams constructed in upstream countries.

The impacts of climate change on the human, social, economic and environmental, happen mostly through water changes in, significantly affecting its quality, quantity and through disasters. Water flows within basins regardless of borders and needs to be managed in an integrated manner. (Moss, et al., 2010).

The distribution in space and time of our water resources, disparate, are under pressure for increased demand due to major population change. The access to reliable data on the availability of water quality and water quantity and its variability form the necessary foundations are the sound management of water resources. The different options for increase expand the boundaries of the water resource in a traditional sense, serving to match demand and supply. All human activities influence by components of the hydrological cycle and it needs to be understood and quantified to efficiently and sustainably develop and protect our water resources. (UNESCO World Water, 2006)

Transboundary river basins with high economic subjections on water resources, low levels of social welfare and high facing to floods and droughts have the highest climate-related risks. In the basins, governance capacity may need to be improved continually with high climate-related risk. Almost all deltas in transboundary river basins have moderate to very high risk for one or more indicator. Special attention should be paid to the impacts of upstream activities on deltas, in particular, the reduction of sediment supply (resulting in sinking deltas) and of water flows due to dams and abstractions, and to pollution.

In the next 15-30 years, the risks are projected to rise, particularly for the regions, the Middle East, Central Asia, the basins in Southern Africa. Action should be taken now to reduce future costs and impacts. (Rao and Aliyar, 2017).

Through their use of the water in the river basin the countries share and linked together, the value they derive from it, and the impacts they cause through development and pollution. The below figure (2.1) is showed typical relationships between the countries watersheds and the transboundary activities and relations between the country located in upstream and the middle country as well the downstream country such as greater Zab river basin which is Turkey is upstream country and Erbil which is located in the middle of the basin and the rest of Iraq which is located in the downstream. For Greater Zab River basin, action plans and the activities will be similar to the below figure, on the other hand, the other river basins, Turkey produced the agriculture to Iraq also.

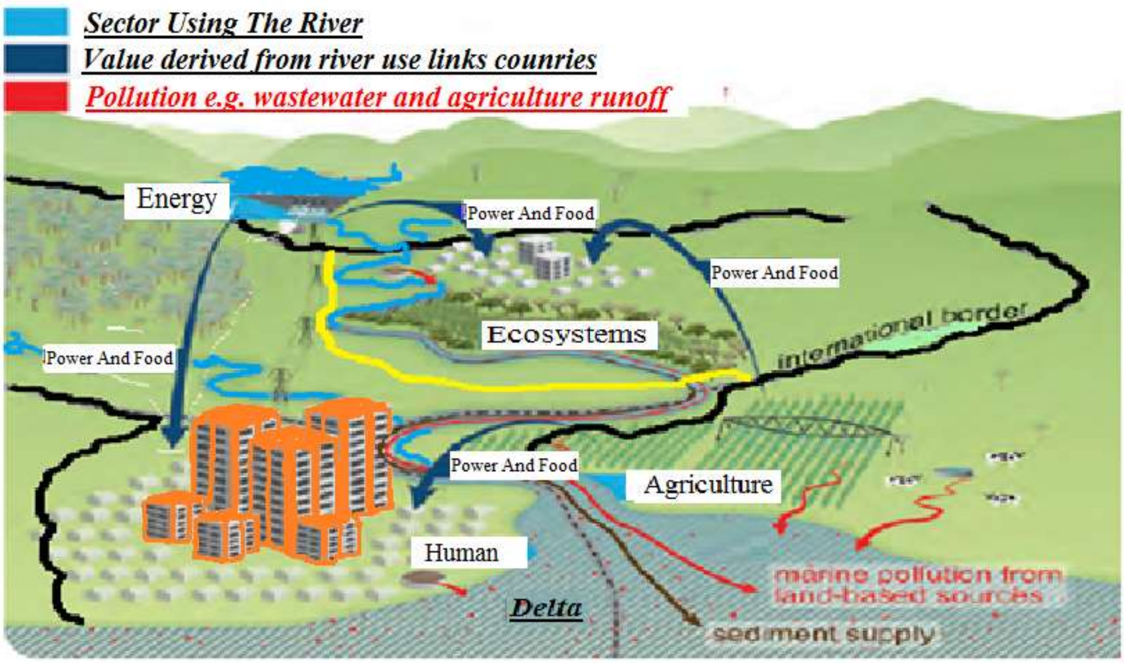

Figure 2.1 Typical trans-boundary relationships and activities

2.5 GZRB Previous Studies

There are many researchers were studying the area of GZRB especially and Tigris river basin. For instance, Ismail (2013), studied HYDROLOGICAL CHARACTERISTICS of the GZRB by using ArcGIS. He estimated the average rainfall-runoff coefficient by the rational method for five sub-basins. The resulting coefficient for the whole basin was (0.53). (Ismael, 2013)

Other research on the geomorphology of GZRB done by Varoujan K. Sissakian the geomorphology and morphotectonics of the Greater Zab River basin are studied. Six Morphometric indices have determined in this study, using ArcGIS technique, which indicated high, Moderate, Very High, Very High and high relative tectonic activity for the five sub-basins, respectively. Geomorphological and basin drainage maps of the studied area are prepared, too. (Sissakian et al., 2014).

Osman et al. (2017) used daily rainfall and temperature data of Greater Zab basin, for the period of 1961-2008. The data were used in constructing evapotranspiration and rainfall models utilizing LARS-WG and multiple linear regression models. A rainfall-runoff model, in the form of autoregressive model with exogenous factors, has been developed using observed flow, evapotranspiration and rainfall data. The model was used to examine the effects of climate change on the Greater Zab flows for three different periods, for example, near (2011-2030), medium (2046-2065), and far (2080-2099) future. Their model results revealed that the river basin is faced to suffer a remarkable lowering in overall annual flow in the far future; with a significant drop during the spring and winter seasons in the range of 25 to 65%. This could have severe ramifications for the recent agricultural activity in the river basin. Osman et al., (2017) further explain, the study result could provide significant advantages for water management planners in the study catchment as they could be utilized in allocating water for different users in the river basin.(Abdalla et al., 2017)

The Aquastat Survey, also particularly studied on the Greater Zab, generally study the negotiations and conferences held by the three riparian countries on Tigris and Euphrates which originates in Turkey. GZRB generates 13.18 km^3/year at its confluence with the Tigris; around 62 percent of the total area which equals to (16880 km^2) of the GZ river basin of 26306 km^2 is in Iraq. (Stivanovic and Markovic, 2004).

Some Iraqi researchers have done researches on climate change effects on water resource of GZR. They have shown that the catchment area is currently being plagued by pollution problems and water scarcity. Recent studies have shown that green and blue water of the catchment have been showing substantial variability owing to severe floods and droughts due to climate change. SWAT (Soil and Water Assessment Tool) has been used to obtain a better understanding of the influences of climate change on water resource in near and distant future (Rahaman, 2009).

The EIA of construction of the dam (weir) high 23.5 m with power production 30 MW on the main branch of GZR 20 km far from Turkey border studied by MAPCOM company, the study included of land use and water quality. Their key physical, chemical, and biological qualities of the water samples were analyzed. The results show that almost all studied water systems were ranging from clean to moderately polluted waters. (MAPCOM, 2008).

A study for Evaluation of Water Quality for Greater Zab River by Yahya Ahmed Shekha conducted to determining the variable effects on water quality of GZR in Erbil province, Iraq, using multivariate statistical analysis. Generally, results of most water quality parameters revealed that Greater Zab River was within the permissible level for drinking water consumption, while it regarded as safe water type for all kinds of crops. (Shekha, 2016).

The researcher Alex K. mentioned that the national and ethnic identity plays a big role in the framing of problems, while the actual victims and perpetrators are defined by socioeconomic status. Moreover, along the Greater Zab River where planned dams exemplify the global processes of states and corporations that prepared both illegal and legal harm for the benefit of powerful vested interests. (Alex, 2014)

The HARZA company 1963 were studied the GZRB, suggested to establish a reservoir in the junction of two sub rivers in the location called Bekhme, The justification for the addition of Bekhme to the ultimate development is questionable. Bekhme adds little benefit, at very high costs, comparing to the other dams in Iraq the benefits attributable to Bekhme are significant, although it is doubtful whether the incremental benefits from the Bekhme would justify its cost. (Harza, 1963). The Iraqi government started to implement the project to build the Bekhme dam in 1984 and completes 30% then stopped in 1990 due to the 1st gulf war.

Thair (2016) applied Soil Water Assessment Tool (Arc SWAT, 2009) on the Greater-Zab River Catchment water balance. The data for calibration model was from 1993 to 2002 and for validation was from 2003 to 2012. The calibrated model was used to evaluate the water quantity (monthly streamflow). The results of Tahir's (2016) study revealed that mean simulated streamflow accounted 417 m^3/sec for the study period (1930-1992) which is higher than the average value of streamflow 363 m^3/sec for the period (1993-2013). Thus, the observed water shortage (1993-2013) problem influences on the water management resources. (Thair, 2016)

Iraq ministry of water resources report (2006), worked on water resource assistance strategy, and greater Zab is the biggest tributary feeds Tigris river so that partially the Bekhme dam project on the Greater Zab with 17.1 BCM capacity (the construction was abandoned after the Second Gulf War), The suspended Bekhme dam project on the Greater Zab is designed for generation of a further 1,500 MW, adding 60 percent to the existing capacity. Other projects under consideration include the Mandawa regulation dam on the Greater Zab below the Bekhme dam, which could generate 570 MW. The proposed Bakerman dam on the Khazer would generate 67 MW.

CHAPTER 3
STUDY AREA

3.1 Introduction

The biggest of Tigris transboundary tributary is GZR generated in Turkey and flows to Iraq through two provinces Erbil and Duhok and part of the river also generated in Erbil Province Mountains as shown in figure 3.1

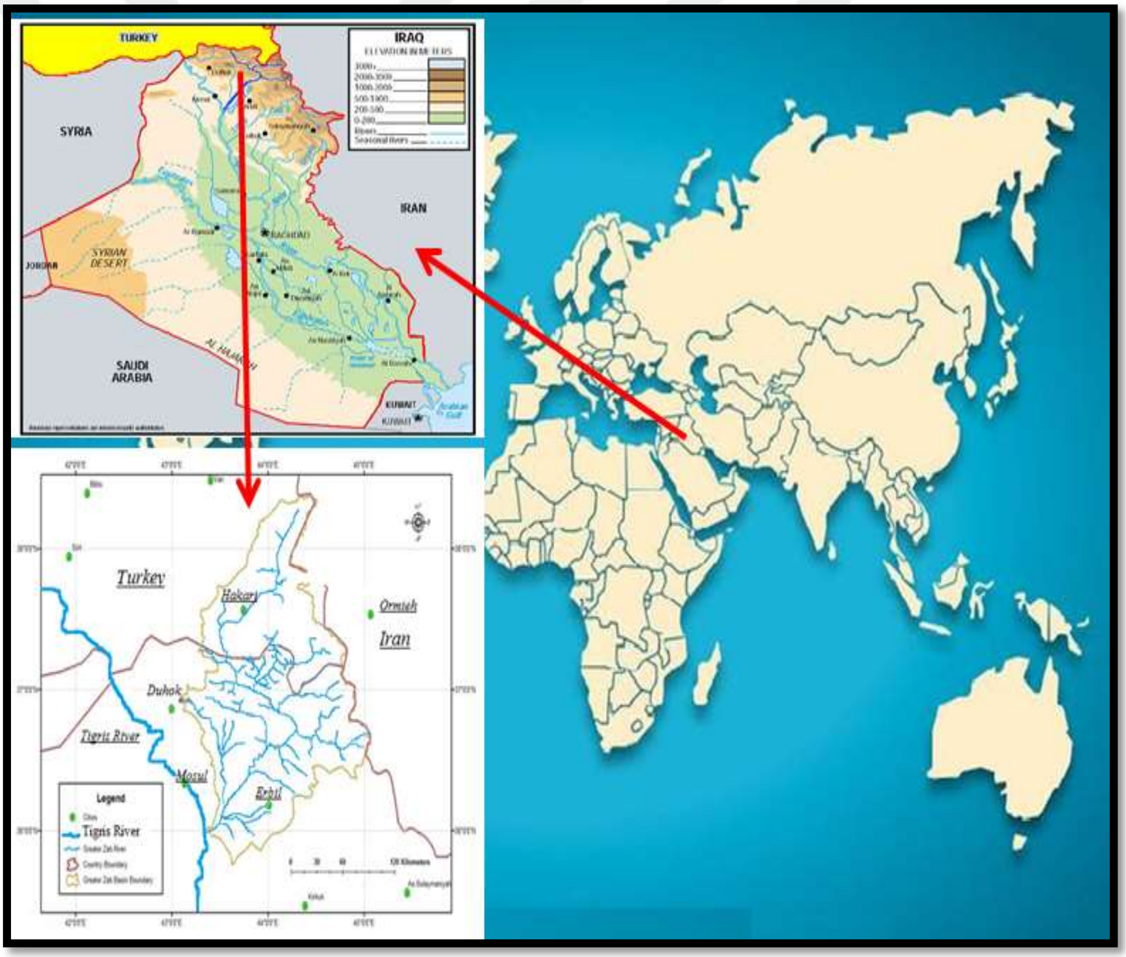

Figure 3.1 Study area descriptions

The hydrographic pattern of Northern Iraq dominated by four major, roughly parallel rivers with a general flow direction from the northeast to the southwest (figure map 3.2). Four rivers – from north to south Khabur, Greater Zap, Little Zab and Sirwan are joining to the Tigris, outside the border of Iraq. Those four main rivers and some of their major tributaries originate in Turkey (Khabur and Greater Zab) or Iran (Little Zab and Sirwan). A fifth, smaller river basin, the Adhaim basin, is entirely within Iraq.

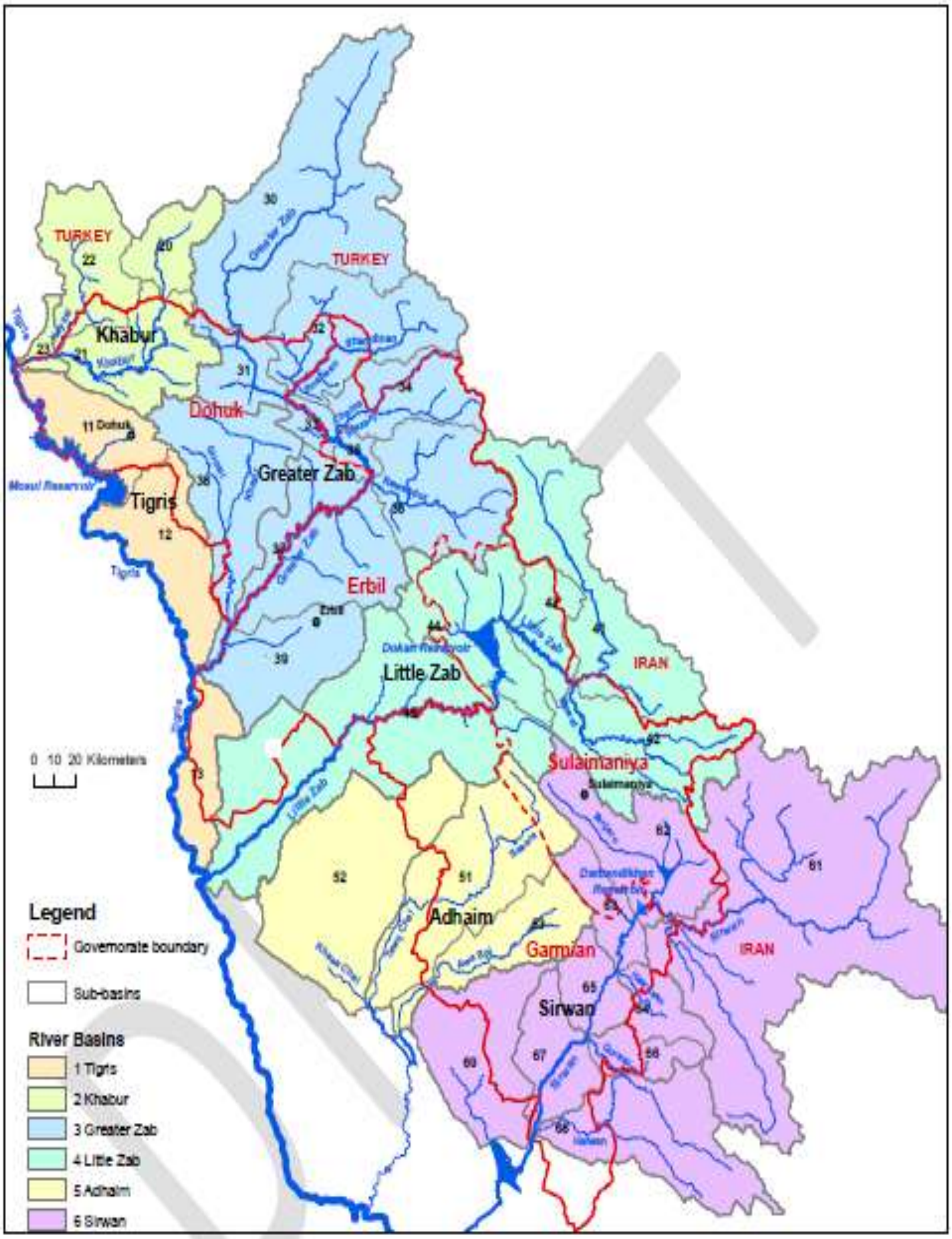

Figure 3.2 Tributary map for Tigris Tributary River within Iraq

The Table 3.1 provides an overview of the situation. Although Iraq has a relatively large share of the river basin, about 50% of the surface water resources originate from upstream of the border. Hence, they allow for inter-annual storage and for a complete change of the seasonal flow distribution (man-made flow regime) downstream of the dams. A third large storage dam, Bekhme, planned on the GZR uncompleted; in fact, this dam had been under construction during the 1984s. (MA&WR, 2016)

Table 3.1 Tigris River Basin Tributaries

River basin		**Tigris (direct)**	**Khabur**	**Greater Zab**	**Lesser Zab**	**Adhaim**	**Sirwan**
Origin		Turkey	Turkey	Turkey	Iran	Iraq	Iran
Catchment Area Km^2	Upstream/ Iraq Border	40,600	1,303	9,414	4,883	-	17,423
	North Iraq	2,770	2,627	16,696	12,229	5,774	9,266
	Total at mouth	n/a	6,027	26,331	19,593	n/a	n/a
Existing Large Dam		Mosul	-	Bekhme 30 % implemented	Dokan	-	Darbandi khan
Province		Dohuk		Erbil	Sulaimanya		

The GZR joins the Tigris about 60 km south of Mosul. The confluence of the two rivers situated midway between Mosul and Sharqat city. This tributary drains an area of which about (62 percentage) lies in Iraq. This tributary is one of the largest with a mean annual flow of (418 m^3/s). (Al-Ansari, 2013)

Figure 3.2 shows Erbil river basins map, mainly five tributary flows to the Tigris and biggest tributary, is GZR, which generated in Turkey and Iraqi Erbil Mountain in Erbil and Dohuk provinces.

3.2 Study Area

The GZR originates from the mountainous area of south-eastern Turkey where it springs at an altitude of 4168 m above sea level. The river is 407 km long (290 in Iraq), it is one of the main tributaries of the Tigris river and flows into the Iraqi Erbil, the Erbil province located between latitudes 36° and 38°N and longitudes 43°18’ and 44°18’E.

The whole river basin has an area of (26306) km^2, a sizeable part is outside Iraq mostly in Turkey with a little part in Iran. In Iraq, the river basin is mostly located in the fourth (Erbil, Duhok, Sulaimanya and Mosul provinces. It is the most important river basin in Erbil province as it covers 1/3 of the whole north of Iraq provinces area including the city of Erbil. (MOM&T, 2016)

Table 3.2 is GZRB area and its international catchments and table 3.3 national catchment within provinces in Iraq.

Table 3.2 Repartition of the RB Area (regional and national level) (MOM&T, 2016)

	Iraq		**Outside Iraq**		
Area Located	In Erbil & Duhok	Outside Erbil & Duhok	Turkey	Iran	Total
Area (km^2)	16664	216	9422	5	26307
Total Area (km^2)	16880		9427		
Proportion of RB	63 %	1%	36 %	insignificant	100 %

Table 3.3 Repartition of GZRB in Iraqi provinces (MOM&T, 2016)

	Erbil	**Duhok**	**Sulaimanya**	**Mosul**
GZRB Area km^2	10203	6333	128	216
Area %	60	38	1	1

Although integrated water management takes into account the whole river basin from the origin of the river to the outlet of the Tigris. Mostly political and practical reasons oblige to restrict the area study, on the other hand, the main part of study area of the river basin is located outside Iraq in Turkey and in Iran International relations regarding water with Turkey is part of this study and the also the area of the river basin in Iraq but outside. The GZR outlet up to inter Tigris River, which is in Mosul province, given the difficulties to access to these data, due to un-secure this area will not take into account.

The GZR rise in the mountains lies in the center between Ormia Lake in Iran and Wan Lake in Turkey. Then it flows in North-West direction across the Iraqi border beside Al-amadieh, afterward it flows in South East direction parallel to the Iraqi Turkey borders until it combines with Rwandwz River that rises in the heights, close to the Iran-Iraqi borders. It flows again in a North West direction until it combines with GZ near Bekhme. The river diverted due to construction Bekhme dams that finally not completed, from the Bekhme location, which is the conjunction between the main two parts of the river Blea River generated in mountain Turkey and Rwandwz River generated from the mountain area in Erbil province closed to the Iranian border. After the junction, two parts Blea and Rwandwz River, the river flow direction changes to South West, then it flow through a range of hills with different heights. It combines with

Tigris River, around 50 km from Mosul. Its width varies between around 50 m and 300 m near Tigris river outlet. (MOM&T, 2016)

The Sub Rivers and the tributaries which feed to the GZR are mainly four tributaries supply most of the water into the GZR within Erbil province in Iraq:

1. Zab River in Turkey inter to Iraq, the catchment area (9422 km^2) Average annual precipitation 1200 mm and The Average Annual River flow 168.06 m^3/sec. (5.3 BCM)

2. Sheen River in the mountain area, the catchment area is (3341 km^2). Average annual precipitation 600 mm and The Average Annual River flow 67.38 m^3/sec. (2.10 BCM)

3. Chama River also in the mountain area, the catchment area of is (1844 km^2). Average annual precipitation 1100 mm and The Average Annual River flow 34.1 m^3/sec. (1.07 BCM)

4. Rwandwz river as well as in the mountain area, the catchment area of is (2956 km^2), Average annual precipitation 900 mm and The Average Annual River flow 44.71 m^3/sec. (1.41 BCM)

5. Khazer river part of this tributary generated in mountain area within Duhok province and flows to the plain area then conjunction with the main river at the location closed to the entrance Tigris Main River downstream of Erbil province with the catchment area (3303 km^2) , Average annual precipitation 600 mm and The Average Annual River flow 31.4 m^3/sec.(0.99 BCM)

Table 3.4 GZR tributaries and its catchment area with average annual flow feed GZR

Sub River	Catchment Area km^2	Annual Precipitation mm	Average Annual Flow m^3/sec	Annual Flow BCM
Zab River Turkey	9422	1200	168.08	5.3
Sheen River	3341	1200	67.38	2.1
Chama River.	1844	1100	34.1	1.07
Rwandwz River	2956	900	44.7	1.41
Khazer River	3303	600	31.4	0.99

In general, the GZR is fed by four above branches and a large proportion of the total flows comes from the above four tributaries, the annual flow for the GZR more than 13.3 billion cubic meters. (DIE, 2016)

The area of the river basin in Sleamany province, for the purpose of simplification we decided to neglect the small part of the river basin located in Sleamany Province, in the eastern part of Erbil. The removal of the Sleamany part will not have many impacts on the assessment of the balance between the needs and the resources. The resources will take into account the tributaries and aquifers in the study area.

Although integrated water management takes into account the whole river basin from the start of the river to the outlet (Tigris River) (even to the Gulf).

Mostly the political and practical reasons oblige to restrict the study area, the GZRB divided to two parts, the first part Transboundary River Basin, which is, comes from Turkey mostly and in Iran is a very small part. The second part is national river basin that is inside Iraq.

International relations regarding water with Turkey and Iran are presented in this study as political issues between Iraq/ Erbil and Duhok, Turkey and Iran make very difficult the data access in these parts, it was decided to consider Turkey and Iran as an input for the study area.

Second part national basin: Area of the river basin in Iraq mainly included two provinces Erbil and Duhok. The outlet of the GZR into the Tigris River is in Mosul province which is part of Iraq but outside of North Iraq, figure map (3.3) shows GZRB and all sub-basins. Given the difficulties with access to these data, this area will not be taken into account.

Figure 3.3 Study area map GZRB included sub basins

The study area is limited to the part of GZRB located in Erbil and Duhok provinces in Iraq. The boundaries are technical limits, delimited according to terrain elevation with a "Digital Elevation Model" (DEM): Digital Model of the terrain's surface. For the delimitation of the GZRB, the scale is 30 meters. In the long run, political and administrative boundaries will have to overcome to reach integrated water resource management. In the following report, the "river basin" without more information will correspond to the study area. (Ismail, 2013)

3.3 GZRB Topography

Topography and limits of topographical basins, the topography is at the origin of the river basin boundary, and consequently, of the river basin management. Each raindrop (precipitation) will indeed go from the highest elevation to the lowest elevation, in our case from the North to the South, from the mountains to the GZR.

In the GZRB, three major tectonic zones can distinguish, the Thrust Zone in the north (along with the border with Turkey and Iran), the High Folded zone in the central part and the Low Folded zone in the south. Roughly, these tectonic zones are associated with corresponding major morphologic units: mountainous ranges, anticline ridges/foothill pediments, and fluvial accumulation plains (Stevanovic and MarkoVic 2004).

Elevations within Erbil province range between 3600 m a.s.l (meter above sea level) and 200 m a.s.l and hence cover a wide range of climatic zones. The average elevation of the Greater Zab basin (including the part outside of Iraq) is about 2300 m a.s.l upstream of the Iraqi border and about 1700 m for the entire basin upstream of Eski Kelek (Khabat) then 200 m a.s.l its elevation inter to the Tigris River. The alignment of the main rivers is roughly rectangular with respect to the major geological (tectonic and lithological) boundaries and mountain ridges.

Each river basin, therefore, includes three major hydrological zones:

1) A high mountain zone (equivalent to the geological “thrust zone”) with limited groundwater storage but high precipitation and significant snow storage. The area is sparsely inhabitant (even partly uninhabited due to security issues) and characterized by steep slopes and narrow valleys.

2) A more or less certified zone that drains the major karstic-fissured aquifers of the region. The relief is dominated by elongated mountain ridges that are often crossed by the rivers through narrow gaps which offer suitable sites for dam construction. From a hydrological point of view, the area is very heterogeneous, with phenomena such as canyons, dry valleys and, on the other hand, large springs (yielding several m^3/s throughout the year) which are fed by large subterranean karst systems. Depending on the tectonic situation several basins and plains are embedded in this zone (Soran basin and Harir basin plains); these are the main population centers of the zone.

3) Finally, the lowland plains, with a typical elevation between 300 m a.s.l and 600 m a.s.l The area is partly agricultural land, partly eroded ‘badland’ and includes both densely populated (around the regional capital Erbil) and sparsely inhabited areas. Significant parts of the plains are made up of the highly productive Bakhtiari aquifer, which is partly covered by fluvial deposits and terraces or less permeable layers. Groundwater resources, which are mostly of good quality but limited due to low precipitation (300 to 500 mm/y), are being used intensively by several thousands of deep wells. Most of the lowland tributaries are seasonal valleys, without permanent base flow during the dry season. The above concept necessarily simplifies the complex situation to some extent, but it is useful to distinguish the key water management zones. (DAE, 2016)

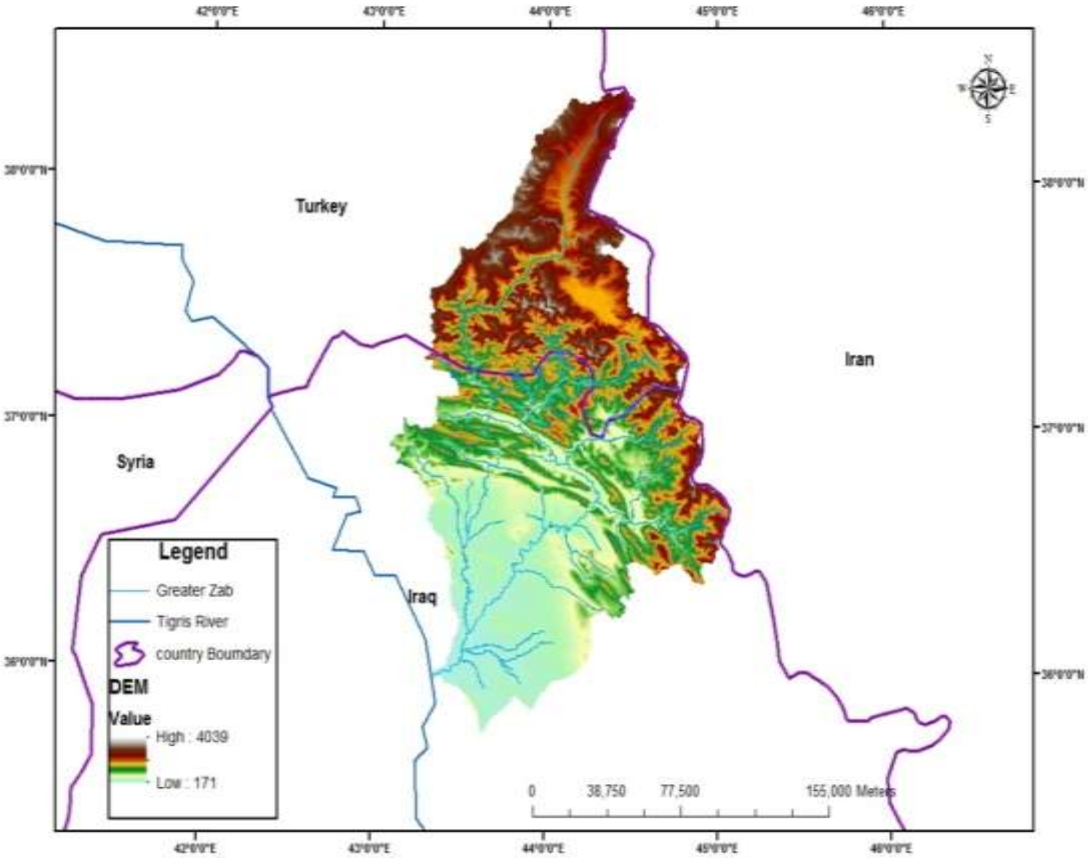

Figure 3.4 Elevation map for GZRB study area

3.4 GZRB Climate

Precipitation (rainfall and snow) is the source of the Erbil’s internal water resources, both surface and groundwater resources. Together with the inflow from Turkey and

Iran, it constitutes the total water resources that are theoretically available within the region.

3.4.1 Climate Characteristics

The climate of Erbil - Iraq generally characterized by warm, dry summers and cold winters. The transition periods in spring and autumn are very short. Precipitation is concentrated during winter, which contributes 85% of the annual total (November to April). A significant percentage of the annual precipitation, therefore received as snow, except in the lowland regions where snowfall still occurs but is less important. The main source of humidity in the region is Mediterranean cyclones that move eastwards during the winter. However, Arabian Sea cyclones from southerly directions can also cause abundant precipitation as they carry large amounts of moisture. In the summer maximum temperatures in the lowland areas exceed 45°C and dust storms are a common phenomenon. (DAE, 2016)

3.4.2 Temperature

The monthly average values of air temperature recorded at the gauging stations are given in Table 3.5 and shown in Figure 3.5 & Figure 3.6 Air temperature ranges from minimum values of –6 °C in February to 46 °C in August, exhibiting strong fluctuations during the day in all seasons. Data are recorded in the period 2001 – 2016. Data from Erbil meteorological station are available for the period 2000 – 2010.

Table 3.5 Monthly Average values of temperature (°C) (Erbil Metrology, 2016)

Loc.	**Temp** (°C)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual aver.**
Qadish	T Ave.	3.4	10.3	13.6	11.7	16.0	28.8	30.8	27.7	25.8	19.7	12.2	2.7	16.9
Soran	T Min.	-5.0	**-6.0**	-2.0	2.0	8.0	8.0	22.0	20.0	14.0	5.0	-1.0	-6.0	
	T Ave.	4.4	5.3	10.8	15.2	21.6	26.5	32.7	32.1	27.2	20.4	12.2	6.5	17.9
	T Max	14.0	19.0	27.0	28.0	37.0	40.0	44.0	**46.0**	39.0	35.0	25.0	23.0	
Gopal	T Ave.	6.6	9.9	13.4	18.0	23.4	31.1	35.1	32.7	28.6	23.7	14.6	7.7	20.4
Erbil	T Ave.	8.4	9.9	15.0	19.1	25.3	31.5	35.0	34.2	29.9	24.8	16.7	10.9	21.7
Aver.		5.7	8.8	13.2	16.0	21.6	29.5	33.4	31.7	27.9	22.1	13.9	7.0	19.2
Standerd Dev.		2.2	2.4	1.7	3.3	4.0	2.3	2.1	2.8	1.8	2.5	2.2	3.4	2.6

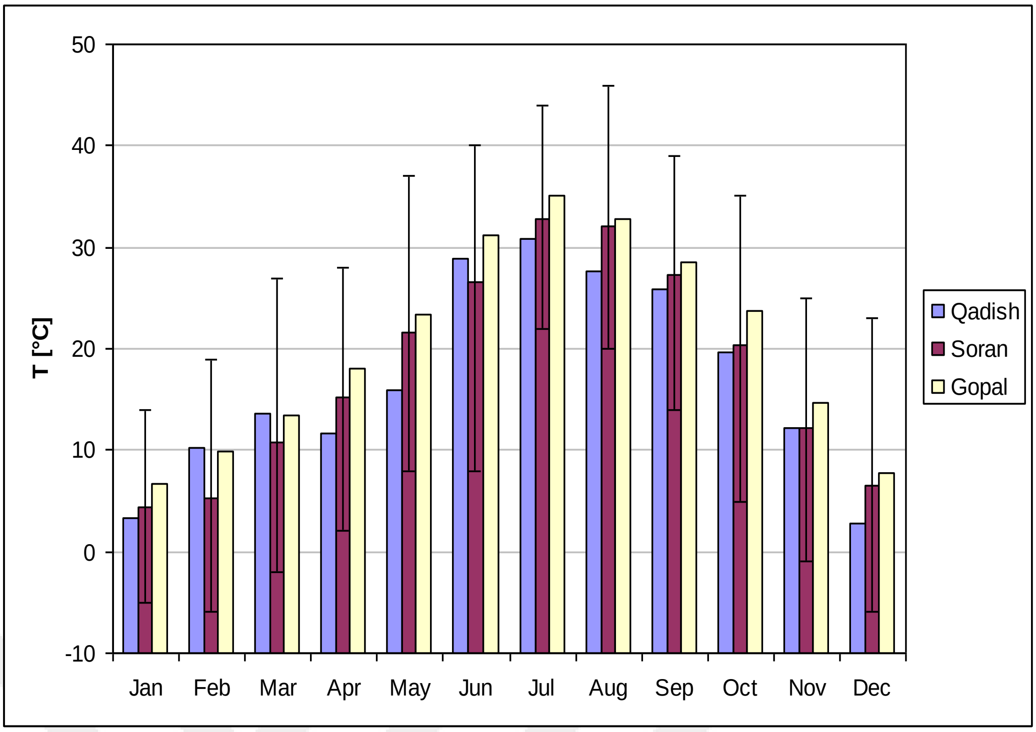

Figure 3.5 air temperature ranges

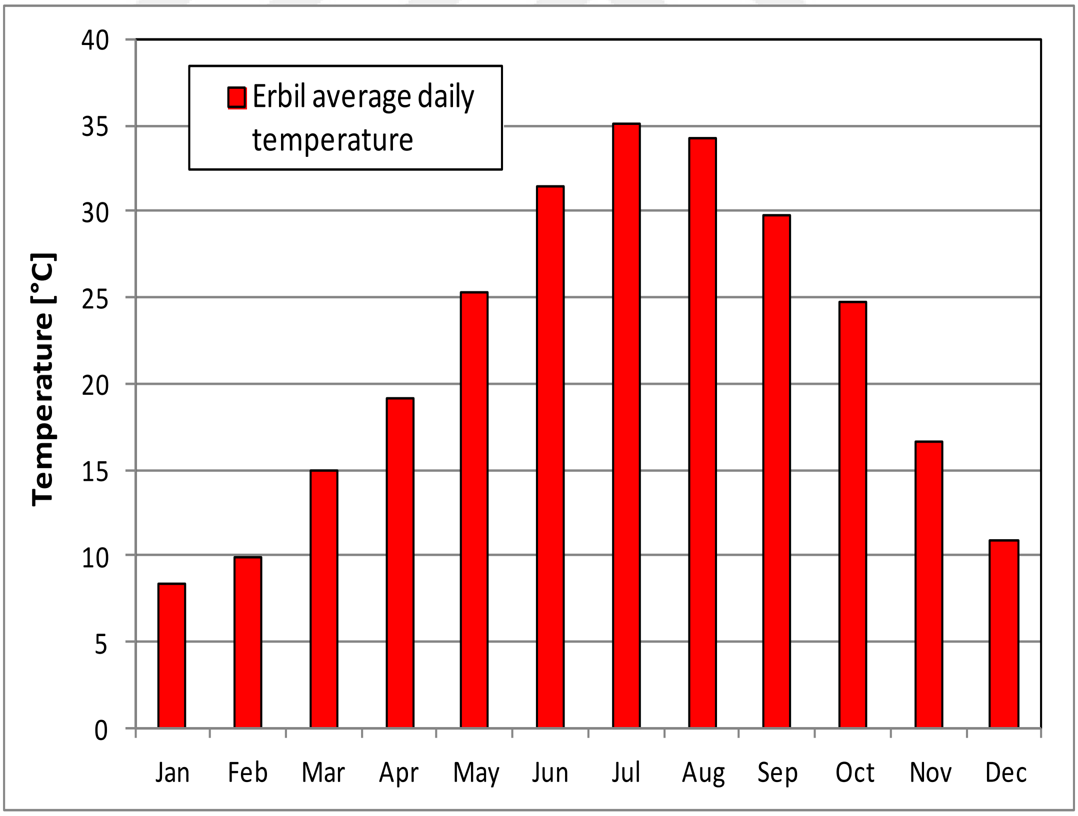

Figure 3.6 Average temperatures at Erbil station for the period [2000-2009].

3.4.3 Humidity

The monthly average values of relative air humidity recorded at the gauging stations are given in MOM&T (2016) and shown in figure (3.7). Air humidity reaches its minimum in the summer when the temperature is high and average daily values reach 18% in Gopal, 23% in Qadish and 44% in Soran. The maximum values of air humidity are recorded during the cold winter months, reaching 77% in Soran, 78% in Qadish and 82% in Gopal. The parameter exhibits strong variability during the day, especially during the autumn, when a range from a daily minimum of 20-30 % to a maximum of 100% is observed. Data are the averages of minimum daily relative air humidity, of mean daily relative air humidity and of maximum daily relative humidity, recorded in the period (2001 – 2016). Data from Erbil meteorological station are available for the period (2000 – 2016). (MOM&T, 2016)

Table (3.6) compiled from original data provided by the various meteorological and agro-meteorological departments; provide key data for two stations at different altitudes and monthly average values of relative air humidity [%] in the selected meteorological stations for the period [2001-2016] at Erbil station. Temperatures can be estimated reliably from elevation. Figure (3.7) below shows that there is a close linear relationship between temperature and altitude above sea level, with a gradient of about 0.62 degrees C per 100 meters. The figure also provides formulae for estimating the average temperatures of July and January as well as the annual mean from altitude.

Table 3.6 a) Climatological data for selected stations

Erbil period: 1992-2013 station elevation: 420 m

	Unit	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
T mean	°C	8.2	9.6	13.5	18.3	26.3	30.9	34.2	33.8	29.2	23.6	15.3	9.8
T max	°C	12.6	14.4	19	24.3	34.5	38.4	41.7	41.6	36.7	30	20.6	14.5
T min	°C	3.8	4.7	8	12.2	18.1	23.4	26.6	26.1	21.7	17.1	10	5
Rel. Hum	%	69	67	59	54	39	26	25	26	30	40	56	69
Vap. Press	Mbar	10.3	8.4	9.9	12	12.5	12.3	13.8	13.9	12	11.3	9.7	8.5
Sunshine	H	4.9	5.6	6.7	7.7	8.9	11.1	11.3	10.9	9.7	7.7	6.2	4.9
Wind	m/s	2.5	2.7	2.7	2.8	3	2.6	2.5	2.3	2.2	2.3	2.1	1.9
Pan evap	mm/d	1.6	2.3	3.9	5.4	8.8	12.3	13.5	12.7	9.9	6.2	3	1.7

Table 3.6 b) Climatological data for selected stations

Salahaddin period: 1992-2009 station elevation: 1087 m

	Unit	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
T mean	°C	5.4	6.3	10.4	15.3	21.4	26.9	30.9	30.9	26.4	20.4	11.7	7.3
T max	°C	8.4	9.5	14	19.5	26.1	31.8	36.3	36.6	31.7	25.4	15.6	10.4
T min	°C	1.9	2.5	6.3	11.1	16.6	22.1	25.5	25.2	21.1	15.5	7.7	4.2
Rel. Hum	%	74	71	61	56	42	34	34	34	39	48	62	68
Vap. press	Mbar	6.3	6.5	7.8	10	11.6	12.5	15.6	15	12.8	10.7	8.3	6.5
Sunshine	H	4.8	4.5	6	6.8	9.1	11.3	11.5	10	9.6	7.5	6	4.9
Wind	m/s	2.1	2.4	2.8	2.9	2.7	2.8	2.4	2.4	2.3	2.2	2.1	1.9
Pan Evap	mm/d	1.2	1.5	2.9	3.9	6.7	9.8	10.3	9.6	7.1	4.6	2.1	1.4

Total annual pan evaporation is 2,470 mm for Erbil and still 1,860 mm for Salahaddin, at an altitude of 1,087 m. Evaporation losses from open water surfaces are therefore significant and need to take into account in planning water resources development. Alternative options such as subsurface storage and artificial groundwater recharge should be carefully considered in order to minimize water losses.

Temperatures can estimate reliably from elevation. Figure 3.6 shows that there is a close linear relationship between temperature and altitude above sea level, with a gradient of about 0.62 degrees C per 100 meters. The figure also provides formulae for estimating the average temperatures of July and January as well as the annual mean from altitude.

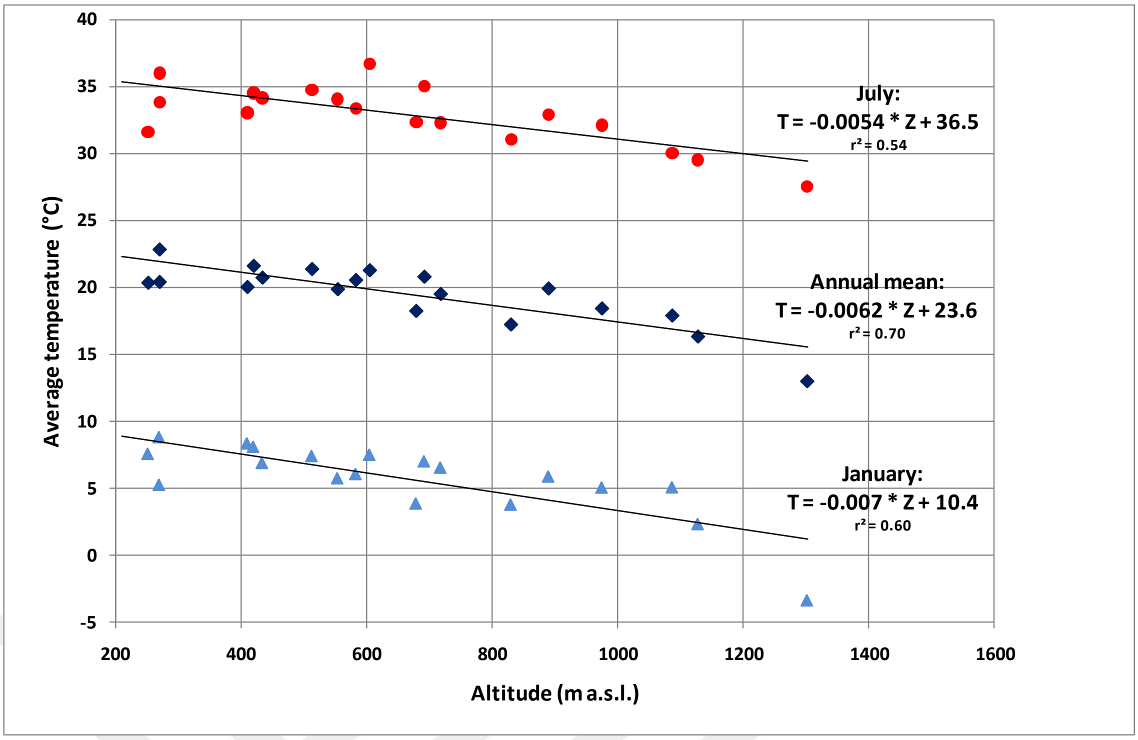

Figure 3.7 Correlation between altitude and temperature in Northern Iraq

The outlier at the far right end (coldest station) Meargasor, where temperatures are particularly low due to high precipitation (among the highest recorded in Erbil) and long duration of snow cover.

3.4.4 Metrology Stations

The Directorates of Meteorology operate a small number of official meteorological stations, which are important for long-term statistical analyses as for some of these stations continuous time series since the 1940s are available. In addition, a number of automatic weather stations and rain gauges have installed recently but processed data were not yet available for analysis.

The assessment of the spatial distribution of precipitation in this report essentially based on the much denser network of agro-meteorological stations and rain gauges operated by the Directorates of Agro-Meteorology. Most of these stations have started operating in 2000 or 2001.

The following table 3.7 provides an overview of data availability by province. Some of the rain gauge stations are also equipped with the monthly hydrograph; some are or were temporarily equipped with automatic weather stations. A few stations have stopped operations but could still be used for interpolation, as several years of data were available to establish correlations.

Table 3.7 Characteristics of the agro-meteorological networks by province

Province	Long term metrological station	No. of agro meteorological Stations	No. Of rain gauges (agro-met)	First year of data	Average no. of complete Years
Erbil	Salahaddin	8	15	1941	8
Dohuk	Zakho	6	23	1975	11
Total		14	38	1941	19

3.4.5 Evaporation

Evaporation rates are high in summer due to a combination of high temperatures, the absence of clouds (high radiation) and low air humidity: Summer maximum day temperatures reach 42°C in Erbil (average of the months July and August) and still 35°C at an altitude of 1300 m above sea level . Relative humidity during the summer months ranges between 20 and 30% in the lowlands and is less than 50% even at the highest meteorological stations. Table (3.8) shows monthly averages of reference evapotranspiration calculated with the FAO CROPWAT software (v8.0). (MOA&WR, 2016)

Table 3.8 Reference evapotranspiration (based on the Penman-Monteith equation):

Metrology. Station	Altitude a.s.l.	Annual ET_0 (mm/y)	Month (average in mm/day)											
			J	F	M	A	M	J	J	A	S	O	N	D
Erbil	420 m	1799	1.5	2.0	3.1	4.4	7.1	8.5	8.9	8.2	6.6	4.7	2.6	1.4
Salahaddin	1087 m	1540	1.1	1.5	2.6	3.8	5.7	7.5	7.8	7.3	5.8	3.9	2.0	1.3

3.4.6 Distribution of Precipitation

Precipitation is generally increasing with elevation, i.e. from South West to North East Average annual precipitation is:

- 200 to 500 mm in the lowland plains (Erbil City: 400 mm), with lower values (down to less than 250 mm) found in Makhmur District (Erbil Province

- 500 to 900 mm in most of the central, karstified zone. There are considerable variations according to the local topographic conditions, and it is likely that higher values occur (but are not measured) at high elevations.

- 700 to >1200 mm in the high mountain zone along the borders with Turkey and Iran. Annual averages above 1000 mm are recorded in Meargasor, Sherwan Mazin (Erbil Province)

Precipitation in the high mountain regions is likely to rise well beyond 1000 mm; however, isohyets of more than 1000 mm are only shown on the map where higher values are justified by measurements figure (3.8) illustrated contour map for rainfall.

Some of the inner valleys surrounded by high mountains (Soran, Choman, Amadia, and Kani Masi) seem to be shielded - a phenomenon that is well known from other mountainous regions – and have moderate precipitation around 700 mm/year.

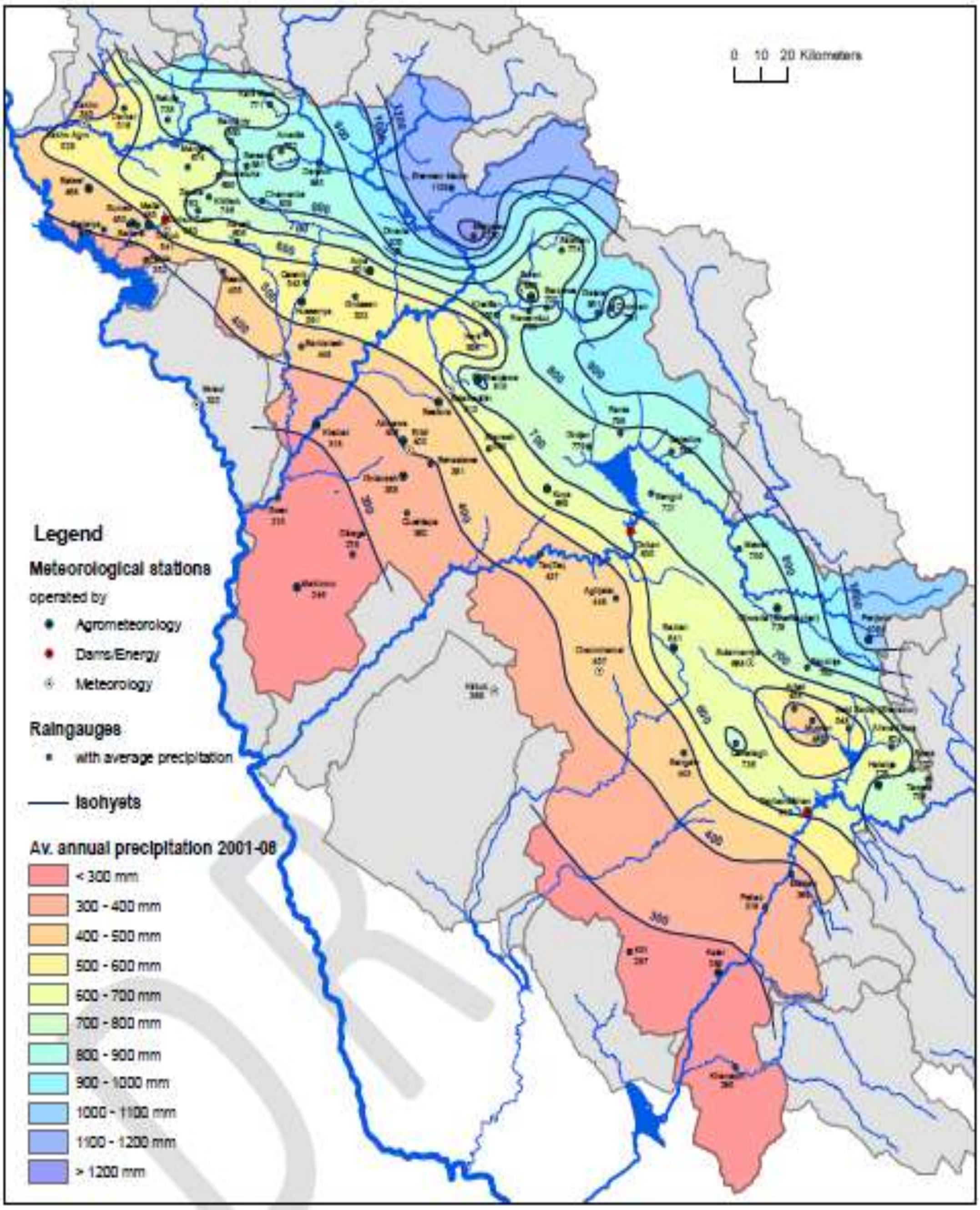

Figure 3.8 Average annual precipitation for reference period: 2001-2008

3.4.7 Seasonal Distribution of Precipitation

The climate diagrams demonstrate that despite the differences in elevation and annual precipitation in absolute terms the seasonal distribution of precipitation is very similar. Excess precipitation and hence groundwater recharge and runoff generation occur from October lowland: November to April only 85 % of the annual precipitation is concentrated in half of the year November to April whereas the four summer months June to September contribute less than 5%.

3.4.8 Snow

In the mountainous areas, most of the winter precipitation is stored as snow. Data on snow depth or water equivalent are not available but the clear spring peak of river flow is an indication of the significant role of snow storage and snowmelt processes.

Snowfall and snow storage is a key factor for the volume of runoff and seasonal distribution of it and, hence, the availability of surface water resources. Automatic snow stations installed at high elevation would produce valuable data on snow accumulation and snowmelt for long-term flow forecasts. Installation of this type of stations was under preparation but not accomplished at the time of writing. The annual average depth of snow around (1.0 m) in Meargasor and Choman districts according to the (Directorate of Irrigation Erbil), annual report (DIE, 2016)

3.4.9 Drought Periods

Drought periods are a common climatic feature in regions with high precipitation variability such as Erbil, where the average coefficient of variation of annual precipitation is around 30%. Any water management and water use infrastructure should plan and designed taking drought probabilities into account, including the occurrence of a cluster of dry years (1999) have been the driest year ever observed at most stations. The table (3.9) compares drought characteristics for several stations with long-term records.

Table 3.9 Dry years for selected stations with long records (DME, 2016)

Station	**Period**	**Average Precipitation (mm)**		**Dry Year 10 Year return period**		**Driest year over recorded**	
		All Years	2001-2016	Mm	% of Average	mm	Year
Erbil (city, center)	1941-2016	417	403	262	63%	228	1999

Precipitation in a dry year with a return period of 10 years is 30% to 40% less than in an average year. Total precipitation in a wet year again with a return period of 10 years is approximately twice as much as in a dry year. For example, Erbil, with an average precipitation of 417 mm, receives 589 mm in a wet year but only 262 mm in a dry year with a return period of ten years.

The variability of water resources availability depends not only on climatic drought patterns but also on groundwater drainage patterns and storage characteristics, which are highly variable. The effects of climatic drought are "buffered" in watersheds with significant groundwater storage whereas flow may be reduced to zero where the storage capacity is small or where groundwater is drained to other watersheds due to the geological situation.

3.4.10 Trends and Evidence of Climate Change

Climate change is a phenomenon takes into account in master planning as it affects the decision to make and the appropriateness of designs in water management. A full discussion of the phenomenon, in particular downscaling of regional predictions to analyses local effects in Erbil province, is beyond the scope of this study. However, the length of some of the available meteorological records allows analyzing whether any trends can detect.

Two relevant questions can be analyzed in this way:

1. Is precipitation generally decreasing?
2. Is there a change in the seasonal pattern of water availability?

The second question is relevant because there is evidence that in certain regions, such as Central Asia, rising temperatures tend to cause earlier snowmelt and a smaller percentage of the total precipitation being stored as snow. Consequently, runoff in spring tends to become more "peaky" and to occur earlier, a phenomenon that reduces water availability during the growing season. The available evidence from Northern Iraq wills discuses in the context of flow regime changes.

Whether precipitation is generally decreasing in Northern Iraq has been widely discussed, in particular after the exceptional drought period from 1999 to 2001, which caused a significant depletion of water resources (including the emptying of Dokan and Darbandi Khan Reservoirs). However, clusters of dry years are a normal statistical phenomenon in regions with high climatic variability and are not necessarily an indication of climate change. In order to investigate possible downward long time-series (between 120 years of data) have been analyzed the results are shown in Figure (3.9).

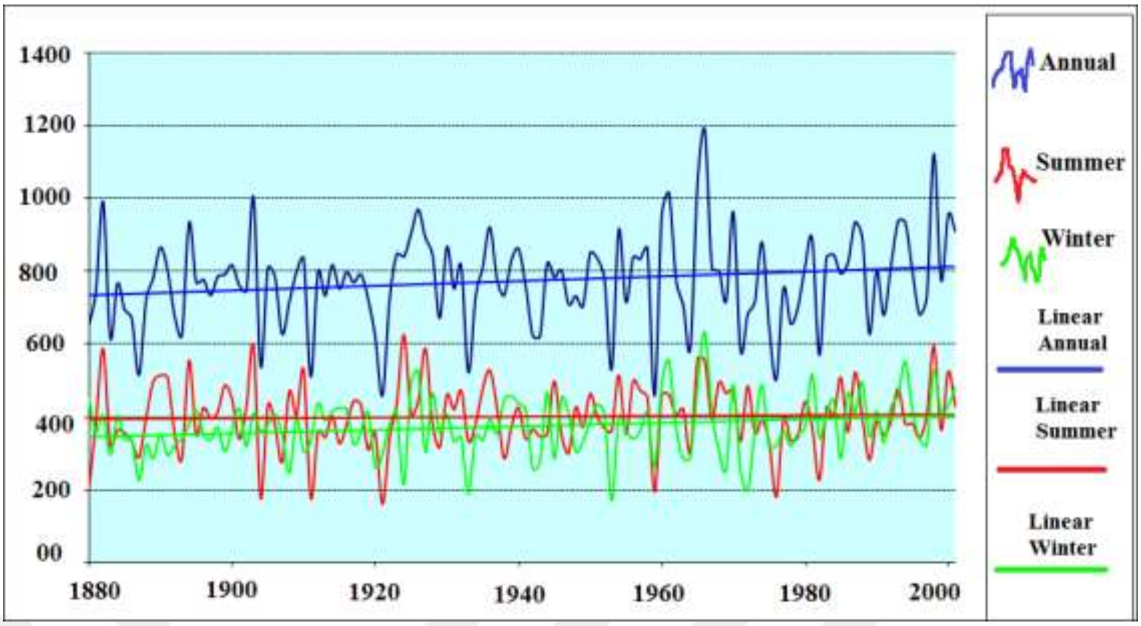

Figure 3.9 Observed data of Average annual rainfall Erbil Governorate. stations

3.5 Water Resources

The Erbil province located in Northern Iraq is not an exception from rest of the Middle East. Similar conditions apply to this city as well. The water scarcity is increasing and a binding constraint on economic and social development in the region. The scarcity of water is a result of neighboring country Turkey branching of water, changes in population growth and weather changes. It is important to make a survey the current economic, social and water resources conditions and alternative sources of water and to propose measures to enhance the effectiveness in the use of water resources to reduce the shortages in supply and negative environmental effects.

The water Resources in Erbil province generally divided to two parts, the first part is surface water (rivers, streams, springs, kahrez) and the second part is groundwater including different underground lakes in different depth underground.

3.5.1 Surface Water

As for meteorological data, hydrological data availability has seen a significant improvement in the last decade. The information that exists such as hydrological data, historical and recent, could be used for this study. Recent stream flow gauging data made available by the directorates of irrigation, Erbil (DIE). Finally, additional data (in particular the results of temporary measurement campaigns) were available from the consultant's earlier work under UN programs with hydrological components (FAO, UNDP). The historical network of gauging stations in Northern Iraq had not been dense. Installed in the context of the Hydrological Survey of Iraq (1956-1963) or earlier, it included just eight stations within up to date: (One station on Tigris, one station on Khabur, four stations on Greater Zab and its tributaries, one on (Little Zab) Lesser Zab, and one on (Sirwan river (or Diyala river))

In total, the existing network in Erbil and Dohuk Provinces consists of 26 stations (including two stations installed for spring flow monitoring). For two stations, no discharge data are available, as no rating curve has been established; hence, 24 stations were available for the analyses. Key stations characteristics and periods of record both for the historical and recent networks. Figure.3.10 shows the locations of these stations within the river basins.

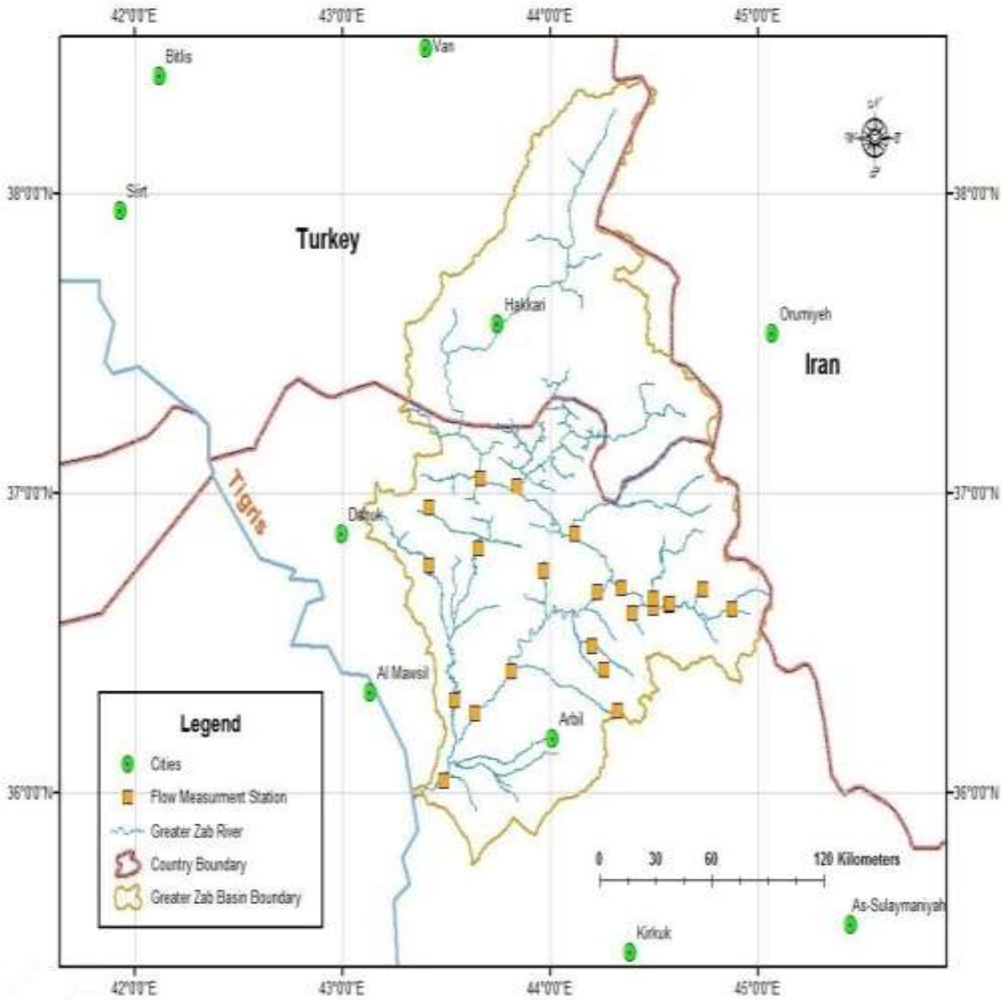

Figure 3.10 Flow measurement locations on the tributaries of GZRB

Description of the hydrographic network: the river and its tributaries, GZR generated from the mountainous area in Turkey and flows to the outlet to the Tigris River in Mosul province. There are 15 tributaries supply the main GZ River:

A. Two (2) of them are trans-boundary namely Shamdinan (from Sheen) and Haji Bak (from Chama river), which delimit a portion of the boundary between Turkey and Iraq

B. Six (6) main tributaries are totally located in Erbil Province (one on right bank namely Khazer, 5 on left bank namely Shin river, Chama river Rwandwz river, Mawran river, Bastora river).

C. Seven (7) secondary tributaries with the hydrographic network

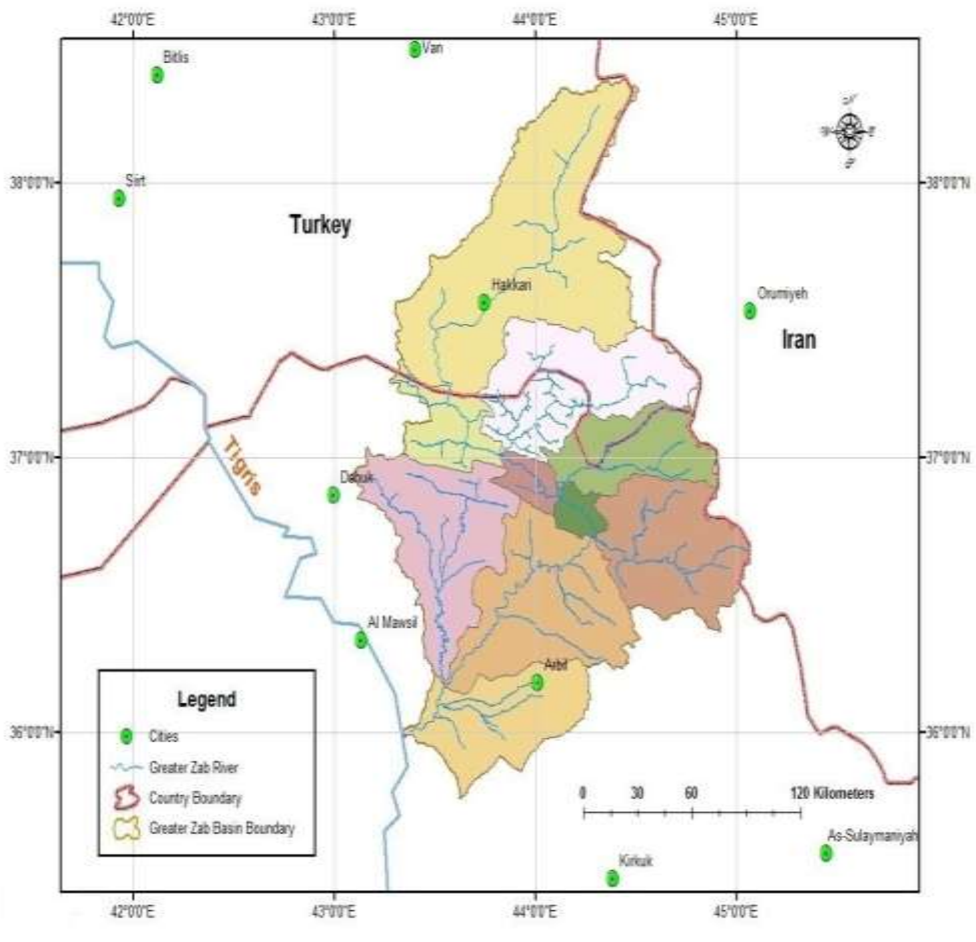

Figure 3.11 Map of GZR and its tributaries

A hydrographic network concentrated and seasonal Because of an undulated topography, the hydrographic network includes many lowest points of a streambed or a valley. These streams are seasonal, which drain water to the Greater Zab in the rained season and are dry in summer season

Conceptual scheme of the hydrological network in order to analyses water resources and uses in the study area decided to the division the whole basin into 22 sub basins. The division is made according to topography, hydrology, and according to the location of main infrastructures for water management. The 22 sub-basins linked together according to the following conceptual scheme, as shown in figure 3.12 and the monthly discharge for five sub-basins illustrate in table 3.10

Figure 3.12 Illustrates map of GZRB sub basins

Table 3.10 Annual and monthly river flow for GZRB

		Mean annual flow rate (Mm^3)	Ecological limit (Mm^3/ month)	Lowest monthly flow rate (Mm^3)	Months
SB1	Mean Year	2700	23	80	September
	Dry Year	1900	23	20	June – Aug.
SB2	Mean Year	8700	73	220	September
	Dry Year	5700	73	150	September
SB3	Mean Year	9000	75	230	September
	Dry Year	5900	75	150	August
SB4	Mean Year	8900	75	220	September
	Dry Year	5900	75	150	August
SB5	Mean Year	9300	80	230	September
	Dry Year	6200	80	160	August

First differentiation is between the sub-basins of the main river and those of the tributaries. Greater Zab divided into (6) sub basins figure (3.12 & 3.13) illustrated Catchment area and sub basins. The sub-basin zero (SB 0) is located in Turkey. The other five are determinate as follow:

- Sub-basins 1 and 2 defined according to the elevation 90 meters
- Sub-basins 3 and 4: separated with the location of planned Mandawa dam
- Sub-basins 4 and 5: separated with the location of the intake of Khabat project 16 sub-basins correspond to the tributaries. 2 of them are in Turkey (SB 21 and SB 22).
- Sub-basin Zero, the generation area of the river basin which is located in Turkey as well as the sub basin (SB 21 & SB 22) also located in Turkey

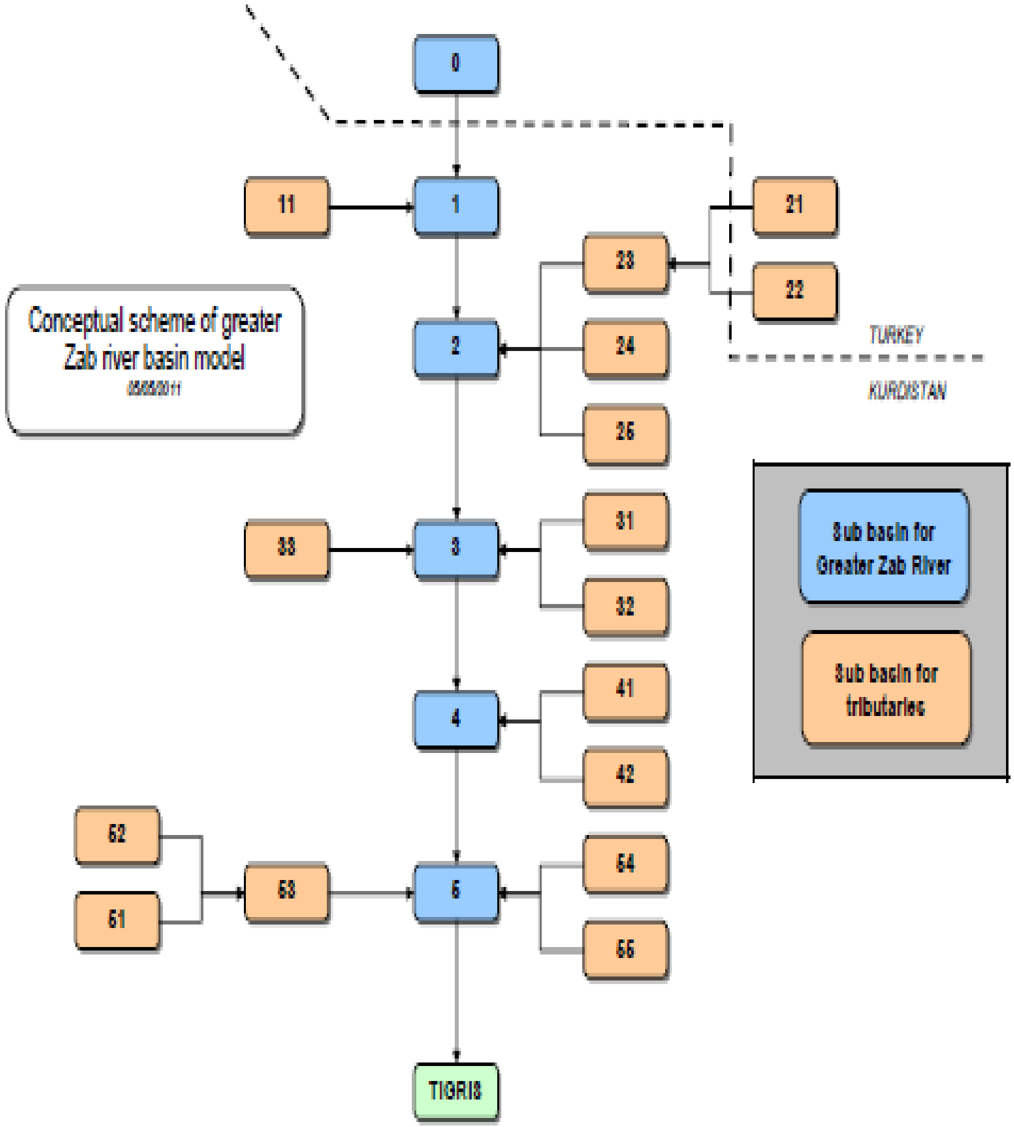

Figure 3.13 Conceptual scheme of GZRB and sub basins

3.5.2 Ground Water

Knowledge of the groundwater resources of Erbil province has significantly improved since 2000 when a major hydrogeological investigation (and drilling) program was launched by FAO.

Earlier hydrogeological investigations undertaken in particular by R. Parsons Company (1953), the Institute of Applied Research on Natural Resources (IARNR), Bagdad (1975) and others were resumed in the study resulting from the FAO program: Hydrogeology of Erbil province (Stevanovic and Markovic, 2004). This program also launched well and spring monitoring program as well as a field investigation and mapping program including remote sensing and geophysical surveys.

In Erbil governorate, the discharge of the important springs of Bekhal and Jundian is being monitored by the Irrigation Directorate. For other springs, the monitoring data of 2000-2003 (and/or the interpretation provided in the "Hydrogeology of Northern Iraq") could be used to assess the average values and variability of discharge.

Generally, the current situation for groundwater depth more than 300 meter in Erbil province, during last 50 years was 100 meter, due to an abstract big amount of water from groundwater and used for domestic as well as Agriculture and industrial sectors

3.5.3 Problems Definition

Water resources developments in Iraq are strongly influenced by hydrologic conditions. There are difficulties in term of management (difficulties in coordination between users, lack of organizing management between stakeholders, lack of coordination between reservoirs, lack of combination management between surface water and groundwater, lack of water demand measurements).

This research focuses on the water analysis and planning system within the GZRB as well as the controversial impacts that the planned different water supply and demand project may give along the Greater Zab and more downstream. This demands and projects led to the several research questions and sub-questions:

1) What are the existing projects in GZRB and how is related to the water plans and to water users?

2) What are the water lows and current environmental instructions and regulations follow within the river basin?

3) What are the current and future social harms as a result of population increase within the river basin?

4) What are the effects of all activities and development projects on environment issues within river basin?

5) Who are the beneficiaries and affected by development projects within the river basin?

6) Who is harmed by the establishment of water and investment projects and how to compensate them for their loss and what are the views of these victims?

7) What are the effects of (Megaprojects) especially water projects and dams on the upstream and downstream countries, what's the relations, cooperation's and coordination's are among them?

8) What are the most appropriate water allocations and how uses of water by all sectors?

9) What is the Optimum use of the river basin waters and what are the sector's priorities?

While the ground water used by digging many deep wells in the downstream area of Greater Zab watershed the ground water level draw down the water supply in Erbil city and its districts faced many problems (supply surface water from river and ground water from deep wells by pumping, population 1.2 million in addition to 0.750 million refugees located in downstream of Greater Zab watershed) therefore construction this reservoirs, water supply projects and water treatment plan as well as the other agriculture projects with new system using will solving these problems and the planning to stop pumping groundwater established to save the ground water which its part of the project then conservation of ground water indirectly.(MOM&T , 2016)

The Water users system in GZRB will be described in details, and is presented in figure (3.14) shows a conceptual description is given of this system and the associated planning and operation problems after completion the GZ watershed on the upstream of the river, the focus is finally on identification of the greater Zab management problems.

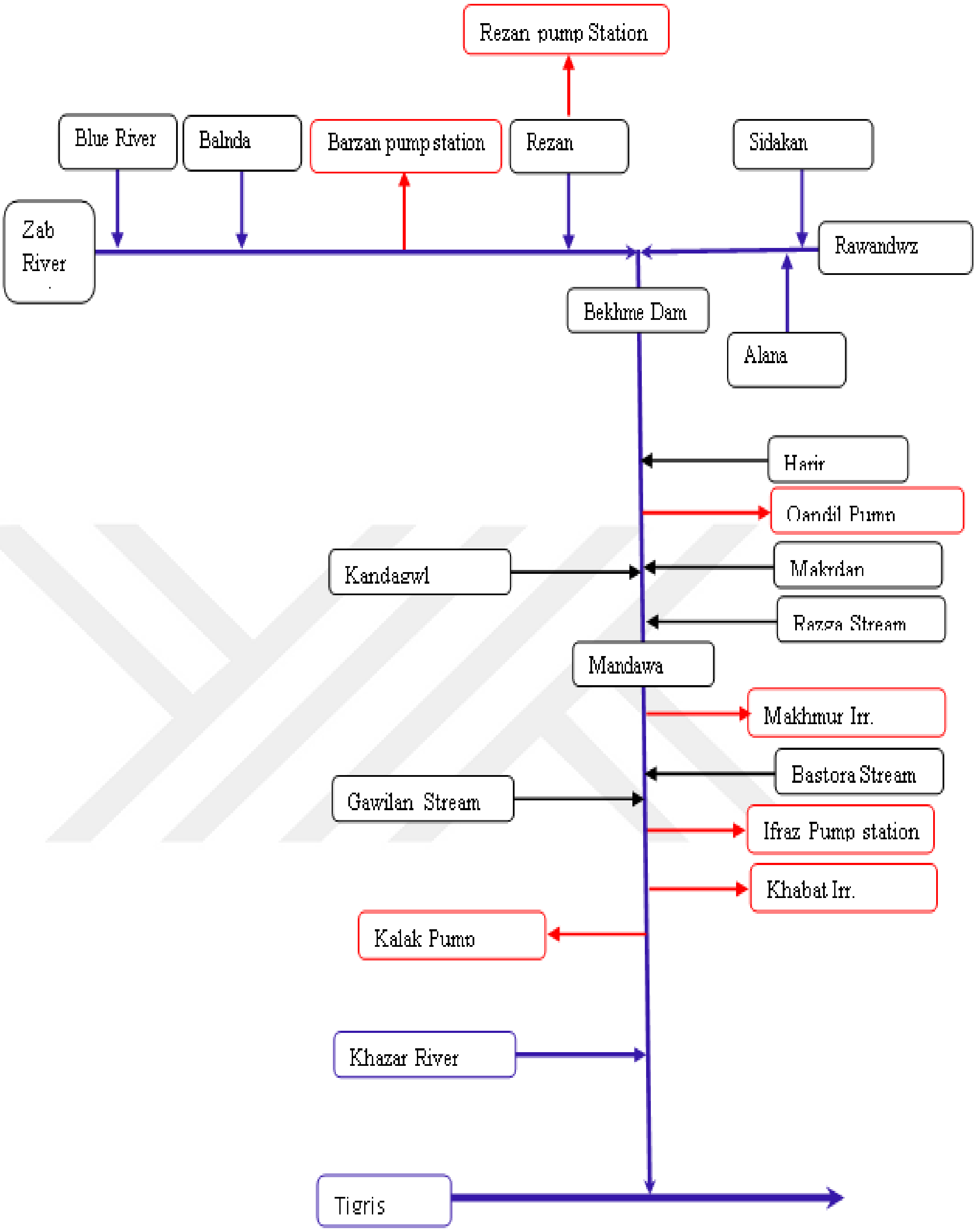

Figure 3.14 Water system configuration of the GZR to the Tigris River

The reservoir system planned to construction on 2030 and provides water to an existing irrigation area rather than increasing agriculture land in the downstream and domestic water allocation for Erbil city and reservoir system provides flood control to the downstream part of the river basin

Generally supply of electricity in Iraq very poor, the average supply 6 hr. per day with free of charge, the local generators installed in the area for power supply to the houses with very high charge therefore the Erbil Province, give the priority to restarting the water projects and dams construction, for supply electricity to the cities with law charge will be calculate and fixing by government, as well as water supply for Irrigating and domestic, and floods in the second priority.

In that way, WEAP is a mean of achieving three key strategic objectives being: efficiency of resource use, equity in the allocation of a scarce resource and environmental sustainability. Thus, Integrated management is not just technical but also covers the legal, administrative, economic, financial and of course political aspects of an issue

The different objectives for the different purposes for this research can be summarized as follows:

1) Restart construction of Bekhme dam with capacity 17.1 for controlling river flow.

2) The interest in outflow is to provide a maximum amount of water to the downstream with a high reliability of meeting a planned target, downstream projects. Maintaining a high reliability for meeting water need during infrequent drought or low inflow conditions expected to occur at unknown times in the future is a key consideration in water supply management.

3) The interest in (flood and drought) control as well as minimizing flood and drought damages in GZRB rather than Tigris River.

Therefore Erbil province decided to plan for controlling the water systems and the evaluation of impacts should consider the impacts of shortage in the GZR system. For a given source of water, the shortage damage will increase with an increasing target for water supply, its most important things to planning for finding this result in an economical optimum value.

Usually the target water supply for a given source it will be determined by specifying a specific return period over which a shortage is allowed and it will be based on the consequences of a shortage for projects in the past. Specification of a return period as a criterion avoids the need to make an elaborate analysis to determine an economic optimum for each new water supply project

3.6 Optimization of Operation Strategy

The main objective of this thesis is to derive operation strategy for the GZRB and its project structures to determine its effect on the performance of the Greater river water system. The approach to such analysis is introduced to decision variables, which should be chosen to optimize the performance of the system, comprise the longer- and short-term operation rules.

Those operation rules are strongly related to the targets or the different water users, the growing demand for urban water supply and irrigation; it is expected that an efficient operation strategy covering the extreme situations can substantially improve the ability to provide extra water supply with a sufficient reliability Due to the lack of power production and electricity shortages reconstructing Bekhme reservoir and the energy has a priority and should optimize with the other purposes. .

Similarly, the operation rules have a strong interaction with the firm energy target, the quality of water flow will be one of the objectives due to the availability of several big cities within the basin, on the other hand, there's no water treatment plant available.

A modeling approach will be tested using a new program for model formulation in combination to carry out the optimization. Several extended versions are now available, capable of handling large and complex optimization problems. During my research, The GIS used for mapping as well as WEAP software programming which is water evaluation and planning system for the river will outcome.

An optimization approach using a mathematical search routine would be very useful for a systematic and automated search among the many possibilities. The concept of such approach is presented in Figure (3.15)

The objective function to be maximized or minimized measures how well an object is attained. A typical operation objective might be the minimization of operating cost C (Eq. 1) or to maximize the total net annual benefit NB (Eq. 2). Both NB and C is potentially dependent on the volume in storage (st), the inflow (qt) and release (rt) in each presumed operation period t (Jain and Singh, 2003).

$$\min \mathrm{Z} = \sum_{t=n}^{T} \left\{ C_t(s_t, q_t, r_t) + v(s_{T+1}) \right\} \quad (1)$$

$$\max \mathrm{Z} = \sum_{t=1}^{T} \{ NB_t(s_t, q_t, r_t) + v(s_{T+1}) \} \quad (2)$$

Where

t = index of time; st = state vector of storage at the beginning of period t; qt = state inflow; rt = decision variable releases $C_t(s_t, q_t, r_t)$ = immediate cost function; $v(s_{T+1})$ = new feature terminal start value function; $NB_t(s_t, q_t, r_t)$ = immediate benefit function.

The system dynamics or state-space equations are written as follows, based on the preservation of conservation of mass throughout the system:

$$s_{t+1} = s_t + Cr_t + q_t - l_t(s_t, s_{t+1}) - d_t$$ (For t = 1,……….. T)

Ct= system connectivity matrix mapping flow routing within the system; l_t = vector combining spills evaporation, and other losses during time t; and d_t = required demands, diversions, or depreciation from the system. In some formulations, diversions are treated as decision variables and included in the objective function as related to benefits of supplying water (Labadie, 2004).

Explicit lower and upper bounds on storage must be assigned for recreation, providing flood control space, and assuming minimum levels, dead storage and power plant operation.

$$s_{t+1,\min} \le s_{t+1} \le s_{t+1,\max}$$ (For t = 1,…… T)

Limit on reservoir release is specified as

$$r_{t,\min} \le r_t \le r_{t,\max}$$ (For t = 1,……T)

Stochastic dynamic programming (SDP) formulations can be developed to solve reservoir operation problems (Tejada et al., 1993). SDP recursively constructs the benefit function (f_t), which depends on the volumes in storage and on the hydrologic conditions for each time period and for each state of the system. The components of the state vector typically include the volume of water in each one of the reservoirs (s_t **)** and a description of current hydrologic conditions (q_t). If the operating benefits are being, maximized the recursive SDP equation can be written as:

$$f_t(s_t, q_t) = \underset{r_t}{Max}\{B_t(s_t, q_t, r_t) + \underset{q_{t+1}/q_t}{E} f_{t+1}(s_{t+1}, q_{t+1})\} \quad (3)$$

$$f_t(s_t, q_t) = \underset{r_t}{Max}\{B_t(s_t, q_t, r_t) + P(q_{t+1}|q_t) f_{t+1}(s_{t+1}, q_{t+1})\} \quad (4)$$

Where

$f_t(\mathbf{s}_t, q_t)$ the optimal value function at stage t, st is the vector of storages at the beginning of period t; q_t is the vector of inflows during period t; r_t is the release state during period t; $\underset{\mathbf{q}_{t=1}/q_t}{E}$ is the conditional expectation operator for inflow q_t given the hydrologic state q_t; and $P(q_{t+1}|q_t)$ is the transition probability from flow q_t to flow q_{t+1} Alternatively, in each period t one can solve the model defined by equation (4) to obtain the best decision for the current and sequence of future periods, taking to account all current information regarding the objectives and possible inflow scenarios and their probabilities. The actual release decision in the current period can be expected value of all these releases in this current period. At the beginning of the next period, the model is updated with respect to current initial storage and inflow scenarios and solved again.This process continues in real time.

The solution of the functional SDP Eq. (4) usually requires the discretization of the state space. The future cost function f_{t+1} is therefore only evaluated at the grid points and interpolation methods are usually adopted to approximate the future cost function f_{t+1} between the grid points (Johnson et al., 1993). The so-called discrete SDP algorithm is powerful provided the state space is small, e.g. the number of storage reservoirs does not exceed 3 to 4. If the number of reservoirs is K and that all reservoirs are discretized into N storage levels, the computational effort will be proportional to N^K, making SDP not suitable to solve the large problems.

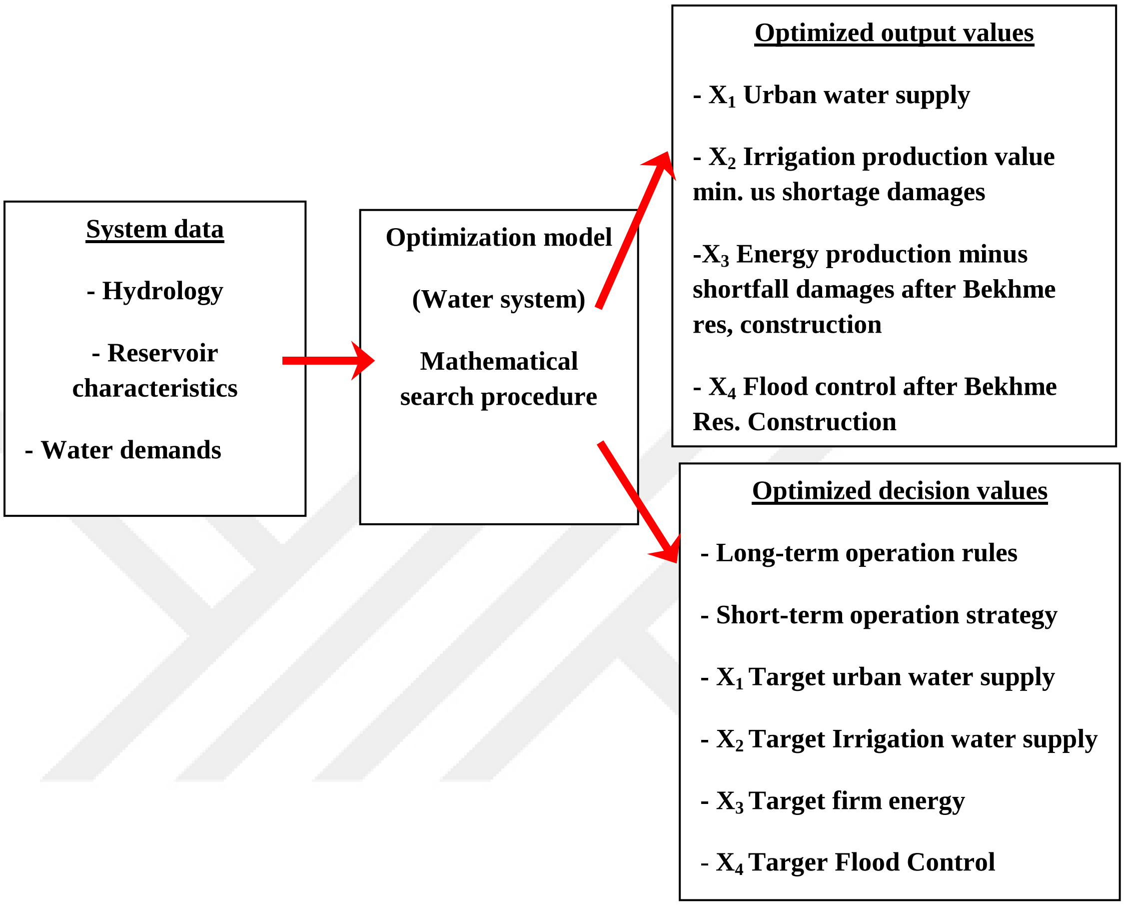

Figure 3.15 Analysis approach using optimization

3.7 Water Monitoring

Water quantity and water quality are not managed by the same stakeholders. “Water quantity” Discharges are measured by gauge stations in several locations on the GZR and on the main tributaries or springs. The Directorate of Irrigation Erbil (DIE) is responsible for discharge monitoring in the Erbil Province. The same directorate is present in Dohuk and manages its stations. The monitoring tools are the same in each province: courant meter and gauging scale. Regarding the methodology for measurement:

A. The gauging stations are read twice a day.

B. The raw data is processed with Graphic and Excel.

C. The flow rate value is calculated as rating curves.

And the table (3.11) shows the gauging station in the GZRB

Table 3.11 Illustrates water gauging stations in the GZRB

Province	River Basin	River and Station Name	Type of Station	Catchment Area Km^2	No of used Year	Observation Period
Dohuk	Greater Zab	GZ / Dearlok	Staff gauge	7768	5	2004-15
		Rosheen Balinda	Staff gauge	3336	3	2005-15
		GZ / Qandil	no Q data	16881	-	2008-15
		Galizanta	Staff gauge	125	1	2007-15
	Greater Zab (Khazir)	Gomel /Khanis	Staff gauge	537	3	2004-15
		Khazir / Asmawa	Staff gauge	727	5	2008-15
		Chamanke	no Q data	44	-	2008=15
		Khazir- Manquba	Historical-St	3127	49	1934-94
Erbil	Greater Zab	GZ / askikalak	Staff gauge	20445	63	1932-88, 2001-15
		GZ / Ifraz	Recording	19680	7	2001-15
		GZ / Gwer	Staff gauge	26136	5	2004-15
		Jundian	Staff gauge	1197	17	1957-75,2001-15
		Balakian	Staff gauge	1126	27	2002-15
		Alana/Khalifan	Staff gauge	194	7	2002-15
		Basan	Staff gauge	121	6	2002-15
		Gomaspan	Staff gauge	131	6	2002-15
		Hujran	Staff gauge	31		2002-15
		Rawanduz/Khala n	Staff gauge	2907	7	2001-15
		Razga	Staff gauge	183	6	2002-15
		Razan	Staff gauge	1849	7	2001-15
		Roste	Staff gauge	71	5	2002-15
		Bekhal	Staff gauge		6	2001-15
		Jundian	Staff gauge		7	2001-15

Data accuracy is low because the river profile is not always well determined and moreover for some station, it is defined no more than one time for the all-time series. There was also a low flow gauging campaign in 2001 in all northern Iraq. 161 measures were done by UNFAO

The good monitoring program started in 2000/2001 is essentially still operational in Erbil and Dohuk province. Today, the monitoring network consists of (Erbil, 89 monitoring wells)

Monitoring activities are conducted by the respective Groundwater Directorates. Most wells are monitored on a weekly basis. Data accuracy is limited by the fact that the records are taken from production wells, not from dedicated monitoring wells.

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Table 3.12 Illustrate GZR Monthly river flow in Ifraz station flow measurement.

	GZR Average River Flow (flow rate) (m^3/sec.)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2001	68	118	305	290	220	148	88	75	58	**53**	65	129
2002	216	226	383	1039	856	492	292	100	84	83	84	250
2003	201	309	313	598	548	374	188	155	123	118	154	164
2004	366	380	850	640	662	629	330	100	81	79	83	135
2005	404	726	1101	856	611	537	318	98	78	80	82	131
2006	384	1116	1003	995	782	609	297	166	146	155	211	199
2007	321	710	691	802	693	403	248	118	95	91	92	113
2008	90	143	316	301	230	156	92	83	60	78	81	88
2009	99	128	365	425	469	270	144	89	80	76	165	186
2010	289	324	427	454	478	306	185	130	111	87	75	78
2011	94	195	317	601	610	396	237	157	125	121	128	123
2012	148	201	293	576	524	253	162	124	115	113	147	156
2013	387	492	551	593	542	414	372	213	192	184	196	229
2014	239	247	409	397	342	245	189	149	142	209	237	273
2015	244	249	301	429	374	277	221	181	174	2215	242	280
Av.	249	389	523	622	551	383	234	133	115	264	141	172

3.7.1 Water Quality

There are several laboratories for Erbil and Dohuk Governorates control water quality, by both ministries (Ministry of Health and MOM&T). The groundwater included several lakes underground with depth more than 300 m, the deficient 200m through past 50 years and the quality of water monitored by the director of water supply Erbil. Generally, the groundwater is fresh water, therefore, the water supply directly from wells to city network pipeline and distributed to peoples.

Most of the knowledge about GZRB comes from studies that have been running by FAO from 2000 to 2003. Thus, a good monitoring program has been started in 2000/2001 by the General Directorate of Water Resources, this conducted by the Groundwater Directorates of Erbil, Dohuk, and Sulaimanya for the corresponding governorate. (MOA&WR 2016)

Erbil groundwater salinity is measured either as Total Dissolved Solids (TDS, unit: mg/l or ppm) or in terms of electrical conductivity (unit: µS/cm). The conversion factor is: 100 µS/cm = 64 mg/l.

There is no health-based limit for TDS according to WHO drinking water guidelines. However, “drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/liter. The presence of high levels of TDS may also be objectionable to consumers, owing to excessive scaling in water pipes, heaters, boilers and household appliances” (WHO, 2008). “The provision of drinking water that is not only safe but also acceptable in appearance, taste is of high priority.”

The taste of water with a TDS level of less than 600 mg/l is generally considered to be good. The recommended maximum for Iraq is 1280 gm/l (2,000 µS/cm).

In Erbil Governorate groundwater salinity generally ranges between 200 and 400 mg/l (313 and 625 µS/cm). Out of 184 samples taken by Kendal Company in 2002, only 3.8% had a salinity of more than 600 mg/l (938 µS/cm).)

Table 3.13 Groundwater salinity in Erbil Governorate

Salinity Range (mg/l or ppm)	Conductivity Range (µS/cm)	No. of samples	Percentage of all samples
< 200	<313	2	1.1%
200-300	313-469	101	54.9%
300-400	469-625	61	33.1%
400-500	625-781	9	4.9%
500-600	781-938	4	2.2%
600-700	938-1,094	3	1.6%
700-800	1,094-1,250	4	2.2%

Figure 3.16 show map and illustrates the geographical distribution of salinity in Erbil Governorate.

Based on the recent well database it shows all wells with a TDS content of less than 600 mg/l in blue. Wells with a TDS content of up to 1000 mg, less palatable but still considered as acceptable, are shown in yellow.

The map clearly illustrates how salinity increases from the north-east towards the south-west. It is generally within acceptable limits in the Erbil groundwater basin with the exception of the zone near the south-western border of the basin.

In the Makhmur district salinity, exceeding the acceptability limits are frequently encountered. In this area, mixing of groundwater from the Bakhtiari aquifer with waters from Fars underlying layers (marls, gypsum, and anhydrite) causes increased salinity. The Parsons Company (1955) reports a maximum of 6,400 ppm in wells at Ghirda Bagum on the Makhmur plain (Stevanovic and Markovic, 2004).

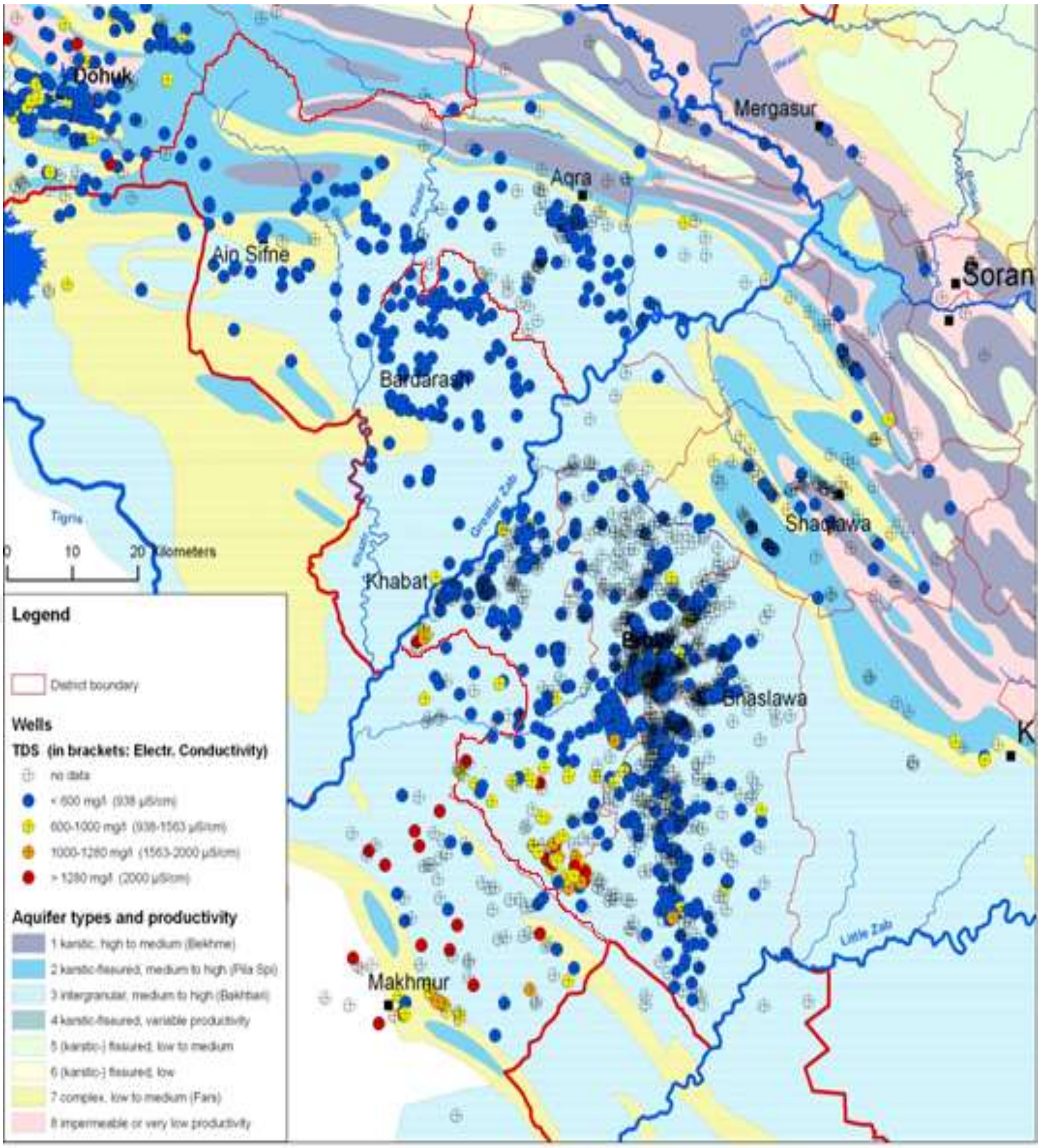


Figure 3.16 Geographical distribution of deep wells water salinity

3.8 Geographical Information

The GZR originates from the mountainous area of south-eastern Turkey where it springs at an altitude of 4,168 m above sea level. The river is 407 km long (290 in Iraq), it is one of the main tributaries of the Tigris river and flows into the Erbil province, north of the plain between latitudes 36° and 38°N and longitudes 43°18' and 44°18'E.

The whole river basin has an area of 26 306 km^2 with a perimeter of 1 516 km, a sizeable part is outside Iraq mostly in Turkey with a little part in Iran. In Iraq, the river basin is mostly located in the Autonomous region of Erbil. It is the biggest tributary and most important river basin feeds the Tigris River.

Although integrated water management takes into account the whole river basin from the origin of the river to the outlet to the Tigris (even to the Gulf), mostly political and practical reasons oblige to restrict the study area, the table shows the permanent sub rivers and its catchment area with average annual flow and annual precipitation.

Area of the river basin outside Iraq in Turkey and in Iran, International relations regarding water with Turkey and Iran are presented in this chapter. As political issues between Iraq/Erbil, Turkey and Iran make very difficult the data access in these parts, it was decided to consider Turkey and Iran as an input for the study area. Area of the river basin in Iraq.

The outlet of the GZR into the Tigris River is in Mosul province which is part of Iraq but not of North Iraq. Given the difficulties with access to these data, this area will not be taken into account. Area of the river basin in Sulaimanya province For the purpose of simplification we decided to neglect the small part of the river basin located in Sulaimanya province, in the eastern part of Erbil. The removal of the Sulaimanya part will not have many impacts on the assessment of the balance between the needs and the resources. Indeed this area is a mountainous area where the needs are certainly not so high. The resources will be taken into account with the tributaries and aquifers in the study area.

3.9 Basin Management Systems

The key points to establishing basin management systems are:

i. The foundation for the establishment of a basin management system requires high-level political will and also requires serious dialogues among water users

ii. National and water policies and legislation as well as international agreements are the highly important aspect of water basin management

iii. The work of the basin organizations should be organized under a three-dimensional framework: the enabling A- Environment, B- institutional arrangements (roles and responsibilities), and C- management mechanisms.

The key to creating a legal and institutional framework as well as administrative structures for basin management is comprehensive, high-level support in all respects

Water management, policy development, regulation and arrangements for the transformation of public institutions to a stable water management need to have the high political will. Even at times of instability and civil unrest, there are institutions running water and work continuously, this means the importance of political management in the field of work with decision makers and explain and explain what is the integrated management of water resources at the time and why it is important to get this high-level support and commitment.

It is difficult to develop a comprehensive approach to integrated water resource management when corruption is pervasive and difficult to implement what is required of IWRM. Freedom of information must be given absolute freedom to find good solutions within water basins, so IWRM is for those affected by decisions on water resources

The IWRM approach should be used, the answer in these situations is to take a step-by-step approach. For example, the first steps could be for groups of stakeholders to meet and find common areas of concern where the action is needed. Once issues have been identified, information can be collected and shared, and proposals put forward for endorsement by province.

3.10 Inter-Ministerial Coordination

The integration approach must be vertical - across different levels of power and horizontal between different water users and affected groups. A key element of horizontal integration is the combination of ministries responsible for activities affecting ministries of water, planning, agriculture, transportation and energy - and those with social or environmental responsibilities - ministries of health and the environment. In any basin, there will inevitably be conflicting demands for water, for example for domestic use, irrigation, environmental protection, hydropower, and recreation, as well as issues such as pollution or modification of the flow system.

The ministerial coordinating bodies within the ministry are involved in the management of water resources, such as the committees of the Council of Ministers and the Councils of Ministers, in the joint coordination of procedures through the Governorates.
However, they only work well when the ministers are committed and when they are supported at the highest level (eg by Prime Minister, Prime Minister). These ministerial coordinating bodies should be established so that there are clear lines of reporting to

senior province executives, basin organizations, local province and water user organizations.

When the issue affects more than one country, summits or conferences of heads of state may need to bring together leaders to discuss and coordinate water issues in transboundary basins. The countries involved in the river basin have participated in several annual meetings and water conferences for cooperation and coordination.

3.11 Mechanisms of Management and Coordination

The establishment of a system for the management of the basin urgent need and imposed to reduce water loss and management of optimization within the basin and this needs to be integrated and work as one in Iraq, the province of Erbil is the urgent need for mechanisms of coordination on the real GZRB, in order to reduce the fragmentation of roles and responsibilities as well as determine the roles of the stakeholders in the basin and below main points:

A. Within the directorates related to Ministry of Agriculture and Water Resources;

B. Between the various directorates related to the water and agriculture quality and quantities and the governorates;

C. With decentralized levels of responsibilities, through the governorates, the districts, the sub-districts, and villages;

D. Involving water users and civil society;

E. With national Iraqi level.

It is clear that such relationships between stakeholder's and water uses within the water resource basin as well as for optimal basin management are often present, particularly during the development of a project (e.g. a dam project, for which specific committees are usually organized) also it is very useful to institutionalize such coordination. In this regard, the proposal to establish three levels of coordination is essential for basin management and recommended:

1- A High River Basin Commission for whole the GZRB, gathering all water actors in an impermanent assembly. This commission would tackle with RBM, involving representatives from different ministries involved in the water sector, governorates, local authorities (municipalities), water users, the private sector, NGOs, universities.

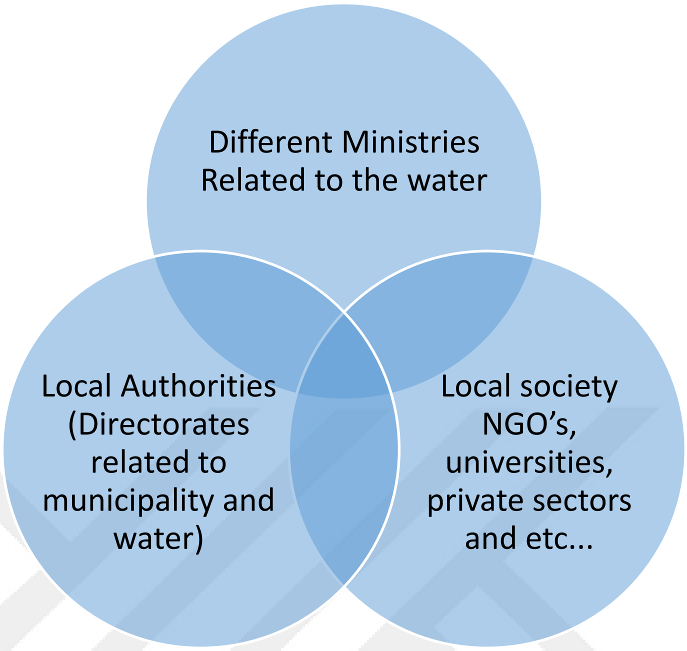


Figure 3.17 High River Basin Commission

The High River Basin Commission, which could include a maximum of 30 members, could be composed as follows:

1-1 Ministries and boards (10 representatives – representative of Prime ministers, Ministry of Finance, Agriculture and Water Resources, Planning, Municipality and Tourism, Environmental Board, Electricity, Trade and Industries, Natural Resources, Health). The representatives could be General Directors and above;

1-2 Governorates (6 representatives), districts (3 representatives), sub-districts (3 Representatives);

1-3 Water users (3 representatives - Farmers' Union, Industry Union, chamber of commercial);

1-4 NGOs and environmentalists (3 representatives);

1-5 Universities (4 science college representatives);

1-6 The Private sector (4 representatives – gravel mining, oil extraction, hydroelectric it, water issues).

Its regular meetings (2 to 3 meetings per year) would aim at making key-decisions for water resources management, in particular regarding planning, concrete priority actions in the basins and ways of funding. High Commission creation will imply a strong real political will and a capacity building program and representatives from districts and sub-districts can change depending on the river basin and subjects treated during the Commission meeting. Other members should be permanent. The participation of Iraqi Central Government to High River Basin Commission is possible, to make the link at whole basin level.

2) A new Directorate for River Basin Management, placed within the MA&WR but acting on an inter-ministerial way of working.

According to this point the MA&WR should create, within general directorate for water resources, a new directorate for river basin management. This directorate would act as the operational arm (preparation/execution of decisions) for High River Basin High Commission (in a short and mid-term). It would be in charge of working with all other stakeholders on a permanent basis, preparing consensus, decision-making tools, and management plans, and then to submit these plans to High River Basin Commission. In that purpose, significant human and financial means should be dedicated to this directorate. It would beneficiate from the participation of experts from the other main Ministries.

This new directorate will replace the formal department of water basin management (in the Directorate of studying and designing, general directorate of water resources). It will then take charge its current activities but will be enhanced in the general directorate for water resources at the level of a directorate.

3) The Sub River Basin Committees at the local level.

Local water committees can be set up in each of the 3 main sub-basins for GZR in Erbil province. Those committees would be responsible to prepare a sub-basin water scheme, which would be the local adaptation of the plan for water management and development. Sub-River Basin Committees would bring together about ten water actors at the local level. Their composition could follow the same repartition than the High River Basin Commission: one third of State representatives (beginning with the local representatives of agriculture, groundwater resources, sewerage and drinking water), one third of representatives of local authorities (districts, sub-districts and villages) and one third of civil societies' representatives (including Farmer's Union, local NGOs).

Each Committee could be presided by District Head. The installation of Sub-River Basin Committees and the nomination of members could be decided by province authorities in coordination with the Ministry. Creation of such Committees will participate in the strengthening of local governance in the water sector. As for the High Commission, this will imply a capacity building program

Farmer Union: Farmers’ Union seems to be the only structure (as Industry Union as weak relations with water sector) gathering water users in an organized way in Erbil province. They have an executive office in Erbil with seven members and have chambers in districts.

Farmers’ Union has one representative in Agricultural Committee in governorate office and the union is participating in the distribution of materials like seeds, fertilizers, Irrigation equipment’s, tractors, harvesters. It is also assisting farmers in buying suitable agriculture machines.

University role: The points of view of the universities (through their professors particularly) can be very useful for water management. Their advice and research results have to be taken into consideration in decisions. Several universities can be involved in GZRB management: Salahaddin University, University of Soran, Cihan University, etc.

The different colleges are concerned (College of Agriculture; College of Engineering; College of Education; College of Art - Geography department; College of Art - Archaeology department; Women’s cultural and social center and Social sciences.

Civil society and NGOs: In line with Iraq Briefing Book, it would be very useful to “Develop an enabling legal and institutional framework to ensure the independence of civil society”. Historically, there has been no effective framework to protect the independence of civil society in Iraq. The new NGO law is a positive step forward, yet it will require support for implementation and monitoring to ensure its effectiveness.

Further improvement of the NGO registration process is required under the new legislation to prevent arbitrary decisions. Governmental structures charged with responsibility for civil society matters will require further capacity building and training to ensure that activities are effective, coordinated and politically neutral.

In all sectors including water management, civil society participation in the development of provincial policies must be promoted. Civil society has a limited capacity to engage effectively in advocacy or “networking” to influence government policy, and consequently has played a limited role in contributing to the policy-making process, and defending the human rights and preserving the environment. Its activities are including water sector. The NGO active in whole Iraq also important Nature of Iraq, accredited to the United Nations Environment Program. Journalists are also representatives of the civil society. They represent one of the means to increase awareness and communication (newspaper, television, radio) to a large audience of people.

3.12 Water Disputes, Tribunals, and Conflicts

The river is not a comfort but a treasure. All people feel right to get the highest amount of water in order to get maximum benefit, and there arises, unfortunately, a collision of interests among people in the region, and the river winds its way through. It is universally accepted that water quantity is still the same thought in different places, forms or stages (Kumar et al., 2010).

Water resources facing global challenges are multiple factors including the steady increase in population, urbanization, environmental degradation, and industrialization. These challenges exacerbate the water shortage, leading in turn to increasing international conflicts on water. These conflicts are becoming increasingly complex and novel, involving not only States but also legal entities, corporations, and individuals against other States. These claims now go beyond conventional water quantity issues, including water quality, river boundary boundaries, and water rights issues.

The GZR can be the extra communication bridge between Turkey, Iraq, and (Erbil), through several activities can produce energy through several dams available and construction new dams in the area of the basin located close to the border and at the same time the Iraqi, can, buy and used this energy for the tourism activities area and development.

Although awareness of the nature of conflict and cooperation in water has improved over time, the potential for water conflicts can increase as population growth and climate change continue. Details of water conflict nature, and water cooperation. Water disputes can be resolved, how water can be considered a vehicle for change among countries, and future directions that can be taken in research into cross-border water disputes.

In some exceptional cases, courts can be set up to deal with debates on the water that have reached a dead end or controversial water issues. The Tribunal is an independent, but usually temporary, body with judicial or quasi-judicial powers to make key decisions, such as water sharing; water pricing or river flow adjustment. It operates as special courts outside national civil and criminal judicial systems. The Tribunals consider special problems, issue judgments and resolve disputes between countries, states, counties or water users. Very few are available to manage ponds. Stakeholders may participate formally in hearings.

CHAPTER 4
WATER MANAGEMENT IN GZRB

4.1 Introduction

After, the Gulf war in 1991, the region has witnessed a huge increase in its population. Indeed thousands of families who had been forcibly displaced returned from different places of deportation to Erbil. After 2003, the same phenomenon occurred with also relocation of families that seek refuge and stability. Population, especially in the cities increased suddenly. Furthermore, the natural growth of the population is high around 3.5 % per year. (MOP, 2016)

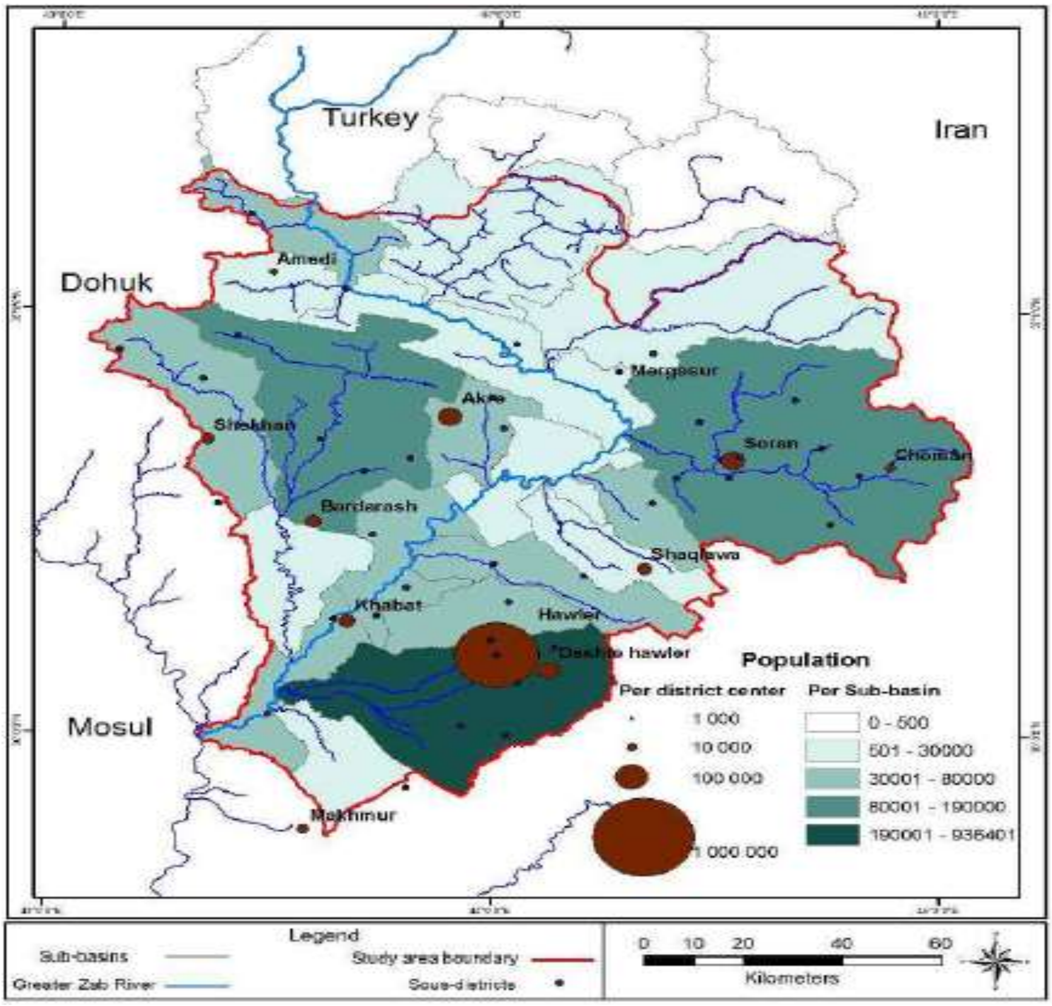


Figure 4.1 Map of distribution of the population (MOM&T, 2016)

According to the data from the population department in the Ministry of Planning, the population estimated in the study area in 2009 as shown in the figure (4.1) illustrated population distribution within GZRB and is around 1, 7 million inhabitants. 1 million of them live in 12 large districts (Erbil city alone gathers 680 000 inhabitants), while 500 000 live in 37 middle towns. Approximately 1000 villages with a limited population (<2000 inhabit.) represents 15 % of the whole study area population, the updated population in Erbil province is around 2,450,000 inhabitants.

4.2 Economical Context

The study explains rebuilding on water resources in Erbil province, although the political readiness to develop economic activities especially from the private sector is strong, the region faces a series of difficulties.

Farming and breeding were the main economic activities of the region before last century events. Erbil was considered the breadbasket for all Iraq and fruit products such as apples and peaches from the mountainous areas were reputed. Means of production, both technically and humanly, were destroyed during the last period leading to a strong dependency of the region towards foreign imports.

The strategy for agriculture 2016-2020 is planning to achieve self-sufficiency by the year 2020. The public and private investments in agricultural sector led to the return of population to their villages to grow their lands. This plan faces difficulties to be implemented and notice among others for the following reasons:

A. Lack of know-how (knowledge) of farmers (especially displaced),
B. Lack of links between services of the government in charge of agriculture and farmers.
C. The large importation of vegetables, in particular, at very low prices, disturbs the local market, these prices are much less than the local produce costs; it is hardly possible for farmers to sell to a rentable price. Powerful import companies are preventing changes in the actual strategy.
D. Agriculture became a less attractive field, in which the return of investments is too long and too low according to the work to do and in comparison with the current dynamic.

The authorities are willing to see an industrial sector develop, but as for agriculture, short-term rent ability do not favor its development. Furthermore, difficulties in electricity provision prevent the development of industries as the production means cannot be operated securely.

For the moment, major industries are those linked to the construction sector. To fulfill the demand for construction materials, a local sector is developing. Extraction of gravels from riverbeds is a key-issue for water management of GZR. Crude oil production and exploitation is under prospection at the moment, and the coming years may see profound modifications in this peculiar sector.

4.3 Focus on Agriculture

Erbil is the first agricultural zone of the country producing 50 % of local wheat, 40 % of local barley, and 50 % of local fruits.   Land occupation and use in the GZR presents many contrasts from south to north, because of different kind of climatic zones, topography, soil, resources of water, proximity to cities.

4.4 Typology of Agro-Climatic Zones

The basin has been divided into two main zones: the plain area including Erbil plain and the mountain area in the Northern part of the basin.

Zone 1 Plains and foothills: This area is characterized by flatter soils permitting easier cultivation than the mountain zones. Precipitations do not usually exceed 700 mm / year and are even less than 350 mm for the driest part close to Erbil city. Therefore, possibilities of growing wheat without supplementary irrigation are limited. Farmers will often plant barley to limit the loss of yields in cases of restricted rains. According to different factors including proximity to the river, to main urban centers, amount of rain, we have differentiated three sub-zones.

Zone 1a on GZR shore around Khabat: An irrigated collective scheme has been constructed in the 70’s (see below for details); the vicinity of the river allows irrigation thanks to surface water with a high percent of irrigated lands. Family farmers irrigate a mix of wheat and vegetables (2 seasons of vegetables, one in autumn and one in spring). Each family cultivates small plots of ¼ to 1 hectare.

Table 4.1 Average cropping pattern of irrigated farms in Khabat rea (Zone 1a).

	%	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Cereals	61%			Wheat									
Chickpea	7%							Chickpea					
Vegetables	29%	Tomatoes						Eggplant					
Orchards	3%	Orchards											

Zone 1b Erbil plain: Although the climate does not favor agriculture, the proximity of the city, availability of land, and use of groundwater wells have permitted the development of farms. It is the zone where most of the irrigated agriculture of the basin can be found (more than 50%). Non-irrigated farms grow mostly wheat or barley during the rainy season. Irrigated farms grow vegetables in open-fields (1 to 5 ha) or under greenhouses using drip irrigation systems mostly imported from Jordan. They can also grow wheat with central pivot or sprayers on (5 to 20 ha).

Table 4.2 Average cropping pattern of irrigated farms in Erbil plain (Zone 1b)

	%	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Cereals	61%			Barely									
Chickpea	7%			Chickpea									
Vegetables	29%	Tomatoes							Melon				
Orchards	3%	Orchards											

Zone 1c foothills area: Structure of farms is approximately the same than in Erbil plain, but as the rains are more secure, farmers grow more wheat and plant more irrigated trees. When the farm is irrigated, as the distance to the main city increases, the production of fresh vegetables is less competitive than in the previous zone.

Table 4.3 Average cropping pattern of irrigated farms foothill area (Zone 1c)

	%	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Cereals	31%			Barely									
Chickpea	3%			Chickpea									
Vegetables	39%	Tomatoes							Cucumber				
Orchards	3%	Orchards											

Zone 2 Mountain area**:** The mountain areas see a succession of forests, rangelands, arable lands and irrigated valleys. The tree cover of the region's mountain slopes reaches elevations of 600 m to 2000 m and dominantly makeup of Oak woodlands and some Oak forests, holding medium-sized trees, often with a widespread crown. They are a major source of income and essential to the livelihood of the mountain population (small farmers). The breeders of the region follow transhumance, moving their group of sheep and goats to higher mountain pastures in summer and down to the plains in winter. The amount of rain (over 900 mm/year) permits rained cultivation of wheat (and barley), while irrigation of vegetables and orchards is concentrated in small areas in the valleys thanks to permanent springs and rivers. With forced migrations and destructions, the irrigated area has been reduced and due to accessibility problems, most of the production is directly consumed by the families.

Table 4.4 Average cropping pattern of irrigated farms in mountain area (Zone 2)

	%	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Vegetables	71%	Onion							Tomatoes				
Orchards	29%	Orchards											

The following Figure map (4.2) presents the limits of the agro-climatic zones and subzones.

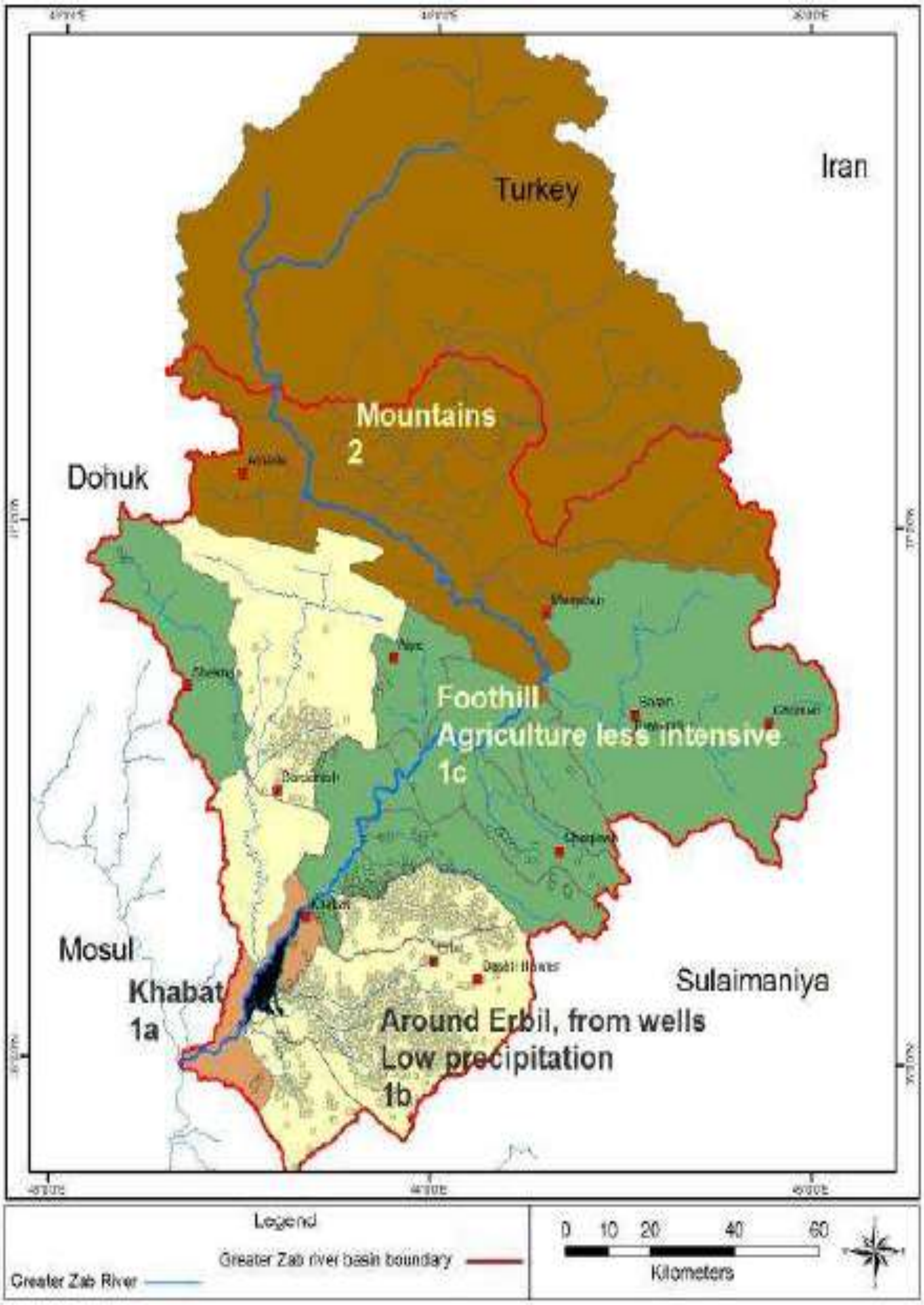


Figure 4.2 Map of agro-climatic zones (MOM&T, 2016)

4.5 Estimation of Cultivated and Irrigated Areas

Based on statistical data from MOA&WR and MOP and on appreciation from experts, we have estimated the total cultivated area in the river basin to (660 000 ha) including almost (100 000 ha) irrigated hectares (15%).

Table 4.5 Cultivated area per agro-climatic zones (rain-fed and irrigated)

a) Total cultivated area

Location	Total cultivated area (ha)				
	Cereals	Chickpeas	Vegetables	Orchards	Total
1a – Khabat	16477	1883	4708	471	23539
1b - Erbil Plain	288380	57676	30761	7690	384507
1c – Foothill	159059	31812	6362	14846	212079
2-Mountains	31319	6264	3132	4027	44742
Total Area	495235	97635	44963	27034	664867

b) Total rain fed area

Location	Total rainfed Area (ha)				
	Cereals	Chickpeas	Vegetables	Orchards	Total
1a – Khabat	6591	753	0	0	7344
1b - Erbil Plain	273961	56523	0	0	330484
1c – Foothill	151106	31176	0	4454	186736
2-Mountains	31319	6264	157	2819	40559
Total Area	462977	94716	157	7273	565123

c) Total irrigated area

Location	Total irrigated area (ha)				
	Cereals	Chickpeas	Vegetables	Orchards	Total
1a – Khabat	9886	1130	4708	471	16195
1b - Erbil Plain	14419	1154	30761	7690	54024
1c – Foothill	7953	636	6362	10392	25343
2-Mountains	0	0	2975	1208	4183
Total Area	32258	2920	44806	19761	**99745**

The difference between irrigable area and the non-irrigable area is very high. The figure (4.3 illustrated in) was the comparison of general (rainfed and irrigated) cropping patterns in agro-climatic zones for the year 2013 in GZRB, this indicates a large difference between irrigated area and non-irrigated area, meaning in the future it is possible to change the land from rainfed area to irrigation area which leads to increasing water demands.

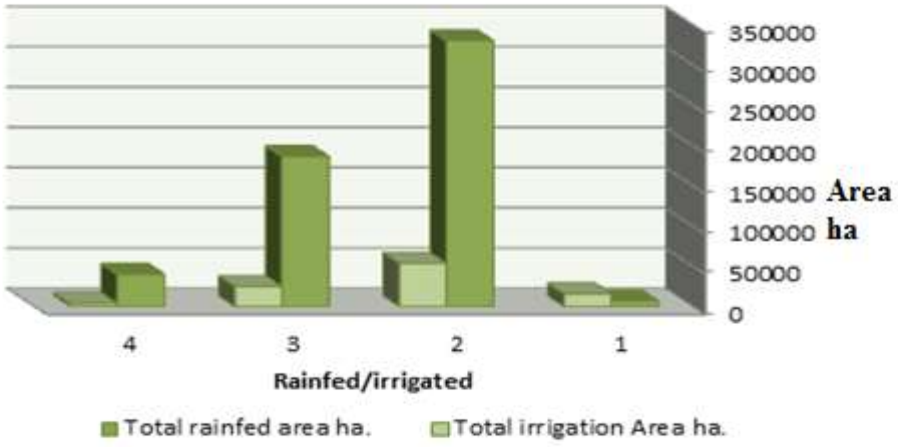


Figure 4.3 Irrigated land contribution in each agro-climatic zone

4.6 Drinking Water and Sanitation:

Ministry of Municipalities and Tourism, in particular, the General Directorate of Water and Sewerage, is in charge of the provision of water and sanitation. They have to provide services to a little part of the population disseminated in numerous small villages and to a very fast growing urban population concentrated in few towns. Technical difficulties such as electricity shortcuts and raw material access (chlorine for example) are even more difficult to overcome if we consider that water is almost free for all.

4.7 Access to Drinking Water

Most of the households (77%) obtain their drinking water through pipes. The other main source of drinking water is through tanker-trucks. Drinking water is supplied by a mix of surface and groundwater: for instance, 5000 wells are used for drinking purposes in Erbil province Erbil city gets 40 % of its drinking water from wells, while in the mountain area, main intakes for drinking purposes come above all from the surface and springs resources.

Water production and distribution are mainly financed by the government. Water is almost not paid by the population: (10000 ID) per month and per connection house (200 m^2) (around 8 $). Municipal buildings, as hospitals, schools, don’t pay water as well.

Provision of water for villages is most households are connected to a municipal water network even in the villages. The Annual domestic water consumption, in this case, is estimated to (177.11 MCM) for the year 2015. Some houses, not connected get water from trucks or from private wells. Water from springs or wells is very often distributed without pre-treatment apart from a simple chlorination in some cases.

Provision of water for cities a mix of surface and groundwater is used to tackle the needs of fast-growing cities. The following table recapitulates the existing domestic water supply projects in the River basin, taking water from the GZR and using and supply water to the main cities.

Table 4.6 The existing water supply projects supply water to the cities

Domestic Water Use in GZRB year 2015			
Name of Project	**Capacity m^3/hr.**	**Water product Capacity MCM/ Year**	**City Supply To**
Ifraz 1	1680	11.04	Erbil
Ifraz 2	2880	18.92	Erbil
Ifraz 3+ extension	10000	65.70	Erbil
Kalak	300	1.31	Khabat
Gwer	300	1.10	Gwer
Bekhal 1	1000	6.57	Soran
Bekhal 2	2325	15.28	Soran
Meargasor	1625	8.30	Meargasor
Qandil shaqlawa	5000	25.55	Shaqlawa
Amedi	2400	10.51	Amedi
Akre	3000	13.14	Akre
Groundwater 2241	7200	2.63	Erbil Gov.
Bardarash	1387	8.10	Bardarash
Total domestic Erbil		177.11	

MOM&T has to face important and great challenges to supply urban populations due to :

1) The population is growing very fast with massive unforeseen migrations.

2) Construction of new housing projects with large demand.

3) Individual drinking water needs for districts and sub-districts are quite high (300 l / day/ capita) mostly due to un-cautious practices of users (as water services are almost free, the population does not have incentives for water savings).

4) Current status of existing networks is high deteriorated with an average leaking rate of 50%. Renovation of urban networks is a priority.

5) Public infrastructures co-exist with private investments and illegal equipment's and therefore, monitoring and planning are difficult.

6) Renovation and planning are even more challenging considering the absence of water meters and the symbolic price for water supply that one pays.

Generally, there are two ministries MOA&WR and MOM&T working directly in the water sector and facing several problems regarding the above points.

4.8 Organization per Sector

This section divided into several sectors regarding the province and ministries structure

1- Water and Sewerage: This sector is under the responsibility of the Ministry of Municipality and Tourism. This directorate in Erbil province has three water treatment plants with a total capacity approximately (241,000 m^3/ day), considerably short of the daily demand of (442,000 m^3/day). (MOM&T, 2016)

Additionally, in Erbil, much of the water piping was lined before the 1950s and it has significantly deteriorated. The MOM&T is currently leading a project for the development of the water and sewerage policy of the Erbil province (funded by the European Union) with the support of UNICEF. It stresses the limited access to drinking water in rural areas. The province capitals alone well supply, but the quality of the water distributed is poor. Sanitation services are practically non-existent. Besides the environmental challenges, (lower groundwater levels, more frequent use of surface water). (UNICEF, 2011)

2- Agriculture and irrigation: The irrigation projects come under the General Directorate of Water Resources (in the Directorate of Irrigation, which handles applications for deep drilling operations in particular), but may be implemented by the General Directorate of Agriculture. Most villages having an intake on the river or with a spring have small irrigation schemes.

For the maintenance, villages can ask for guidance from the directorate, which is also supposed to go through villages to see where there are maintenance problems. In each village, which has some irrigated area, the distribution of water is organized by the Chief of the village and decides on the irrigation strategy: schedule, gates opening and closing.

Table 4.7 Total irrigation area indifference (zone and crop)

Location	Total Irrigated Area (ha)					Ave. Water Req. M^3/sec/ha	Total Annual WR MCM
	Cereals	Chickpeas	Vegetables	Orchards	Total		
1a - Khabat	9886	1130	4708	471	16195	0.01	85.12
1b - Erbil Plain	14419	1154	30761	7690	54024	0.01	283.95
1c - Foothill	7953	636	6362	10392	25343	0.0047	62.61
2-Mountains	0	0	2975	1208	4183	0.0034	7.48
Total Area	32258	2920	44806	19761	99745		439.15

3- Dams and hydraulic infrastructures: The General Directorate of Dams, within the Ministry of Agriculture and Water Resources develops the projects in close cooperation with Hydropower sector within the Ministry of Electricity (Directorate of Hydropower and Renewable Energies).

In the current situation, electricity in the Region depends on around 90% of the independent Power Producer Gas power plants. Thus, there is potential extra power after midnight up to early morning.

The industry sector it seems that following scheme is followed, the investor should enter in contact with Investment Board, which will dispatch to suitable ministry in charge of the related domain of investment and to MOM&T which will check if a suitable piece of land can be identified. Environmental Protection and Improvement Board will have to check if any regulation applies and is to be respected. In case of water withdrawal, a permit will be necessary from MOA&WR for drilling a well or for surface water intake.

4.9 Access to Sanitation:

There is currently no wastewater treatment plant in all cities of Erbil. Except for few exceptions, there is no sewerage network either. Blackwater (from the toilets) is at best collected into cesspools. The inhabitants choose if the emptying of the cesspools is made by the municipality or by a private company. Then, the transport of sewerage by water tanker is generally done to the streams and then goes into the ecosystem without treatment.

Some districts and sub-districts have a portion of the storm- and grey- water networks. Hence, such a network has been built in the city of Erbil and is presently being extended to cover almost all the city. The network goes 10 kilometers South from Erbil to the villages of Toraq, Arab kand, and (Swerey) in the Taajeel and Besta Piazza valley by an underground pipe. It goes afterward through an open channel to the GZR some kilometers upstream from Gwer. Some farmers, who are next to the channel, use this grey and stormwater for their cultivation, without preliminary treatment.

4.10 Agriculture and Water

According to the type of access to water, farmers develop a different kind of on-farm irrigation systems from surface furrow irrigation to drip irrigation systems. Due to recent history, collective irrigation infrastructures are not well developed (only one large-scale irrigation scheme exists in the area, and there are no dams for irrigation completed yet), small irrigation canals that were destroyed in past period are rebuild in the villages but on the very limited area and with low technical level. Private investments which are the farmers (accessing the water either from wells or springs) is the main reason for the increase of irrigated area in the last decades and is the backbone of increase in farm productivity.

As far as we know, there is no evaluation at the local river basin level to coordinate the development of those schemes. Evaluation of water resource and demand do not seem to be taken into consideration and we can wonder if the conflict of use between up and downstream could not arise if those practices continue without coordination.

Irrigation systems from ponds are local open stock of water, volume collected comes from runoff of rainfall. The storage depends on a dick located in an outlet of the topographic area, general height of ponds is between (8m and 15m) meters and water capacity varies. Respectively each of capacity can irrigate the land between (5 to 12.5 ha). Ponds are not only for agriculture, even if their main use is to supply water for animals and irrigation and recharge the groundwater, they also are used for drinking water, total of 12 ponds are located on the study area with a total stock around of 10 millions of cubic meters and other 12 are under construction and not completed due to financial crises in the region. (DIE, 2016)

4.11 Individual Irrigation Projects

Individual farmers, mostly in the plain of Erbil dig some wells to irrigate their farms. Those wells are censed. According to official data, around 2100 wells are under function for agriculture nowadays in Erbil, out of about 2600; most of them are illegal wells. Private diversion of rivers or springs often thanks to diesel motor-pump is one of the strategies for the farmers to increase their irrigated lands. (DAE, 2016)

Those private investments allow the irrigation of wheat thanks to central pivot or surface irrigation. This supplementary irrigation secures the yield that is very sensitive to rains. Drip irrigation systems in the plain and furrow irrigation in the mountains are used to irrigate vegetables. Orchards are also planted mostly in the foothill area where the rains are higher but also around Erbil city although the climate is not adapted at all to those permanent crops. Indeed, a phenomenon of re-creative or prestige farming seems to start close to the capital: landowners grow few hectares of fruit trees around a secondary residence thanks to water coming from wells adding pressure to the groundwater tables. The efficiency of the irrigation system has been estimated as follow:

A. From collective open-channel networks and surface irrigation at farm level: 50%

B. From Private system from surface water: 60%

C. From wells using pressurized irrigation systems at farm level:85%

4.12 Fish Farms

Fish doesn’t belong to traditional Iraqi food culture, but aquaculture is developing. The fresh fish market is dominated by Iranian imports, (5,100 tons), only (200 tons) are produced locally in fishponds. Wild fishes are mainly (shabut) and redfish (Sula masi). Breeding fishes are carp and silverfish, and salmon in the mountains. No data is available about wild fish fishing. An authorization from Ministry of Agriculture is required for professional fishers, fishing in big reservoirs does exist, but no data is available at the Ministry of Transportation. The totals of fish farms are 162 fish farmer for the year 2015 in Erbil province. (DAE, 2016)

4.13 Upstream Demand (Turkey) on GZR

The diagnosis of existing resources highlights the importance of the Turkish side of the basin in the constitution of water stocks. 36% of the basin is located in Turkey and 80% of the rainfall and snowfall occur in this upstream part. Turkish strategy on uses of its "share" of the greater Zab water is therefore of main importance.

Turkish demand in 2030 has been estimated considering the following criteria:

I. Agricultural and domestic demand in the GZRB territory in Turkey.
II. Constitution of water stocks for Hydropower production in the territory.
III. Possibilities of Water or energy transfer outside the GZRB territory.

Turkey plans to develop the sectors of irrigation, hydroelectric energy and water supply for domestic and industrial use by 2030. The following table summarizes the development targets of those different sectors in Turkey for the next period including GZRB region.

Table 4.8 Development targets (Irr. Hydropower and water supply use in Turkey.

Water Use	2005	Goals by 2030	Development Rate
Irrigation	4.9 Million ha	4.9 Million ha	58 %
Hydropower	45.3 Billion KWH	45.3 Billion KWH	36 %
Domestic and Industrial	10.5 Billion m^3	10.5 Billion m^3	27 %

The estimation of Turkish future withdraws on GZRB water resources as below:

1- Agricultural demand

GZRB territory in Turkey is a mountainous area, with an average elevation of 2350 m. Therefore, no large irrigation scheme can be developed and irrigation could only occur in small valleys. Estimation of agricultural demand is extrapolated thanks to the projection of irrigated area and cropping pattern found in the mountains. The land has considered that 11 300 ha. could be irrigated in subbasin zero which represent the Turkish catchment area for GZR in figure 3.13 in chapter 3 which represents a yearly withdraw of only 35 Mm^3. This amount is not significant if we compare it to the 5 billion m^3 flowing down yearly from Turkey to the GZRB. Agriculture demand in SB 21 and 22 is also neglected following the same argument.

2- Water storage and demand in hydropower

Topography in the Turkish area of the Greater Zab River Basin is quite complex and doesn't allow the implementation of big water storages. However, energy production can and should be developed in this area. Some projects are already identified and some information collected is presented in the figure 4.4 map of GZR catchment in turkey.

Figure 4.4 Possible hydropower dams on GZR in Turkey catchment

Until 2030, we consider that the implementation of hydropower plants reaches a production of 3000 GWh (1000 MW). Those dams will have an incidence on the river flow but not on the annual volume. Because of lack of information, we could not simulate the expected impact on the monthly river flow.

This question has to be monitored carefully. The water balance model can be fed with any new information regarding Turkish use, especially for Hydropower production.

Water transfers outside the river basin Massive water transfer outside the river basin to supply other areas for domestic, industrial or other demands are not considered a real risk in the GZRB.

In the long run, this risk could be reevaluated, but in 20 years' time, technical difficulties such as topography and distance to the potential water demanding areas and Turkish priorities to the GAP project which is still on-going, limit the possibilities of significant water transfer from Turkish part of GZRB to the rest of Turkey. Hence, the model considers this water transfer very limited to only 20 millions of cubic meters per year which are very limited compared to available water resources.
There are three dams and hydropower plants are presently under construction in Turkey and a fourth is in advanced stage of design in Iraq, intercepting the main watercourse in close vicinity to the border with Turkey:-

A. Fukuoka dam, with a reservoir capacity of 143 hm^3;

B. Doğanli dam, with 462 MW HPP;

C. Hakkari dam, with a reservoir capacity of 801 hm3;

D. Deralok-Rashawn dam, with a reservoir capacity of 457 hm^3.

CHAPTER 5

WATER GOVERNANCE AND CONFLICTS

5.1 Introduction

The Middle East is a region characterized by scarce water resources, rapid population growth and fast developing consumption-based economies. Water scarcity is increasing and expanding in the region. The scarcity of water is a result of neighboring countries divergence of water, changes in population structure and concentration, climate changes as well as the use of water in hydropower based electricity production. It is important to investigate the current economic, social and water resources conditions and alternative sources of water and to propose measures to enhance the effectiveness in the use of water resources to reduce the shortages in supply and the negative environmental effects. (DES, 2013)

Water considered as a binding constraint on sustainable future economic and social development in the region. Improved efficiency in the water use must be combined with the provision of new and additional water sources in the region to minimize the shortage of water. A detailed and clear water and environmental law will greatly help in the design and implementation of strategies for regional cooperation, in development and management of water resources, interregional trade relations, development of regional institutional arrangements, and joint regional water planning.

Through an extensive network of partnership action programs, many organizations from Africa, Asia, America and Europe are sharing their experiences and successes in this important aspect of International River Basin Management (IRBM), persuading decision-makers to move away from a fragmented, sectoral approach toward more integrated policies and practices. (Hooper, 2017)

The sound and balanced management of water resources in the world, especially within the international watercourses, is an essential condition for ensuring the quality of life on our planet. The sustainable social and economic development of our societies because water resources are the main source of prosperity and the source of problems as well as and it may be caused to destroy civilizations. It, therefore, recommended that agreements, strategies, programs, funding, and controls were designed for high-impact basins. Cooperation agreements should sign and formalize among riparian countries in relation to large rivers, lakes, seas and transboundary aquifers. (Hooper, 2017)

International Network of Basin Organizations (INBO) created in 1994 for that purpose. It counts today as many as 182 member-organizations coming from 88 countries (INBO, 2018)

The Network is open to the organizations managing large national or federal, or even transboundary river basins and the cooperation structures they have developed among them. The governmental administration in charge of water management in the countries applying or being interested in applying integrated water management:

1. Organized through large hydrographical units (River Basins);
2. Associating administrations and local authorities, as well as users from the various sectors;
3. Having specific budgetary resources at its disposal, obtained by applying the "user-polluter-pays" principle.
4. Multilateral cooperation agencies supporting institution-building activities related to large catchment areas and aquifers.

5.2 The Chapter Aims

This chapter includes clarifications on water governance and international agreements as well as the conflicts on the Transboundary River Basins on interrelated water resource practices. Review and explain the relations and agreements between Iraq and Turkey, and decide on the share of water between them. Provide an overview of the past and status of the current water resources management and development practices in Iraq, and identify the challenges in managing the demands on the water sector resources.

Rather than advise Iraq on how to balance its efforts between the needs of short-term rehabilitation/ reconstruction and of longer-term infrastructure and institutional development using economic criteria (DES, 2013)

This chapter has the following objectives:

A. To developed permanent relations with the organizations interested in a Transboundary River Basin management, and facilitate exchanges of experiences and expertise among them.

B. To promote the principles and means of sound water management in cooperation programs to reach a sustainable development.

C. To facilitate the implementation of tools for institutional and financial management, for programming, for the organization of data banks, of models adapted to the needs.

D. To promote information and training programs for local elected officials, for users' representatives and for the different actors involved in water management as well as for the executives and staff of the member basin organizations.

E. To encourage education of the population, the young in particular.

F. To evaluate ongoing actions and disseminate their results.

G. Finally establish examples for conditions should Iraq government to take for INRBO agreement between on Transboundary River Basin and especially for GZRB.

The section contains draft conditions for prepare agreements on water resources, and generally, whole Iraq and especially applies to GZRB. This chapter also contains guidelines on various rules, regulations, policies and incentive mechanisms for the successful implementation of the International Water Law (IWL) in the world. The gains in this area achieved through a review of the experience gained elsewhere, and care is taken to adapt it to the conditions of the GZRB. In the latter part, suggestions were made on organizational changes and the agreement of Iraq and Turkey model, as well as between Erbil and Iraq, in particular, the Zab Basin, educational programs, and various activities to facilitate smooth implementation. In addition, effective for the proposed agreement model between Iraq and Turkey, therefore between the province of Erbil and Iraq, as well as the result shows the law and incentive policy programs on water resources.

This chapter aims at preparing a combined draft covering important laws in a modern economy. It covers the specific water resources agreements and the general environmental laws, but when necessary it also deals with production, consumption, investment, business and health and education laws as well. In the preparation of the agreement water law account will be made for local conditions- Thus, the proposed result will serve as an example for the introduction of similar region-specific water laws to be prepared for the Iraq and turkey and for Erbil province and Iraq.

5.3 Euphrates and Tigris River Basin

A fifth example of rivers shared by different countries is the Euphrates and Tigris rivers case. The Euphrates and Tigris rivers originate from the Anatolian mountain southeast of Turkey. This plateau has an annual rate of rainfall of more than 1,000 mm.

These two river basins are international share water between Iraq and Syria share the Euphrates basin with Turkey and the Tigris basin with the Islamic Republic of Iran and Turkey.

Euphrates River has a catchment area of about 444000 km² within Iraq, the Syria, and Turkey. The annual water flow, for the Euphrates at its entry into the Syrian borders is estimated by 29.8 billion m^3 and the Euphrates total length from its source will it joins the Tigris in Iraq is about 2700 km. (Kolars, 1994,)

The catchment area of Tigris River 471606 km² within Iraq, the Syria, Iran, and Turkey. Four tributaries (Lesser Zab, Greater Zab, Al-Adheim, and Diyala) feeds the Tigris within Iraqi boundaries. Annual River flows around 48.7 billion m^3 with length 1800 km.

The Turkey government started to implement the largest developmental project in the Euphrates-Tigris River system “South-Eastern Anatolia Development Project” known as GAP. The GAP project included construction of 21 dams and 17 hydropower plants on both rivers. The land to be irrigated around One million hectares and 625000 ha with the extension plan. The GAP power plant capacity 7500

MW with 26 billion kWh an average annual power production. This, in turn, represents 19 % of the total irrigable land 8.5 million ha in Turkey, and 20.5 % of the country's hydropower. (Kolars, 1994)

All past negotiations have failed because of the determination river flow for each riparian countries to keep exclusive control of the Euphrates-Tigris river flows. The main dispute over the Euphrates-Tigris waters stemmed out of the different attitudes of the riparian states as regards the "International River" or "Transboundary River.

The only agreement exists was signed in 1987, by which Turkey agreed on five hundred MC per second river flow of the Euphrates in the Syrian border, although Iraq and Syria requested the river flow of 700 m^3/s. A tri-partite technical committee for the exchange of technical information is the only accepted forum for cooperation between the riparian states. Kolars (1994) has reported that the GAP when fully implemented would have conceptually three main impacts on downstream countries.

First, the diminishing of downstream flow to about 360 m^3/s as a result of water loss by evaporation from storage reservoir surfaces instead of the agreed upon of 500 m^3/s.

The second impact is the detouring of significant quantities of water from the main channel through Urfa Tunnel to Urfa-Harran-Mardin irrigation projects.

The third impact river more pollution, the river flows of possible pollution by the return, flow from irrigated fields.

5.3.1 Turkey and International Relations on Water Resources

The total area of Turkey country is 783560 km^2 and the amount of surface water is 14300 km^2 (1.8%). It has around 177714 km rivers length, as well as 2036 km^2 the surface area of natural lakes and surface area of dam reservoirs and artificial lakes around 1799 km^2, it has over 10000 km coastline length. Turkey located in Asia and Europa, around 3% of its land in Europe and 97 % in Asia (Anatolia), so it has a great position. Turkey has a border with several countries (Azerbaijan, Bulgaria, Georgia, Greece, Iran, Iraq, and Syria, as well as the Aegean, Black, Marmara, and Mediterranean seas, figure 5.1 it has a population 75.9 million (2017) and remains one of the fastest- population growing countries. Major movements from rural areas to urban area, (industrial and tourist) areas continue. The current available water resources capacity around 110 billion m^3 and the water use rate is 39%. About 1500 m^3 annual per capita water volume by 2013, Turkey is one of the countries with water restrictions. (Delipınar and Karpuzcu, 2017).

Figure 5.1 River Basin and Provinces border in Turkey

The future annual amount of water available per person predict to be 1100 m^3 in 2030, Turkey also may become a country facing problems and shortage of water demand situation. This situation is clearly shown in figure 5.1. In Turkey, there are 81 provinces and is distributed into 25 river basins. Transboundary and national boundary-forming water- courses put together roughly 40% of the gross water potential generating in Turkey. The Ministry of Forest and Water Affairs in Turkey (TMFWA) and the Turkey Ministry of Foreign Affairs (TMFA) determine these management strategies for this transboundary basin'.

Delipınar and Karpuzcu (2017) The rapid population growth rate in the region, the increasing urbanization, used of technology, intensive industrial and agricultural activities within river basins, causes degradation and contamination of water resources, soil erosion and sliding, changes in hydrological systems around the world. In order to overcome these situations, it is required to develop an effective management methodology, called integrated river basin management (IRBM). It is an acceptable and internationally accepted management tool.

Delipınar and Karpuzcu (2017) also explain that regarding the IRBM turkey is closed to enter the EU and It is ready with all requirements for implementation of the

European Water Framework Directive (WFD, 2000/60/EC) of the EU Member States and Candidate Countries. Turkey trying hard to enter the EU country and part of EU systems as a candidate country to enter the European Union has already begun and continues to hard work to adapt to the WFD. Since the early decade of the 2000s century, studies have carried out in river basins to facilitate the task of entry and integration into the WFD and according to Turkish legislation. (Lepper, 2005)

Although Turkey is a country with a strong legislative background and international assistance and acceptance, there are many challenges in this transitional period and the lack of environmental infrastructure due to many large river basins. Where the main sources of rivers generated within Turkey, the upstream state of the Tigris and Euphrates rivers, and the cost of implementation of the WFD.

Delipınar and Karpuzcu (2017) in their article, explained the implementation of IRBM in Turkey were analyzed the political, legislative and institutional progress. Before assessing, the new Turkish legislative developments and the new basin institutions, the general principles of IRBM and how they were applied to the management of water resources in Turkey were explained. Finally, some recommendations made to improve the effectiveness of new basin organizations and water legislation within Turkey. (Delipınar and Karpuzcu, 2017)

Also in this article, recommended that the basin boundaries determined by the TMFWA be usually fair by all public institutions that working in water resources and water management. For instance, the (TGDSHW) (Turkey General Directorate of State Hydraulic Works) should change the strategy of its management unit from its regional borders to defined basin boundaries. The Turkey statistical institute (TSI) also should implement its studies for both the provincial and basin levels. (Delipınar and Karpuzcu, 2017)

5.3.2 Iraq and International Relations on Water

Due to its geographic location basins, Erbil province has to share its expertise in the water sector with neighboring countries and with the rest of Iraq. The Greater Zab river basin and more generally those of the Tigris and the Euphrates shared between Iraq, Turkey, and Iran as well as shared with Syria as regards to the Euphrates. There are several major dam projects on the Tigris River, particularly in the Greater Zab river basin.

These are multipurpose projects including a reserve flow component, irrigation, and hydroelectric power generation. A comprehensive approach towards water is required to address both the internal and external aspects of the issue based on a strong and sustainable regional dialogue and cooperation, and the improvement of water management. (Yuksek et al., 2006)

It is necessary to "Manage Transboundary River Basins with several of technical and political initiatives. From point of view, there is a strong required for a strategy at a river basin level involving Turkey, Syria, Iraq, and Republic of Islamic of Iran. These type of plan required to highlight a coordinated strategy to address topics drought events, hydroelectric production, water flood management, and irrigation uses as a first priority to optimize the utilization of available water resources. Account the reduction in the availability of water in the Tigris and Euphrates, it is also important to reach an agreement on equitable and just regional water allocation within a water resource management plan. (Yuksek et al., 2006)

A technical committee of experts from Turkey, Syria, and Iraq made a set up a few years ago (1982). The general director of water resources of the Erbil is one member of this committee. This committee includes around 10 persons, three from each delegation, and discuss on water management: water distribution, investments. They meet only when a specific need expressed. The agreements coming out from this committee need to be approved by the parliament in Baghdad. (MOA&WR, 2016)

An agreement on the use of Euphrates and Tigris water signed as early as 1946. An agreement signed between Syria and Iraq in 1990 on sharing of Euphrates water. There is today no international agreement regarding the discharge and volumes into the Tigris.

The annual report from Iraqi ministry of water resource 2016 mentioned that Iraq has ratified on 9 July 2001 the United Nations Convention of 1997 concerning Non-Navigational Uses of International Watercourses. Turkish is one of the three states (with Burundi and China) around 133, which had voted against the resolution in 1997. (IMWR, 2016)

5.3.3 Iraq Transboundary River Basin Cooperation.

Due to economic well-developed Turkey, being substantially more developed than its Syria and Iraq is most efficient in its water usage. Due to increasing the overall economy in Iraq and Syria, the water flow from river required by Iraqi and Syria. The river flow calculations, that dry season flow treaty of about 60 % of the average Euphrates water of river flows from Turkey to Syria would be needed to achieve this effect. Therefore, the political measures the sustainability negotiation, and highly important, should also be observed to guarantee a minimum downstream flow requirement of both rivers. On the other side, the regulate fluctuations option of the rivers is to build reservoirs in the basin. (Kolars & Mitchell, 1991)

The Turkish GAP Project announced the construction of 22 dams, among which 15 have been completed so far. (Carkoglu & Eder, 2001).

These have a high economic potential for the surrounding region. Agreements between the three countries are required very soon, as the high population growth also causes to increasing water shortages in the downstream countries. For example, the water salinity in the south of Iraqi Euphrates has high increased in the last thirty years and it causes to damages big parts of marshlands.

On the other hand, the recovery of farmlands would have the potential of creating thousands of unskilled jobs in the upstream country. A sustainable joint usage of the Tigris Euphrates by the all-sharing countries, therefore, increases the overall welfare of the region. It should also be on the topic of international institutions such as the EU and the World Bank to support cooperation between all adjacent countries. The important next step in such a process is Turkey's potential ratification of the "UN Convention on the Law of Non-Navigable Uses of International Watercourses". Extra steps such as loans for the GAP project have to be pressed forward to reward and compensate Turkey for guaranteeing certain minimum water releases to its downstream, neighbors. (IMWR, 2016)

5.3.4 Summary for Tigris and Euphrates River

As the Euphrates and Tigris flow beyond the borders of Turkey, Iraq, and Syria, their use is related to Turkey, Syria, and Iraq. To use these two rivers to increase prosperity and prosperity in the region, the three countries should agree on common principles for water use. Turkey has presented its options, and opinions on this issue to the participating countries in the water basin with a "three-phase plan".

So far, no clear agreement has been reached between Turkey, Syria, and Iraq on the issue of the peaceful and optimal use of these waters. Syria has not succeeded in its objections in the last few years and has begun to retreat with Turkey. However, Iraq has not yet offered a compromise on the subject, which may also be due to political instability in Iraq and the region over the past 50 years. In addition, the United States and European Union countries are showing a difficult approach by appearing to protect the interests of Arab countries and to influence the peoples of these countries against Turkey. Regrettably, many third world countries have taken this deceptive act. (Karpuzcu et al., 2009)

Turkey offers a comprehensive approach to the region through the Phase III Plan. The scope and purpose of the Plan are presented as a cooperative action by the three countries for the rational and great use of the waters of the Euphrates and Tigris in a wise manner. The following is the outline of the third phase plan on Turkey to Syria and Iraq in 1984 through a joint technical committee from Turkey, Syria, and Iraq. (Karpuzcu et al., 2009):

1- The watersheds of the Tigris and Euphrates should be treated on a different river basis and deal with parting between them as well as should be regarded as a single water basin.

2- In order for the three countries to use this water wisely and Judiciously, it is necessary to establish a joint scientific technical committee from the three participating countries and use scientific methods based on realistic information to provide the best solutions for the basin by following the scientific approaches as described below:

I. Collection of all types of hydrological information for the basin, such as the amount of water carried by the water basin, rain flow relationships, evaporation and loss of water, and sediment flows.
II. Use of data and common standards, identification of water needs for irrigation and drinking, municipal and industrial uses and demand for sustainable wetlands within the basin.
III. Based on this information, joint projects are prepared using the most appropriate technologies, the development, and implementation of the most economical models, and the coordination and coordination required in cooperation with these three countries.

3- The aim of this tripartite plan is to benefit each of the three countries objectively. The plan is humanitarian, reasonable and fair. Turkey hopes that this plan will be studied by experts and that Iraq will receive positive results and that the three countries will take concrete steps to use this water for the benefit of their people and their future. (Karpuzcu et al., 2009)

5.4 Sample Country Experiences

The EU acquis is generally neutral in terms of public and administrative administration, organizational structures, and does not predict any model or structure. Within the EU, there are countries with central, regional, or federal structures, and they are free to choose the approach they will use to implement EU legislation. For this reason, member states have adopted different public administration systems within their state culture and traditions, political and socioeconomic characteristics. However, it is not directly interfered with the administrative systems of member states. Nevertheless, it seems that in some way EU membership has shaped and influenced the administrative structures of the countries. all key areas of resources management to develop a corporate proposal structure applies to watershed management or Strategic Environment Assessment SEA have made the transition to the basin management or improve the structures of the countries selected according to certain criteria in the basin, including water primarily based on watershed boundaries for Turkey were examined. Some criteria have taken into account in the selection of these countries. (Delipınar, 2017)

Figure 5.2 European Water Policy Planning

The following criteria have taken into consideration when selecting these countries. As the leading EU countries in the creation and entry into the territory of the SEA and the country that has won the water and solved the water problems as soon as possible, Situations in which the River Basin Management Plan (RBMP) is prepared in the framework of the time schedule envisaged by the Strategic Environment Assessment (SEA) in EU member states. (White & Howe, 2003).

5.4.1 Netherlands River Basins and Water Management

The Netherlands is a northern European country with a surface area of 41,526 km^2 and a population of about 17,187,700 million. (CBS, 2017). There is a coast to Belgium in the south, a neighbor to Germany in the east, and the North Sea to the north and west. Belgium and Luxembourg, as well as Benelux countries. EU, NATO and OECD member. He also signed the Kyoto Convention. The majority of the territory of the country is below the sea level and the delta, formed by four large rivers (Ren, Meuse, Scheldt, and Ems). By some calculations, the delta covers 25,347 km^2, making it the largest in Europe. Because of its geographical location, a country stands out with its technology that turns water into an advantage because it is a face with continuous flood damage. The Netherlands protected from the seller by means of settling, barriers and dam construction. There are 12 provinces in the country and are seen in the country map in Figure 5.3. (Asselman, 1999)

Figure 5.3 Netherlands map Rhine and Maas River and province.

For more information, the general data on the Netherlands, country and it is water resources given in Table 5.1 (CBS, 2017).

Table 5.1: Netherlands general information and water resources situation.

Administrative and Socio-economic Situation	
Management Shape	Constitutional Kingdom
Surface area (km^2)	41500
Total Population (million) (2014)	16.87
Population Density (persons / km^2)	407
Urban Population%	90.2
GNP ($)	788 Billion
GNP ($ / person)	46310
Land Use	
Agricultural Area (%)	54.9
Arable Area (%)	30.8
Forest Area (%)	11.2
Water resources	
Water (Fresh) potential (m^3) (2014)	11 Billion
Per capita (sweet) renewable water source (m^3/year)	652
Annual total water use (m^3)	10.7 Billion
Agricultural water use (%) (2014)	1
Industrial water use (%)	88
Domestic water use (%)	11
Precipitation (mm / year) (2014)	778

5.4.2 Netherlands and Water Law

According to SEA and 2009 Water Law, the country, divided into 4 river basins (Ren, Ems, Scheldt, and the Meuse). Each is part of a Transboundary River Basin territory. Stakeholder countries; EU member states, and Switzerland. SEA allows smaller basin divisions of basins for international coordination of river basins. According to this, since the Rhine basin in the country is divided into 4 sub-basins, there are totally 7 sub-basins; Central Rhine, North Rhine (Groningen, Drenthe, Nedereems, and Fryslan), East Rhine, West Rhine, Ems, Scheldt, and the Meuse. In the map in figure 5.4, the lower basins of the Rhine Basin and the other river basins are visible.

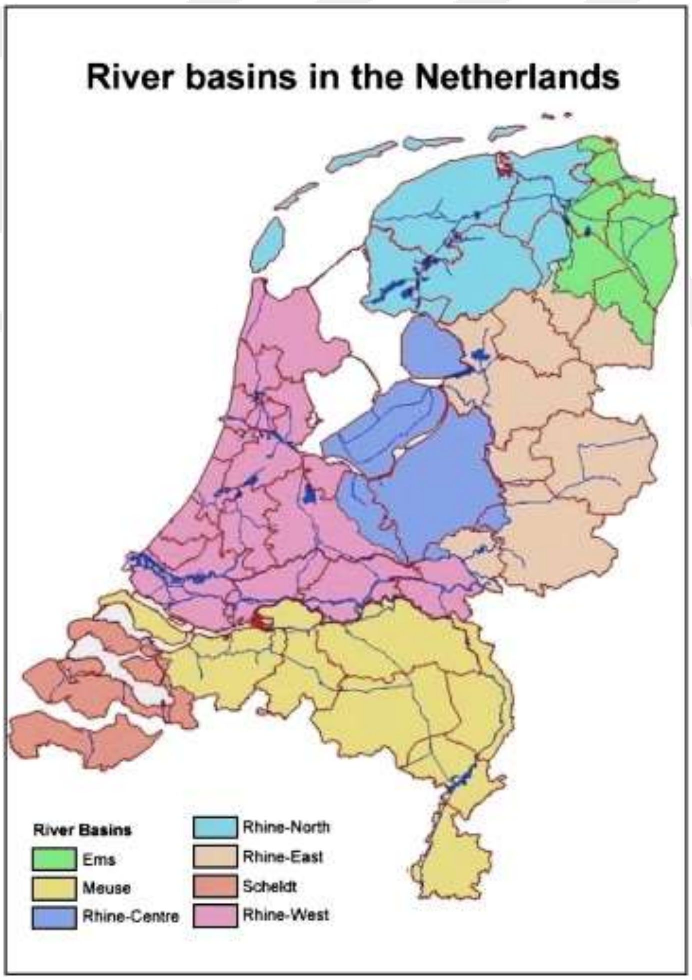


Figure 5.4 Map of Dutch river basins and lower basins.

The largest river basin in the Netherlands is Rhine River with 68% and is a stakeholder shared with five countries. (Germany, France, Switzerland, Austria, and

Belgium) 60% of the drinking water of the Netherlands, obtained from underground waters in the eastern part of the country and from the rest of the Rhine and Meuse rivers in the west. In SEA process, 724 surface water and 23 groundwater masses were determined. Of these water bodies, 42% were largely altered and 56% were artificially classified (Junier, 2010).

After 99% of domestic wastewater is treated, the river discharged to the center. (Leterme, 2014) Point pollution sources controlled according to EU directives. Spilled pollution sources are the main problem. Generally, surface water quality is adequate for drinking water, agricultural use, bathing water and other recreational activities, but insufficient for SEA (Junier, 2010).

Approximately 70% of state waters such as Rhine, Meuse, and Scheldt come from foreign sources, 15% from agriculture and 15% from the rest of the country. There is about 50% of agricultural and sewer water contributions in the regional waters. (Junier and Mostert, 2011)

5.4.3 Dutch Water Policy and Management

Water has always played a central and very important role in Dutch history, in other words, commerce, transportation and fishery, and the water that brings revenue to the country, the floods have caused many damages. The history of water management began in the 9th century, and local water management organizations have developed since the 13th century due to the need to control water. The Ministry of Infrastructure and Environment, (Rijkswaterstaat), established in 1798. Transport channels, built all over the country. The water management of the country is usually very efficient. Water levels manipulated to suit both soil and water functions. (Junier, 2010)

Today, the water management policy in the Netherlands is to protect the water by increasing the level of water. This centennial policy, expanded in 2000 as a river basin, expanding to protect the rivers and withdrawing the sets around the river. Since the Netherlands is in the downstream state, it has supported the implementation of the SEA as a means to take remedial measures for water situation and to persuade other countries to cooperate.

5.4.4 Netherlands Legal Water Framework

In the Netherlands, the duties and competencies of the different institutions, determined by the Constitution, such as the Provincial Act, the Municipal Law and the Water Board Act. Water Management Act 1900 (Water Administration Act 1900) provides provisions on inter-governmental relations and crisis management. The Water Management Act defines the construction of relevant policy plans as well as others. The Netherlands adopted the "Implementation Law (April 7, 2005)" to amend existing legislation, such as the Water Management and Environmental Protection Act, in order to harmonize its laws with the SEA. Which requires that the competent authority or authorities determine the water in each river basin in each basin, other authorities are ministries: Transport, Public Works and Water Management, Ministries of Housing, Spatial Planning and Environment, Agriculture, Nature and Food Quality, and they are responsible for the implementation of SEA in their own authorities. Coordination is important. (Delipınar, 2017)

The most important water laws have been replaced by a single "water law" covering. All areas of water management. The Water Law adopted by the first chamber on January 27, 2009, and entered into force on 22 December 2009. The law contains definitions of SEA terms and identifies river basin boundaries geographically. Authorities for water management have remained the same, with the cooperation the river basin level indicated, but not how it should do (Junier, 2010). Activities to reach the European Nitrates Directive (91/676 / EEC) have been carried out and the second new fertilizer law has been developed. This law was revised in 2006 because it is not directive compliant and does not contain extra restrictions on behalf of the SEA.

The National Water Plan prepared by the Ministry of Infrastructure and Environment and, provides the main components of national water policy and National City planning policy. The National Water Plan covers the Dutch section of four Transboundary River Basin management plans and the program of measures required by the SEA. Regional Water Plans prepared by illusions; the national water plans focus only on regional policy and water systems, covering the objectives and parts of the program of measures for regional waters. Like the National Water Plan, they have a "building plan" status under the City Planning Act. National and Regional

Water Plans are prepared, presented and harmonized and supplemented. (Junier, 2010)

5.4.5 Netherlands Institutional Restructuring

Water management has organized at four levels: international, national, provincial, local level. Ministries at the national level, illusions and water boards at the regional level, and local municipalities. Many operational authorizations have given to local authorities. The Netherlands seen as a decentralized state: it has taken into account regional interests and issues, as well as national oversight and control. (Junier, 2010)

At the international level, cooperation between the River Basin Commissions has existed for many years, for example, the International Rhine Commission (IRC) and the International Meuse Commission (IMC). The Conference of Ministers plays an important role as they make politically binding decisions. EU Directives have an increasing precaution. (Junier and Mostert 2011)

Three ministries play an essential role in the National Seventh, in water management and in the implementation of the SEA. (Junier and Mostert, 2011)

A- Ministry of Transport, Public Works and Water Management (V & M),

B- Housing, Spatial Planning and Environment (VROM)

C- Ministry of Agriculture, Nature and Food Quality (LNV).

The 443 municipalities in the Netherlands have many local government competencies. The residents of the municipality elect the City Council

Here are different strength to solve the conflicts in the water and river basin between the EU countries and the Netherlands one of the EU countries take high-level responsibilities and the points as shown below

1. Water Information Platform: Meetings water experts and advisors gathering the persons who coordinate research programs for water policy development, execution and data required. Forum government, social organizations, science institutes, engineering agencies and so on. The national plan for information and innovation for water is developed through participatory consultation of comprehensive information

2. Deltares; is an institute for working on water resources research in all sectors and doing innovations that focus on water, its resources, rivers, and delta

3. Royal Water Network (Koninklijk Nederlands Water network); It is an over 4000 water professional networks the aims to share information and experience.

4. UNESCO-IHE; international Institution of water and hydraulics research, activities in water engineering, water management, environment, hygiene and land development.

5. Netherlands Center for River Studies.

6. Water Help Desk; It is a group center for requests from experts working on water policy and management (drought, etc.) and water security. Figure 5.5 shows the relation between the responsibility organization within EU(Junier and Mostert, 2011)

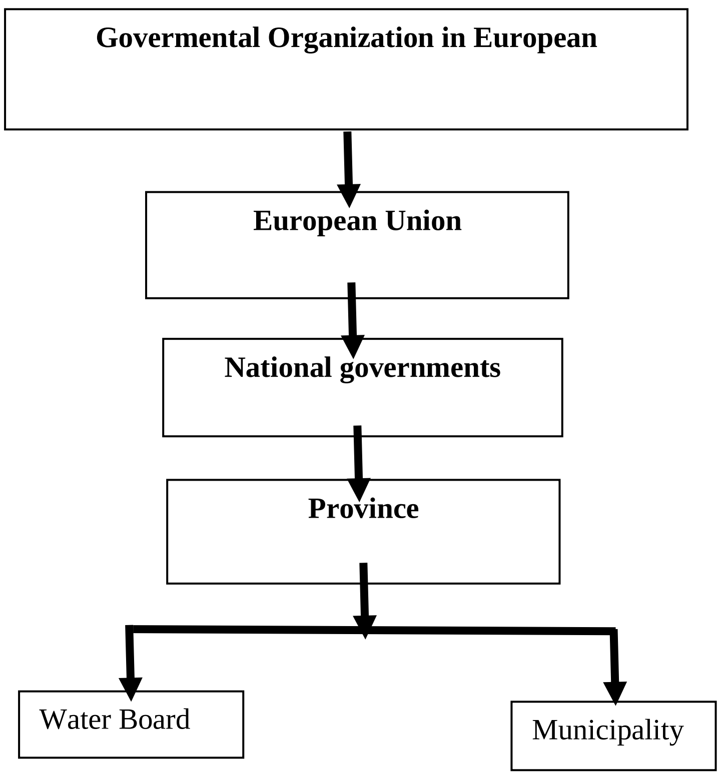


Figure 5.5 European Governmental Organization

5.4.6 Summary for Rhine River

The Rhine is the main river that flows from upstream Switzerland and flows through France, Germany, and the Netherlands to the downstream to reach the North Sea; the river basin includes 9 European countries. International cooperation on the Rhine basin started and has been ongoing since 1815 and is still a solution to cross-border conflicts and management of water problems, including salt intrusion, navigation, flood issues and water pollution.

This chapter focuses on international cooperation needed to reduce pollution in the Rhine. Water quality declined during the 1850s as a result of waste discharged into the river by industrialization and urbanization. Despite the formation of international committees to achieve the pollution problem, water quality improvement plans were not implemented until the 1980s. The Rhine Program of Action for the Restoration of Environmental Habitats and the Quality of Drinking Water for More Than 20 Million People in the Basin, inspired by the Sandoz accident in 1986, has been developed. The Rhine Action Program has succeeded in reducing phosphorus concentrations and reviving salmon populations. After the end of the program in 2000, the "Rain 2020" and the EU Water Framework Directive were adopted for further monitoring of water quality and ecological rehabilitation. The success of the program was attributed to massive cooperation and stakeholder involvement at all stages of the process, water (Water Diplomacy Framework).

The Rhine basin has faced a variety of issues in the past, including navigation, pollution, high levels of salt, environmental degradation and flooding, and some of these issues still exist today. In particular, pollution problems in the Rhine began in the 1850s due to increased flow of water/fertilizer and industrial waste released into the river. As industrialization progressed, more chemicals, metals and organic compounds were released, and the accumulation of these components resulted in lower fish numbers. In addition, urbanization during this period resulted in large quantities of household waste being incurred by the basin. Wastewater treatment plants have not been able to cope with increased capacity, and because industries have achieved such economic growth, policymakers have not wanted to limit the amount of waste generated by the facilities. Moreover, downstream countries, particularly the Netherlands, have experienced high salinity in drinking water supply from the Rhine because of the waste salts are thrown from the potash mining. To aggravate this issue, the Sandoz incident in 1986 triggered toxic chemicals that affected more than 400 kilometers of the river. Sandoz, the agrochemicals warehouse in Switzerland caught fire and chemicals leaked into the river killed many living organisms and contaminated drinking water supplies to those living in the Rhine basin. In addition to the river sediment that causes problems for the Holland country as a downstream state. Generally Rhine river problems and conflicts solve within EU water board and through the WFD.

5.5 Jordan River Basin

The total area of Jordan River Basin around 18,500 Km^2 it is Transboundary River Basin, and the ratio of 40% of the basin located in Jordan, 37 % of basin located in Israel, 10 % of the basin located in Syria, while the 9 % in the West Bank and 4 % in Lebanon. (Table 5.2 and Figure 5.6). The length of Jordan River is 250 km consists of three sub rivers: Dan, Banias, and Hasbani (Danish Green Cross, 2006).

5.5.1 Water Resources in Jordan Basin

In General, most of the water flow in Jordan River basin generated in upstream of Tabaria Lake, and the 40 % of river flow generated in the downstream area of the basin, (Venot et al, 2006). The main sub river is Yarmouk River, which is located in the downstream part of the basin and inters to the Jordan River in an area under slightly Israel controlling. During the dry season, mostly the river dry completely and construction reservoir for storing water during wet season very important, as well as using the water in summer it's most idea for water management in Jordan River Basin, otherwise, during winter the river flows to the Dead Sea, without using (Green Cross Italy, 2006).

Table 5.2 Jordan River basin and proportion of its area in the countries

Basin	Area		Countries Regions include	Basin Area in Country Km^2	As % of total area of the basin	As % of total area of the Country
	Km^2	% of the middle east				
Jordan	18500	0.28	Jordan	7470	40.4	8.4
			Israel	6830	36.9	32.9
			Syria	1910	10.3	1.0
			West	1620	8.8	28.7

	Bank			
	Lebanon	670	3.6	6.4

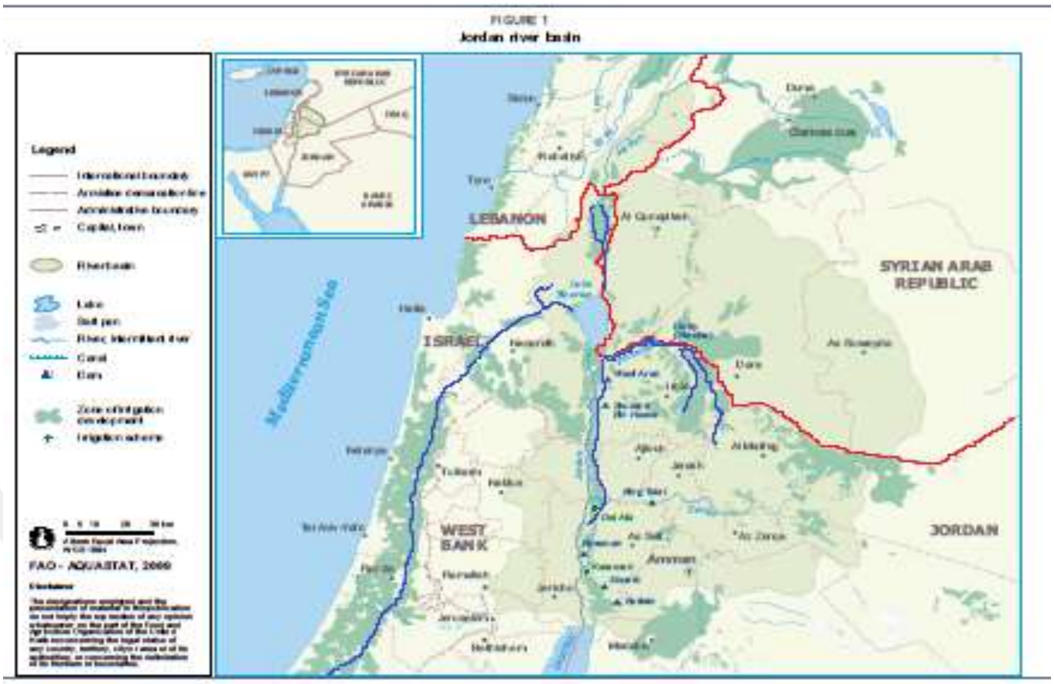


Figure 5.6 Jordan River Basin, source: FAO AQUASTAT 2008

5.5.2 Water Conflict and Negotiation

The Jordan River basin developing water-sharing strategy started as the beginning of 1913, and in the year, 1955 changed to the proposed plan called (Franjieh Plan). The plan intended basin for the irrigation water use, as well as to produce hydropower and to move out Yarmouk annual water flow (100 million m^3) to Tiberias Lake (Sofer et al., 1999). The Plan contained the allocation of 55% of Jordan Basin water availability, 36% use for Israel, and 9 % use for Syrian and Lebanon. However, the plan not ever signed by the countries shared in the river basin. Mostly the river basin conflicts started in 1969 when Israel batter Jordan's because of water diversion (Green Cross Italy, 2006), after that, Israel and Jordan signed an agreement on quantities of river water flow, it called Johnston Plan for participation the Jordan River Basin's water (Milich and Varady, 1998). In the year1978, Israel temporary controlled the Wazzani spring/stream feeding the Jordan River. (Attili et al., 2003)

In the year 1978 prepared the memorandum of the agreement between the Syrian and Jordan, where determined the Syrian share of the Yarmouk and fixed the Syrian to building 25 dams with a capacity of 156 million m^3. İn this time, the Syria government has built 37 reservoirs on the four sub-basins of Yarmouk River with a total reservoir capacity of 211 million m^3 (i.e. 55 million m^3 in violation of the agreement). On the other hand, Syria government continuous drilled deep wells inside of the Yarmouk Basin, also it negatively influenced the river flow and therefore, the water flows reduced by around 30 % (Green Cross Italy, 2006). Finally, they decided to arrange agreements, the agreement included (WAHDA) Dam on the Yarmouk River, with a total storage capacity of 225 million m3, Jordan would receive 75 % of the water stored by the dam, and the Syrian would receive all of the hydropower produced. However, by new study regarding water availability in this basin in 2003 the dam height decreased to 87 m, therefore, the capacity of storage reduced to 110 million m^3. Finally, the dam completed in 2007.

In October 1994, Israel and Jordan signed an agreement called Washington Declaration and negotiated the Treaty of Peace. The agreement comes out with allocations for both the Yarmouk and Jordan rivers and controlling water pollution and this led to Joint Water Committee established from both Israel and Jordan (IJJWC), the committee included three members from each country. The two countries promised to share water resources data on among the IJJWC and included developing plans cooperate for purposes of rising water supplies and improving the efficiency of water use. It also identifies the quantities to use, stored, and supplied by and to each country during the dry season and a wet season (Milich and Varady, 1998).

Jordan is entitled to store 20 million m^3 of the upstream of Jordan River and water flow during the wet season to Israel (in Lake Tiberias) and returned during the dry months. In the agreement Israel is to provide only 50 million m^3/year of additional water to Jordan, have shortage cannot allow the Jordanians to cover their annual deficit, the cooperation done between the two countries and agreed to find sources for supply Jordan with an extra amount of 50 million m^3/year fresh water. To protect the shared water, and established together monitor of the water quality within their boundary, installing monitoring stations to operate under the instruction of the IJJWC. Finally, Israel agreed to an Initial solution for supply three years Jordan with 25 million m^3 of water, until establish of the desalination plant.

On the other hand, Israel and Palestine's negotiated during1993 and 1995, it led the initial agreement to cover the West Bank territory. In September 1995, the “Israeli-

Palestinian extend agreement to include the Gaza Strip” commonly referred to as “Oslo II”, was signed

The most difficult things to negotiate was water rights, therefore for inclusion in the negotiations the final agreement postponed. However, the equalization was carried out Israel recognized the Palestinian water rights – during the temporary duration amount of 70–80 million m^3 should be available to the Palestinians – and a Joint Water Committee was established also to manage water needs in West Bank and to develop new supplies. In 2003, the Quartet committee to find the direction of the United States developed peace roadmap, in cooperation with the Russian Federation, the European Union, and the United Nations, presented to Israel and the Palestinian Authority to discuss a final and comprehensive settlement of the Israel–Palestinian conflict. (Wolf, 1996)

The exchange of the Golan Heights for peace accounted as basic information for negotiation between Israel and Syria. During the year, 1967 Israel controlled the Golan Heights area and then Israel controlled the main water resource in the basin, which feeds Israel’s only lake and its main source of freshwater, supplying the country with a 75 % of its domestic water. (Wolf, 1996)

On the other hands, the water resources of the Hasbani Basin for Lebanon and Israel became a source of problems and conflicts, due to Lebanon announced to the construction of a new water pump station in 2002 and pumping the water from Wazzani springs. These springs feed water to the Hasbani River and flow to Jordan River, thereafter the lake of Galilee, which is main Israel’s reservoir. The pump station implemented in October 2002. It is provided drinking and irrigation water for 60 villages in Lebanon. (Wolf, 1996)

Table 5.3 Israel Palestine water allocation

Source	Palestine	Israel
Jordan river	0	100
Wadi Al fara	5	95
Wadi Gaza	2	98
Eastern Aquifer	60	40
N. Eastern aquifer	35	65
Western Aquifer	6	94
Coastal Aquifer	35	65
Overall	10 %	90 %

The Israelis protested about the noncooperation and non-consultation whereas the Lebanese considered that the project was part of 1955 Johnston Plan for water resources in the region. During the year 2004 and 2005, regarding the agreements between the countries Jordan received annual water around 119 MCM from the Yarmouk River and 92 million m^3/year from Tiberia lakes, it is meaning only around 10 % of the total flow of the Upper Jordan and Yarmouk rivers. It is also much less than, the water share from these two basins proposed by the Johnston plan through his negotiations in the 1950s. In 2007, Jordan and Syria agreed to the implementation of agreements signed by the two countries, regards to share water in the Yarmouk River Basin.

Table 5.4 Main historical events and information's Jordan River Basin.

Year	Plans/projects /treaties/conflicts	Countries & territories involved	Main aspects
1913	Franjieh Plan	Ottoman Commission	Irrigation of the Jordan Valley, transferring Yarmouk River flows to Lake Tiberias, generating electricity.
1951	Jordan announced Plan	Jordan	Jordan Plan to divert part of the Yarmouk river via the East Ghor canal.
1953	Israel began construction of the National Water Carrier (NWC)	Israel	Resulting in military skirmishes between Israel and the Syrian Arab Republic.
1955	Johnston Plan	USA. Riparian countries	Allocation of water: 55% for Jordan, 36% for Israel, 9% each to the Syrian Arab Republic and Lebanon. Not signed because Arab riparian countries insisted the USA was not impartial.
1964	The NWC opened and began diverting water from the Jordan River Valley	Israel	This diversion led to the Arab Summit of 1964.
1964	Arab Summit	Arab League	A plan was devised to begin diverting the headwaters of the Jordan River to the Syrian Arab Republic and Jordan.
1965–1967	Israel attacked construction projects in the Syrian Arab Republic	Israel, Syrian Arab Republic	This conflict, along with other factors escalated in the Six Day War in 1967.
1967	Six Day War	Egypt, Israel, Jordan, Syrian Arab Republic, Occupied Palestinian Territory	Israel destroyed the Syrian diversion project and took control of the Golan Heights, the West Bank and the Gaza Strip. Palestinian irrigation pumps on the Jordan River were destroyed or confiscated after the Six Day War and Palestinians were not allowed to use Jordan River water. Israel introduced quotas on existing Palestinian irrigation wells and did not allow any new ones.
1969	Israel attacked Jordan's East Ghor Canal	Israel and Jordan	Because of suspicions that Jordan was diverting excess amounts of water. Later on, Israel and Jordan acquiesced to the apportionment contained in the non-ratified Johnston Plan.
1978	Israel's invasion of Lebanon	Israel and Lebanon	Giving Israel temporary control of the Wazzani spring/stream feeding the Jordan.
1987	Syrian Arab Republic and Jordan agreement	Syrian Arab Republic and Jordan	Defined the Syrian share of the Yarmouk and limited the Syrian Arab Republic to 25 dams with a capacity of 156 million m^3. The Wadha (Unity) Dam was included.
1993	Declaration of Principles on Interim Self-Government Arrangements	Israel, Occupied Palestinian Territory	Called for Palestinian autonomy. Creation of the Palestinian Water Administration Authority. Water Development Programme.
1994	Washington Declaration and Treaty of Peace	Israel and Jordan	Israel and Jordan signed The Washington Declaration, ending the state of belligerency and negotiated the Treaty of Peace. Allocations for Yarmouk and Jordan rivers and efforts to prevent water pollution.
1995	Israeli-Palestinian Interim Agreement on the West Bank and the Gaza Strip (Oslo II)	Israel, the West Bank, and the Gaza Strip	Israel recognized Palestinian water rights (during the interim period a quantity of 70–80 million m^3 to be made available to the Palestinians). A Joint Water Committee was established to cooperatively manage West Bank water and to develop new supplies.
1996	Israel tries to begin talks on water resources with the Syrians	Israel and Syrian Arab Republic	Syrian Arab Republic refuses because of the conflict concerning the Golan Heights.
1999	Israel reduces the quantity of water piped to Jordan by 60 percent	Israel and Jordan	Due to drought. This reduction caused a sharp response from Jordan.
2002	The Wazzani Conflict	Israel, Lebanon	Lebanon announced the construction of a new pumping station at the Wazzani springs causing tension between Israel and Lebanon.
2003	Roadmap for Peace	Israel, Occupied Palestinian Territory, The Quarter	Purpose: to end of the Israel-Palestinian conflict.
2007	Jordan and Syrian Arab Republic agreements	Jordan and Syrian Arab Republic	Implementation of agreements signed between the two countries, especially with regard to shared water in the Yarmouk river basin.
2008	Negotiations between Israel and the Syrian Arab Republic	Israel and Syrian Arab Republic	Negotiations are taking place in order to resolve the the Golan Heights conflict.

5.5.3 Summary for Jordan River

One of the reasons for the increase of political tension between Israel and its Arab neighbors was the issue of water in the Golan Heights, Israel, and the Jordan Valley, which feeds the Jordan River along with its tributaries and the Yarmouk River. In 1955, the two parties agreed to share the shares of the Jordan River and its tributaries under the supervision and mediation of the United States of America with 35 million cubic meters in Lebanon, 132 million cubic meters for Syria, 720 million cubic meters for Jordan and 326 million cubic meters for Israel with a total of 1213 million m^3 (Karpuzcu et al., 2009)

In 1979-1980, the second agreement was signed among the countries of the region. This secret agreement signed between Israel and Jordan covers the issues of sharing the water of the Yarmouk River and cleaning the King Abdullah Canal. Israel has ordered its own engineers to join the task of cleaning the irrigation canal. As we have seen, although the legitimacy of the governments of the Arab countries at the time was based on the tasks that are trying to throw Israel out of its territory, the water and water resources in the region forced both sides to sit at the negotiating table.

One of the causes of the wars between Israel and its Arab neighbors seems to be the struggle and competition for the sharing of the waters of the Jordan River and for obtaining the largest amount of water. At the end of the so-called historical literature of the Six Day War, Israel gained this strategic superiority over the countries of the region. Syria's project to transfer Banias and Hasbani water on the Jordan River to the Yarmouk River has been frozen and halted.

The main objective of Israeli expansion in the Middle East is access to resources and water in the region. Israel has always considered its plans to include water resources within its borders. The resources of Banias Reef were one of the reasons for the strategic invasion of the Golan Heights; It can also be concluded that Israel invaded Lebanon to control the Hasbani and Litani rivers. It also confirms the fact that Israel provides 40% of its use of water from the West Bank and the Golan Heights this conclusion. The question here is, is the water of the Tigris and Euphrates the source of regional conflict or a promotion for peace?

On the other hand, there is a shortage of water in the area. Each year, the West Bank and the Gaza Strip in Israel and Jordan face a deficit of about 300-400 million cubic meters. According to some scientific sources, this deficit increases to at least 500-600 million cubic meters. Israel now uses 95% of its renewable water resources and is also trying to meet this deficit by importing water, as well as increasing the water tank in Jordan, one of the most important issues in Israel.

Finally, as is clear in the future, it can be said that Jordan and Israel cannot use water resources rationally because of the conflicts resulting from these countries that do not make concessions, especially there is an increase in the population of the region quickly cannot expect. (Karpuzcu et al., 2009)

5.6 Lankang-Mekong River Basin (Eastern Asia Model)

The largest river in Southeast Asia is Lankang River Mekong (Mekong River Basin) it is one of the most fisheries productive in the world. In terms of river flow, the basin is the eighth and tit is twelfth in terms of length in the world (Zev et al., 2012). It generated in the northeastern of the Tibetan mountain plateau in China, with heights 5,000 m a.s.l. In these high-altitude valleys and the water gets from the snow, springs and the rain. The water flows from the river and travels around 2,300 km across Qinghai, Tibet and Yunnan provinces before reaching five other countries. (John et al., 2012). This part of the Mekong River, called Lankang / Jiang River in China

The elevation of the river is 400 m a.s.l. when it passes China, snaking over another 2,600 km through Burma/Myanmar, Laos, Thailand, Cambodia, and Vietnam before pass away in the South China Sea. Lankang and the part of this Mekong River contribute with Burma are called the Upper Mekong Basin (UMB) in yellow of the figure map 5.7 while the Lower Mekong Basin (LMB) in the blue of the figure map 5.7, (Radosevich & Olson, 1999). In the UMB, China shares 16% and Burma 2%, respectively, while in the LMB, Laos, share 35%, Thailand 18%, Cambodia, 18%, and Vietnam 11%, respectively.

The area of the basin around 795,000 m^2 and annual average river flow 475,000 million m^3, in all countries, and flooding 70,000 km^2 from July to October (Hortle et al., 2004); (Snidvongs et al., 2003). Thus, in aquatic resources, the Mekong Basin is very fruitful and fertilized land. These six riparian governments produced 3.9 million tons of fish yearly, catch and produce surplus rice and other agricultural products for international markets. This river used double the volume of cargo along the Mekong from China to Thailand since 2004 (Leitsinger, 2010).

The cooperation and communication of the World River Basin back to 1954 during the conference on independence by the International Institute of River Development and Development Cooperation from France for the countries of Indochina: Laos, Cambodia, and Vietnam. The Joint Working Group on International Docks provided the attention to the Economic Commission of United Nations for Africa and the Far East (UNECA) in direct research and identifying the potential for expansion projects of water resources in the basin. (Lauridsen, 2004)

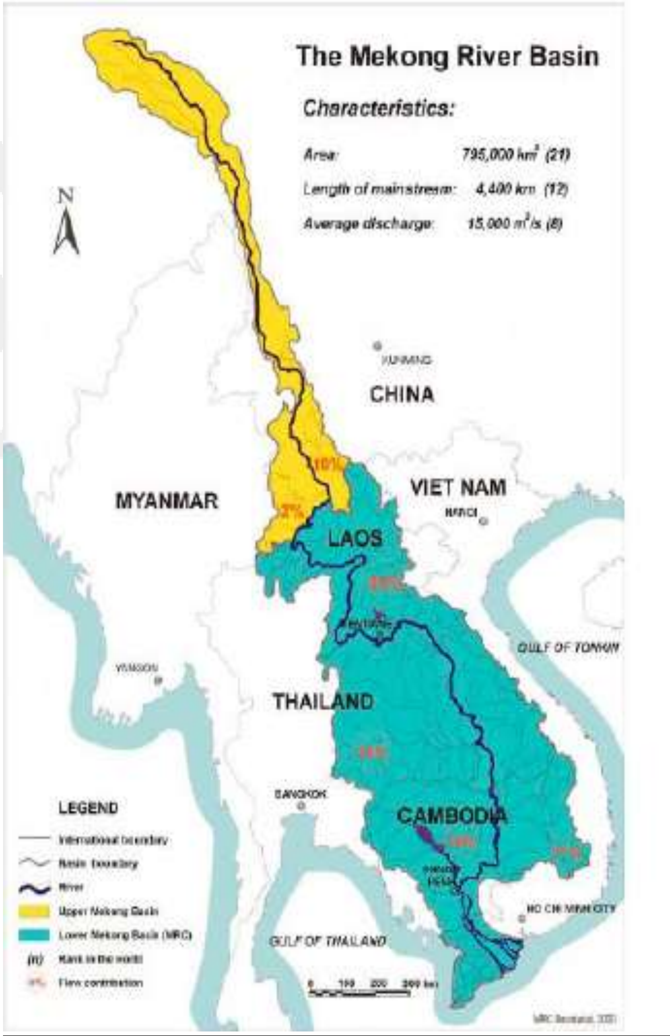


Figure 5.7 River Basin of Mekong

5.6.1 Countries and Development Cooperation (Mekong River Basin)

The cooperation and communication of the World River Basin back to 1954 during the conference on independence by the International Institute of River Development and Development Cooperation from France for the countries of Indochina: Laos, Cambodia, and Vietnam. The Joint Working Group on International Docks provided the attention to the Economic Commission of United Nations for Africa and the Far East (UNECA) in direct research and identifying the potential for expansion projects of water resources in the basin. (Lauridsen, 2004)

On the other hand, the United States is interested in attracting these countries and try to cut off the countries movement to join the communism because of poverty. Therefore, the US Bureau of Rehabilitation confirmed to assistance these authorities, conduct research in 1955/6 and command confirm the 1952 report Economic Commission for Asia and the Far East (ECAFE). At the continuation of the work, they assisted the open of the International River Institute, which was opened in 1957, the Migrant Resource Center, of which all its member States were members.

The Migrant Resource Center, under the sponsorship of the United Nations, it is the responsibility to "encourage, coordinate, observation and follow up strategic planning and checking of water resources development projects" (Lauridsen, 2004). Regardless the growing disagreement over non-exclusivity in decision-making among members, the Migrant Resource Center continued from 1957 to 1978, and the Mekong Provisional Commission became a non-full member of the Mekong Basin (Laos, Cambodia, and Vietnam) and the United States. Urban and regional areas in the end 1970s and beginning of 1980s. After the duration of wars, Laos, Thailand, Cambodia, and Vietnam started negotiations in the beginning of 1990s and the water quota was one of the paragraphs in the negotiations and the restructuring of the Mekong River Commission by the so-called Commission of Mekong River in 1995.

Migrant Resource Center members were, in foundation rule, more cooperative on some 12 programs, including the development of basin; mobility; data and information management; integrated water resource management; sustainable hydropower; fisheries; climate change and adaptation; agriculture and irrigation; (Sunchindah, 2013). In practice, each country has its special interests that may not be in line with the interests of other countries.

The discussions between countries are somewhat conflicted and complex. The common approach to planning the future of the river means assimilating Thailand's dynamic and dynamic society, the military dictatorship of Burma, authoritarian democracy in Cambodia and communist-communist Laos (Fuller, 2010). Perhaps high importantly, the dominant economic development and modernization motives, Each of the Mekong states make the benefits by the development of water projects very attractive, and on the other hand, the danger of displacement is threatened and very dangerous (Smith, 2012).

However, cooperation between these countries is good and the two countries have together worked in all the salient associated factors with development cooperation, flood management. The 1995 Mekong Agreement for Development of the Mekong River Basin on "Cooperation for the Sustainable" underlines the universally recognized "Mekong Spirit of Cooperation" in 1957. The 1995 Agreement and its procedures call for "meeting and maintaining balance".

In addition to mainly there are more cooperative events than the conflicting events in this counties basin, there is still considerable scope for upgrades, which could also be future possible topics for research. For example, China and Burma asked to become members of the Migrant Resource Center. Cambodia is likely damaged most of the losses and disadvantages but it has poorer influence on its neighbors. The Migrants Resource Center should be in high practical and move from theoretical implementation to effective implementation. In addition, as well as the master plan should be developed for all riparian countries, so that competition is not a matter of concern. Finally, every water project should have a good governance in this recently disputed basin.

5.6.2 Summary for Mekong River

Water activities in the Mekong River basin have completed a strategy to mobilize stakeholders in decision-making while facilitating high-level dialogue. This has helped to build a network of stakeholders that will lead to local and regional decision-making within basin management to support improved management of transboundary basins.

Local and multi-stakeholder approaches, together with support from national governmental approaches, have gained momentum in the region and are continuing. Continue to support national Governments and facilitate linkages with regional institutions. Emerging issues identified in the early years remain relevant throughout the region. These results were achieved by focusing on cross-cutting themes of knowledge, ecosystem services, and negotiation and multi-stakeholder platforms.

This was based on the work already done under the broader Mekong Wetlands Project.

Through cross-border action in the Mekong Basin, many lessons have been identified. These include the multi-stakeholder understanding that is necessary to mobilize partnerships and relationships that form the basis for building mutual understanding between partners and multiple interests; for example, between the government sector, non-governmental organizations and civil society. Such research at the community level can contribute to decision-making on integrated water resources management, to ensure that the priorities and needs of the local population are fully represented. Finally, the expansion of environmental flows from the scientific concept to a practical water management tool is difficult, and therefore a step-by-step approach is needed that gains national ownership over time.

The construction and work of Global Migration Network and partners in the region need new sustainability initiatives. The most important of these initiatives are national multi-stakeholder dialogues and the work of national action groups on water policy development. At present, the Mekong Water Dialogue Project has begun and focuses on influencing the development of water policy approaches through multi-stakeholder dialogues in the region. The Bridge Project (River Building and Governance Dialogue), launched in 2011, aims to build water management capacity through learning, demonstration, leadership and consensus building.

High Sentences

1- The platforms for Multi-stakeholder: Through civil society participation, water dialogues have increased in the Mekong Basin.
2- Expanding the scope of popular research in all regions of Thailand, the Lao People's Democratic Republic and Cambodia.
3- The first assessment of the environmental flow within the river in Viet Nam, and then the practice and expansion of the scope to other areas of the Mekong Basin.
4- Improved understanding of ecosystem services through water resources, biodiversity and livelihoods in Atapeu governorate and the Mekong Highlands.
5- The first in-depth study of national legislation to interpret the results of the World Commission on Dams.

6- The ecosystem approach adopted in planning to respond to development challenges.

5.7 Nile River Basin

Nile River is one of the rivers located in Africa. It flowing through ten countries. As shown in below figure 5.8, (Sudan, Egypt, Ethiopia, Uganda, Kenya, Rwanda, Tanzania, Burundi, Eritrea, and Zaire). Right now, there are no agreements between the countries shared the river basin, for managing the Nile river flow, it is complexed relations and difficult to prepare the agreement for getting approval by all countries regarding water resource management and water utilization of the Nile. The biggest while the other upstream countries contribute the bulk of the total annual water flow of the Nile. (Ethiopia is the major water contributor at 86 %), have not as yet used the waters of the Nile river to any appreciable extent. (Murakami, 1995).

Figure 5.8 Nile River Basin, source: World Bank.

Egypt and Sudan created a model for cooperation in 1959 through a bilateral agreement, which not only governs the sharing of the Nile waters but also contains an instrument for settling controversies by negotiation. In 1959, Egypt and Sudan signed an agreement to establish the Permanent Joint Technical Commission of the Nile River, which is the mechanism for proposing and implementing the cooperation projects between the two countries as well as with other countries of the Nile basin. (Cascão, 2009)

The Technical Commission has the right to review the uses of the Nile water in the two countries as compared with their shares stipulated by the 1959 agreement. Since its establishment in 1960, the Technical Commission has been meeting regularly four times a year in Cairo and Khartoum alternatively. In accordance with the 1959 Agreement, Egypt was allowed to go ahead with plans to construct the High Aswan Dam for over-year storage, impounding and controlling the full discharge of the river at Aswan 84 BCM of which the Sudan share was increased to 18.5 BCM and Egypt's share to 55.5 BCM. Largely, the dam mitigated the conflicts between the Sudan and Egypt caused by the restrictions of 1929 Agreement on the Sudan water withdrawal during December to July and increasing Egypt's share. In addition, the 1959 Agreement recognized other riparian is rights (Hirzalla, 2001)

In 1964, the Technical Commission with assistance from the UNDP began to draw up a mechanism for cooperation with the countries of the Equatorial Lakes region. The idea was a success and resulted in the establishment of a project for a hydro-meteorological survey of the Equatorial Lake Plateau in 1967 (Hydro met). In year 1978, the draft by-laws of the suggested Nile Basin Commission where drawn up, and sent by officially to all basin countries.

Lately, under the aegis of the United Nations, helped the Nile basin countries to draw up a mechanism for overall cooperation. The cooperation may achieve if the following points are taken into consideration:

1- Agreement on the historical rights of different parties;

2- Agreement on exchanging the required data which will be the bases for the development projects;

3- Acknowledgment of the prior agreements, especially those which dealt with shared water resources;

4- Acceptance of criteria for priorities of suggested development programme;

5- Consideration of the possibility of using existing resources other than Nile water within each country.

The water affairs ministers responsible for the Nile Basin countries met in December 1992, in Kampala, Uganda, and they decided that future cooperation on water resource matters should be top subjects. They agreed that these matters should be the main subject over a three-year transitional period, under topic "Technical Cooperation for the Promotion of the Nile Basin Development and Environmental

Protection” (**TECCONILE**). An agreement on this topic signed by Ministers from the six countries of Sudan, Tanzania, Egypt, Uganda, Rwanda, and Zaire. (Hirzalla, 2001)

Following one additional ministerial meeting and two international conferences (Nile 2002 Conferences), the Nile countries agreed on a list of practical measures for supporting regional cooperation in water management.

A workshop held in Entebbe, Uganda, in June 1994. The main purpose of the workshop was to develop a draft Nile River Basin Action Plan. A second workshop held in Cairo, Egypt, in November 1994.

The third Ministerial meeting took place in Tanzania, Arusha, in February 1995. The Action Plan presented and approved by the Council of Ministers for Water Affairs of the Nile Basin states.

The Action Plan, as initiated and agreed to contain twenty-two individual projects within five main components:

I. Planning and management of integrated water resources (five projects)

II. Capacity building, construction of (eight projects)

III. Training courses (one comprehensive project)

IV. Cooperation regional (five projects)

V. Protection of environmental and enhancement (three projects.

5.7.1 Summary for Nile River

The waters of the Nile are flowing through the territory of nine countries. There are differences in qualities and quantities of water over the agreement between (Ethiopia, Kenya, Uganda, Tanzania, Burundi, Rwanda, Zaire, Sudan and Egypt). Nile water is used by a large number of people for industrial and agricultural purposes. (Karpuzcu et al., 2009)

In fact, the Nile River is of great importance to Egypt, flows from other countries and leads to the creation of Egypt's opportunity to use its agricultural and industrial potential and depends on the perspective of these countries from the flow of water through the Nile. Due to its large population potential and rapid population growth, one of Egypt's most important strategic planning is to create new agricultural areas. This can be solved by using the Nile water more and more continuously. However, the fact that most of the Nile waters originate from Uganda, Ethiopia and Sudan make it difficult for Egypt to solve water problems .

Egypt has refused to build all kinds of facilities in the Nile basin by the Nile Basin countries because they are contrary to their interests. As well as a strong and sovereign monopoly in the Nile Basin. In order to be prepared against any opposition regarding the use of the Nile River, preparations have been made for this purpose. Military intervention plans have been prepared at Nasser Military Academy and taken as teaching courses. Within the scope of these plans, it is proposed that the plan addressed to Ethiopia be called the "Aida Plan" and the plan addressed to Sudan is called the "Al-Shams" intervention plan. As the Nile is the only major source of water in Egypt, Egypt dictates its views on the water to other countries. An existing military plan for this purpose. There is still disagreement between nine countries benefiting from the Nile water and how to use it. (Karpuzcu et al., 2009)

Sudan, Uganda, Zaire, Rwanda, Egypt and the Central African Republic, all of which are countries of the White Nile. In order to regulate the uses of the Nile River, they established "Group" but the Tanzania and Burundi have been present at the meetings of this group only as observers. However, Ethiopia, of which 85 percent of the Nile water springs, did not participate in such cooperation. The formation of the UNDUGU Group was the most important diplomatic impeachment in Egypt and its aim was to establish a forum to provide a means of opinion and exchange of knowledge on issues related to the common interests of the number of countries, social contribution and economic developments through regional cooperation. (Karpuzcu et al., 2009)

5.8 Conclusion for Water Governance and Conflicts

Generally, the downstream countries Iraq and Syria have to take several actions plans to reach future water demands in all sectors, rather than Iraq have to focus on the following areas:

1- Review of the European Water Framework Directive, European Water Initiative, and the Millennium Development Goals, which serve as global water laws to identify the future, water policy directions.

2- Review of the negotiation's and agreements between countries shared water and water resources.

3- Review of the existing water and environmental law applicable in Iraq, and identification of strength, weaknesses, and shortcomings of the related Iraqi laws.

4- Investigate the law's consistency with the Iraqi's and related international laws and suggest necessary rules and regulations required to successfully implement of the newly introduced law, in addition, to suggest different public investment and incentive programs to implement the law successfully.

5- Suggest guidelines on locally organized training programs, organizational changes and structures, and activities to govern the water resources in the country effectively.

6- Provide guidelines on how to monitor, to evaluate the implementation of the law, and to solve problems raised.

7- Iraq also has to protect water flow quality and quantities by several action plans regarding reducing pollutions and reducing water losses.

8- Iraq has to continue negotiating with Turkey site on the water resource development according to international regulations that are for preparation general agreement is signing by both countries.

9- Regarding GZRB, Iraq has to take two strategies for negotiation,

The First is fixing the annual amount of water release by Tukey government, for example, 5.3 Billion m^3 that is according to the historical annual data flow for GZR. On the other hand, restart and complete of Bekhme dam reservoir, then control the release amount of water from reservoir capacity 17.1 billion m^3 to Tigris river, for using in med and south of Iraq by the implement of special action plan approving from both sides Erbil province and the Iraqi government.

The Second is, paid a portion of dam reservoir project cost. Iraq has to negotiate with the upstream country, which is Turkey, and signing an agreement for construction big dams and reservoirs inside of Turkey, sharing a portion of the cost (for example 30 %) according to the agreement, has to paid by the Iraqi government and it will be fixed. On the other hand, the daily water release from Turkey to Iraq will fix the same agreements. In this case, Iraq will note lose the lands at the same time Iraq will receive a good amount of water from turkey to control scarcity in the med and south of Iraq

CHAPTER 6
METHODOLOGY

6.1 General Information

This chapter is divided into two main parts, the first part comprises field works and cooperation with government responsibility in order to receive all the data requirements such as water supply, demand, population, agriculture area and its production, forestry land rainfall, evaporation and industrial water use, etc. GZRB field works including preparing data according to WEAP program format modeling. There are several directorates in the region that working in this basin. Receiving data from them is difficult and challenging as they are responsible for these tasks are not allowed to send the data to Privet sectors. The second part of this study deals with office working and installation program modeling (WEAP, GIS, and CWR)

The Erbil province authorities understand that water resource management is a serious emerging challenge to the long-term sustainable development. At the national level, domestic, agricultural, and industrial water consumption increases at annual rates roughly consistent with the rapid population growth rate, suggesting that little conservation or efficiency improvement is occurring. These consumption growth rates vary by governments due to differences in economic development, the types of water use, the size of each Governorate, and population growth rates.

However, there is an urgent need to improve the management of water resources in all governorates in order to achieve water conservation, maintain better water quality and restore degraded groundwater systems. High-efficiency irrigation technologies, groundwater-recharge dams, green areas, increased public awareness, and the strengthening of institutional capacity all have been cited as urgent national priorities to help ensure that water demand growth rates decline in the future. (Grey & Sadoff, 2007).

Erbil is the high-density population province of the region and the second largest city of Iraq with a current population of roughly more than (2,400,000) two million four hundred thousand people. The number of refugees from Syria, middle and south of Iraq who has been displaced because of terrorist and sectarianism (interior war) is around 1,200,000 people. (MOM&T, 2016)

Due to the importance of the GZRB, the study explored current conditions of water use and its future prospects in the face of climate change and increasing population pressures and unsafe surround area to Erbil province. Prior to rapid population growth, the local population relied on the river basin system, which includes the GZ river, streams, springs and ground renewable water resource in the region. The introduction of drilling rigs and mechanical groundwater pumps has allowed the exploitation of the regional groundwater on a completely different scale than it has been previously realized.

6.2. Methodology Objectives

The overall goal of the sub-project is to better understand the GZRB water and agricultural management challenges in response to climate change and socioeconomic development. The major research questions underlying the methodological approach were twofold.

First, how climate change will affect the water resources of the GZRB that support the direct human use and uses for a forestry and an agriculture sector that has grown considerably over the past few decades supported primarily by groundwater?
These sectors have an important cultural legacy and heritage, particularly surrounding the production of agriculture products and orchards especially. The region’s important and productive agricultural commodity and other agricultural products, such as water intensive fruit and vegetable production, and the production of fodder have been used to support a relatively large livestock sector.

Second, what water management strategies could explore as measured in water savings associated with various scenarios and that aim to promote efficiency and conserve natural resources under climate change?

In addition to these water-related objectives, in this section of study three broader contextual goals have been important as follows:

1. The link between water resources and economic development goals.
2. The link between water resources and political governance goals.
3. The link between water resources and environmental quality goals.

6.3 Agriculture Water Use

The estimated current annual water use for each of the primary water uses in GZRB are summarized in Table 6.1 and Figure 6.1. These estimates are made by the MOM&T and MOA&WR based on the activities data for the year of 2015. Table 6.1 shows the total number of hectares under irrigation for the study region and the portion of the water used for each activity.

Table 6.1 Illustrates the agriculture land and water demand from (2010-2050).

Year	Growth Ratio per 5 Years	Agriculture Water Demand m^3 /ha/ Year	Irrigation Land ha	Annual Total Agriculture Water Requirement MCM
2010	0.178	3500	99745	349
2015	0.173	3500	117001	410
2020	0.167	3400	136540	464
2025	0.162	3350	158660	532
2030	**0.161**	**3300**	**184204**	**608**
2035	0.161	3250	213860	695
2040	0.161	3200	248292	795
2045	0.161	3150	288267	908
2050	**0.161**	**3100**	**334678**	**1038**

The agriculture land in Erbil governorate was around (100,000 ha) in the year 2015 and these are estimated to be under irrigation in the GZRB, using about (0.006 m^3 /sec./ha) and (10 hours in a day) water flow for (57days) (Apri,4 days- May, 8 days- June,10 days- July,15 days-August,12 days-September, 8 days) irrigation in a year which is calculated as (3500 m^3/ha/ year).(DAE, 2016). The Iraqi government also uses this river for storing the water in the existing reservoirs in the mid and south of Iraq, therefore, it’s required to provide water from the GZR to the Tigris River for agriculture purposes.

The river basin's water demand is driven by population and rising socio-economic growth resulting in higher per-capita water demand in the domestic sector, and more intensive use of water in other sectors, including amenity and agriculture uses. The following assessment is based on a combination of project reports (e.g. Shamamok planning report); personal information obtained from the DIE and DAE the good database, which provides data on the number of wells used for irrigation. In particular, the strategic plan for agriculture, this proposes more than tripling the irrigated area within 5 years.

Table 6.2 Illustrates total cultivated land (ha) in 2010 (DAE, 2016)

a) Total cultivated area

Location	Total cultivated area (ha)				
	Cereals	**Chickpeas**	**Vegetables**	**Orchards**	**Total**
1a – Khabat	16477	1883	4708	471	23539
1b - Erbil Plain	288380	57676	30761	7690	384507
1c – Foothill	159059	31812	6362	14846	212079
2-Mountains	31319	6264	3132	4027	44742
Total Area	495235	97635	44963	27034	664867

b) Total rainfed area

Location	Total rainfed area (ha)				
	Cereals	**Chickpeas**	**Vegetables**	**Orchards**	**Total**
1a – Khabat	6591	753	0	0	7344
1b - Erbil Plain	273961	56523	0	0	330484
1c – Foothill	151106	31176	0	4454	186736
2-Mountains	31319	6264	157	2819	40559
Total Area	462977	94716	157	7273	565123

c) Total irrigated area

Location	Total irrigated area (ha)				
	Cereals	**Chickpeas**	**Vegetables**	**Orchards**	**Total**
1a – Khabat	9886	1130	4708	471	16195
1b - Erbil Plain	14419	1154	30761	7690	54024
1c – Foothill	7953	636	6362	10392	25343
2-Mountains	0	0	2975	1208	4183
Total Area	32258	2920	44806	19761	**99745**

The current irrigation situations in Erbil governorate as follows, (1500), small irrigation projects, in small village schemes, typically consisting of 2-3 km canal length include (intake from a spring or small stream), and irrigation of (3 to 12 ha), water uses about

(8,000 to 10,000 m^3) annually for (1 ha). Interventions will mainly focus on rehabilitation and improvement of existing schemes, such as the concrete lining of earth channels to reduce losses.

Khabat (Eski Kelek): (5250 ha) was (10500 ha), the project completed in 1971 needs rehabilitation; 26 km main feeder canal; water source: GZR; max. water intake(6.5 m^3/s) (was 9.5 m^3/s), and will increase again when rehabilitation becomes effective).

1) The largest project planned: Shemamok (300 million US$, not yet funded). The intake would be at Eski Kelek just next to intake of the Khabat scheme. Irrigated area: (14920 ha); (13.7 km) main feeder canal, (2) pumping stations; max. intake (18 m^3/s). The mix of the furrow, sprinkler and perforated pipe irrigation.

2) Once Shemamok is implemented, Khabat rehabilitated and Ifraz water supply increased more than (30 m^3/s) will be abstracted from Greater Zab between Ifraz, and Khabat / Eski Kelek.

3) Planned project: Bastora (north of Erbil), (4000 ha)to be irrigated from the new Gomaspan dam

4) Dashti Hawler irrigation project (from the planned Mandawa reservoir) will also be a big irrigation project about (100000 ha), again using the water of Greater Zab.

Smaller existing schemes in Erbil: Tobzawa near Sedakan, Alana near Khalifan (75 ha) for each one. (DIE, 2016)

6.4 Domestic Water Supply

Water supply for the domestic uses comes from surface water (underground canals, springs, rivers) and groundwater. Historically, all water uses have met in three seasons (winter, spring, and autumn) and it is unmet in the summer season, although groundwater is the 20 % supply source for domestic water use, agriculture, and industrial water supplies. The water is used primarily to meet domestic, and industrial demand, with estimates of about (264) Million m^3 (MCM) supplied to the basin from groundwater and surface water. (MOM&T, 2016)

Table 6.3 Illustrates Population growth, Dom. And Water Req. (2010-2050)

Year	Growth Ratio per 5 Years	Erbil Population	Indoor Water Demand m^3 /cap/day	Outdoor WR Demand m^3 /cap/day	Total WR Demand m^3 /cap/day	Domestic Water Requirement MCM/Year
2010	0.178	1681032	0.365	0.125	0.49	301
2015	0.173	1981013	0.365	0.125	0.49	354
2020	0.167	2323487	0.3	0.125	0.425	360
2025	0.162	2712192	0.25	0.12	0.37	366
2030	**0.161**	**3150963**	**0.22**	**0.12**	**0.34**	**391**
2035	0.161	3660717	0.2	0.12	0.32	428
2040	0.161	4252938	0.2	0.1	0.3	466
2045	0.161	4940967	0.2	0.1	0.3	541
2050	**0.161**	**5740303**	**0.17**	**0.1**	**0.27**	**566**

The amenity uses of water include municipal landscapes, green parks, and other public spaces that are largely managed by municipalities. A large portion of amenity water is supplied through municipal water deep wells and part of that by water re-use, although demand is also met by surface water supply pump stations and some by groundwater through pipeline system as well as by water tankers. It has aggregated the agricultural water uses into four broad commodities, including green parks, orchards, vegetables, seeds and animal fodder or switchgrass and estimate the amount of each activity irrigated in hectares and their average annual use activity in units of (m^3) per hectare. When all these uses are combined, The estimation year 2015 that the cities, districts, sub-districts and villages around the GZR water uses about 354 MCM of water annually for domestic water uses.

6.5 Environment Water Requirement

Environmental problems have been marked largely by scientific warnings, public interest, political agendas, and media attention. Policy issues remain a problem when it comes to water. Most of the available water supplies in the region, which exceeded 80 percent, were used for irrigation purposes. In addition, water efficiency levels are relatively low in the region, usually between 37% and 53%. As this study suggests, water policies in Erbil province will need to improve supply and demand management as well as allocate more resources for the development of local desalination technologies.

Environmental flow requirements generally focused on the ecosystem parts and specific times of the year likely to be at risk in Erbil. Most water use in watersheds may take place in the summer and may have an impact on species that have special requirements in these months (spawning, fish migration, sluggish vegetation, habitat availability.) At other times of the year, on ecological processes in the river or wetlands in these scenarios, the study will focus on determining the expected interest rates EWRs for the summer period, in particular, and monthly EWRs for each month.

The minimum discharge for GZR during dry year August 2001 was 51 m^3/sec in Kalak water flow measurement station, therefore the study assumed minimum inflow as an environmental flow requirement up to the year start construction Bekhme reservoir on GZR and it is estimated to be 90 m^3/sec in the year 2035 due to the water unmet water requirements.

At the same time the environment flow required to Tigris river by the Iraqi government for center and south started from 50 m^3/sec but after constructing reservoir will arise to 70 m^3/sec and rise up to more in the year 2050. The annual environment flow required totally in 2050 estimated by 2208 MCM as shown in the table 6.4

Table 6.4 Illustrated annual environment water requirement flowing to Tigris River.

Year	**Annual Environment Water Requirement**		**Annual TIGRIS Release Water Requirement**	
	M^3/Sec.	MCM	M^3/sec.	MCM
2010	50	1577	50	1577
2015	50	1577	50	1577
2020	50	1577	50	1577
2025	50	1577	50	1577
2030	**50**	**1577**	**50**	**1577**
2035	70	2208	70	2208
2040	70	2208	70	2208
2045	70	2208	70	2208
2050	**70**	**2208**	**70**	**2208**

6.6 Industrial Water Requirements

Industrial water demand in Erbil province and Iraq government is on the rise. In addition, water use in Erbil governorate industry generally from groundwater and is high due to a combination of factors including obsolete process technology, poor recycling and reuse practices and poor wastewater treatment. There is a very low level of awareness about the problem and needs for wastewater treatment by industry. The efficiency of utilization in all the industrial uses of water should optimize and an awareness of water as a scarce resource should be fostered. The water resources should be kept from change and should be able to be used by making greatest degree retention, taking away pollution and unimportant losses.

The number of deep wells used in the industrial sector in Erbil province was 40 wells during 2010 (MOM&T, 2016), during years 2012, 2013and 2014 the construction of several refinery factories a rose to (140) wells. The estimation for drilling (40) wells per year in future for the industrial sector in all Erbil and it is districts. Table 6.5 shows the deep wells and its discharges, the average discharge for each well (5 l/sec) and operation time is (16 hr.).

Table 6.5 Illustrates a number of deep wells in industrial sector

Year	**Number of Well**	**Av. discharge of one well m^3/sec**	**Annual Industrial Water Requirement**	
			$M^3/Sec.$	**MCM**
2010	40	0.005	0.2	5.26
2015	140	0.005	0.7	18.40
2020	140	0.005	0.7	18.40
2025	180	0.005	0.9	23.65
2030	**220**	**0.005**	**1.1**	**28.91**
2035	260	0.005	1.3	34.16
2040	300	0.005	1.5	39.42
2045	340	0.005	1.7	44.68
2050	**380**	**0.005**	**1.9**	**49.93**

Awareness of conservation should be promoted through education, regulation, incentives, and disincentives. Although some issues related to industrial water have been addressed in the National Water Policy. (Loucks & Van Beek, 2017), but no clear vision has been given to regulate and control the use of industrial water. The key to the problem lies in the effective management of water resources. Appropriate measures are including improved technology process, effluent treatment; reuse of process water for more than once. Re-circulate the process water in the same use for a number of times; harvest rainwater; waste minimization should be adopted. Coordination between different authorities/ministries must be coordinated if conflicts are to be avoided in the future. (Sullivan, 2002)

6.7 Methods and Programs

This section of the methodology mostly includes modeling and software as well as preparing water resource data to special forms, which are required for running the data. The applications of Linear program (LP) are used Water Evaluation Analysis Planning (WEAP) program were used in this study area to water resources management vary from relatively simple problems of straightforward allocation of resources to complex situations of operation and management (Labadie, 2004).

Optimization models (mathematical programming) are formulated in terms of determining values for a set of decision variables, which would maximize or reduce objective function subject to limitations. The objective function and constraints are expressed by mathematical expressions as a function of decision variables. Typical river flow objective can be functioned to maximize or minimize a quantitative measure of an object such as economic benefits and cost, water availability and reliability and hydroelectric power generation. (Williams, 2013).

Decision variables might be targets and release rates. Constraints typically include physical characteristics of the river flow system, such as maximum and minimum storage, maximum and minimum releases, and regulatory or policy requirements (minimum in the stream flows, restrictions on allocations and transfers etc.), and mass balances (Moritz et al., 2014).

The objective of this study is to propose a synthetic view of water resources uses in GZRB by gathering existing data and studies and feeding a simplified water evaluation and planning model. This tool developed by WEAP will permit an assessment of water balance in the River basin is to propose a synthetic view of water resources uses in

GZRB by gathering existing data and studies and feeding a simplified water evaluation and planning model. This tool developed by WEAP will permit an assessment of water balance in the river basin.

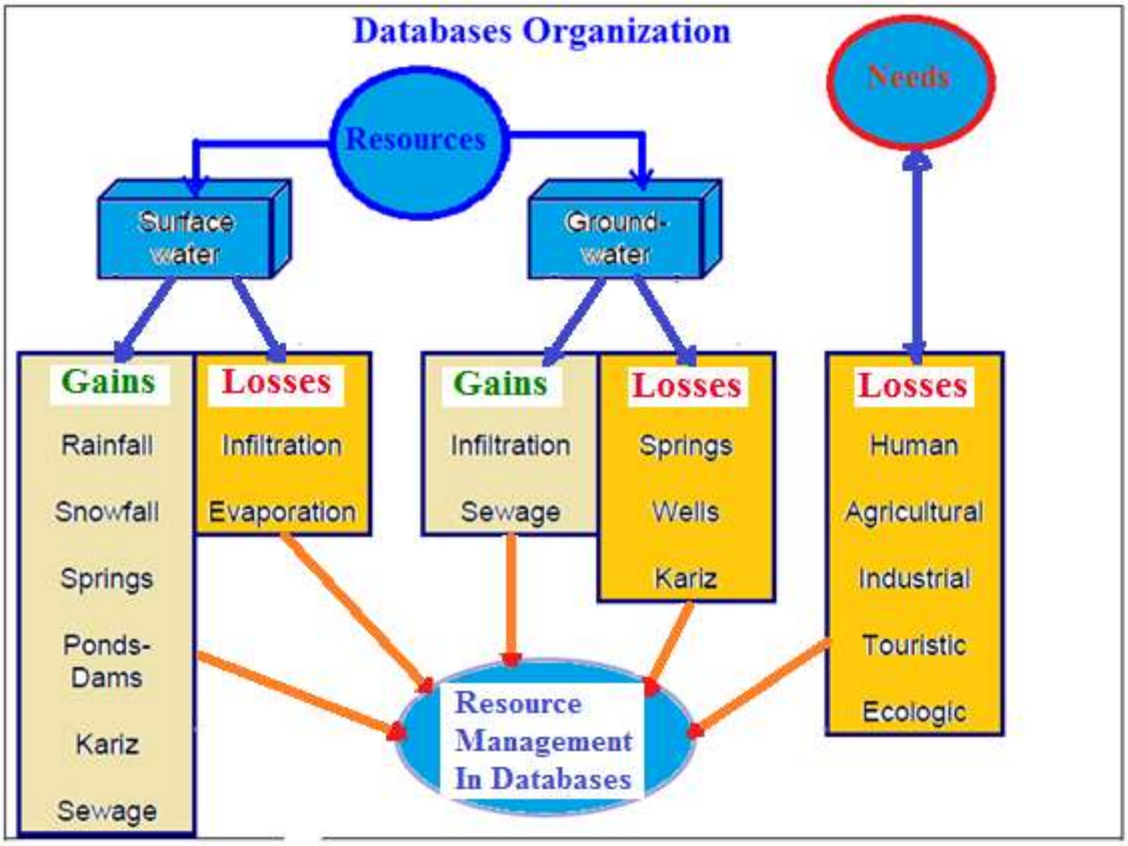


Figure 6.1 Illustrates the database and data input relations, model organization

The water balance is a simple concept to assess the amount of available water.

INPUT in the area – OUTPUT from the area = available water in the area. The model compares:

1) The surface water resources (hydrologic aspect).

2) The groundwater resources (hydrogeological aspect).

3) The total needs (human demand aspect).

4) The river flow required (Environment river flow)

Each of those above aspects has assessed and synthesizes the main findings. Details on each sectorial aspect can found in preliminary mission drafts from experts.

Data processing, analysis, and interpretation essentially involved four steps.

1. Preparation of a dataset of monthly data for each station (rain-gauge, gauging station, monitoring well), including validation and the correction of errors where possible;

2. Calculation of characteristic statistical values (averages, minimum flows etc.) for a common reference period, 2000 – 2016

3. Use geographic information system (GIS) and Arc GIS.

5. Calculate for water resources availability district by district.

The balance between water resources and demand cannot be based on a single figure, as the different types of resources groundwater, local runoff and river flow, have different characteristics in terms of availability in space and time.

Resources generated and available within the river basin, these resources are available in a decentralized way (deep wells, subsurface water (shallow wells), springs, and small runoff collecting reservoirs).

The main resources are:

1- Groundwater (mainly available from natural springs or deep wells, depending on the regional area.

2- Local runoff (typically collected using small dams/reservoirs)

3- Resources of the main rivers and large dams, these resources are originating upstream (often outside of Iraq) and are usually available at the borders of the districts.

The limits of accuracy are essentially due to the following factors:

1. High variability of the climate and hydrological regime in the basin, thus, a short time series (of maximum 16 years for most stations) cannot adequately capture the extremes, although the reference period of 2000 to 2016 does include two exceptionally dry years (2001 and 2008).

2. Hydrogeological variability: Differences in the hydrogeological characteristics and the presence of karst phenomena cause major variations of unit flows and many other hydrological parameters; it is therefore, difficult to provide reliable regional estimates.

3. Data quality: The accuracy of the available data is limited; data collection and data processing practices do not yet fully meet international standards.

4. The presence of trends: Climate change, irrigation projects upstream, reduced groundwater inflow due to increased abstraction and land use changes are all factors that may cause.

6.7.1 GIS and Arc Map (Digital Elevation Model (DEM))

Digital Elevation Models (DEMs) are raster geographic digital datasets of elevations in x, y, z coordinates.

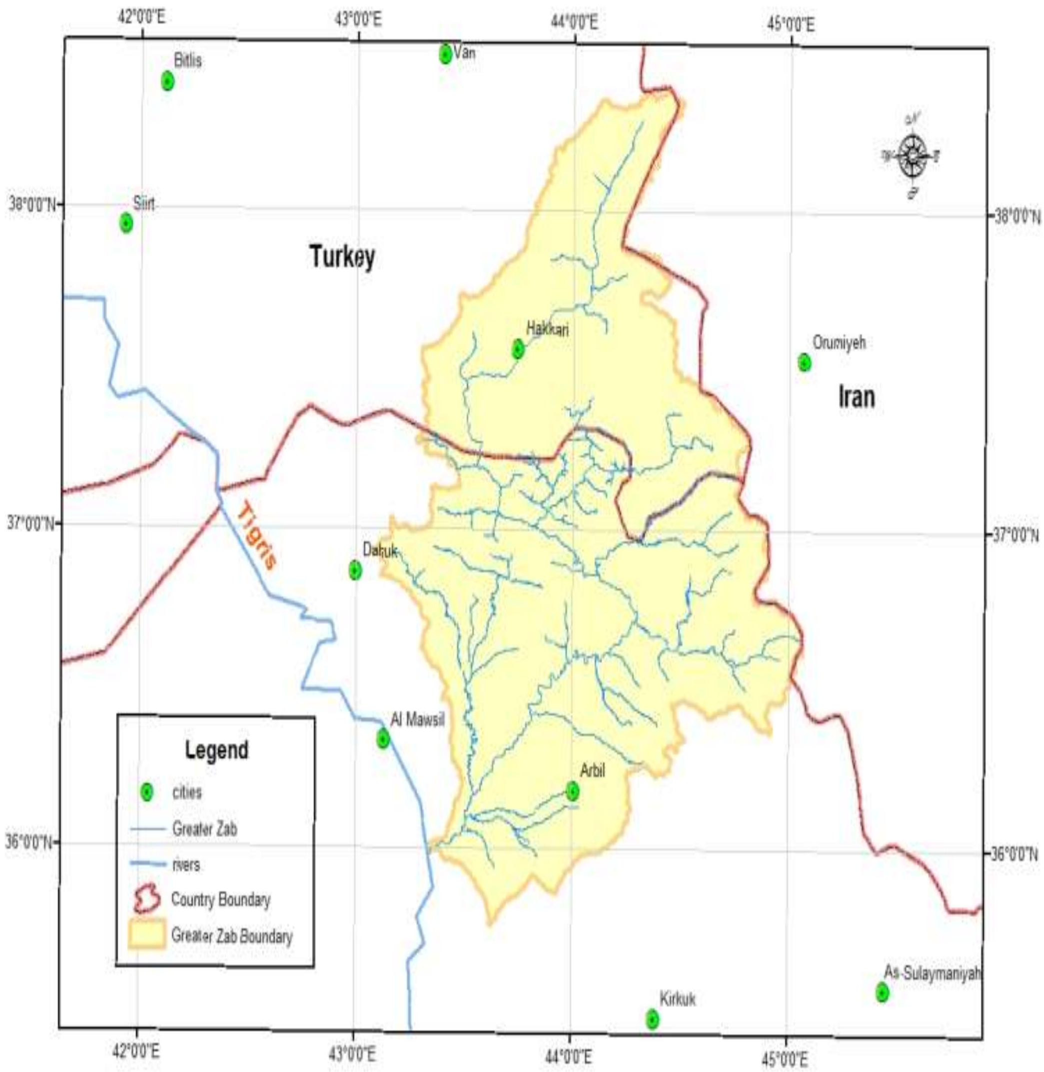


Figure 6.2 GZRB raster geographic digital datasets in (geo reference)

The terrain elevations for ground locations are sampled arrays of regularly spaced elevation values referenced horizontally either to a Universal Transverse Mercator (UTM) projection or to a geographic coordinate system. (Mudgal, 2005). The grid cells are spaced at regular intervals along south to north profiles that are ordered from west to east. There is no common practice of the terms digital elevation model (DEM), digital terrain model (DTM) and digital surface model (DSM) in the literature.

The terrain pre-processing was applied to the Digital Elevation Model (DEM), which has a larger coverage area than the study area in order to identify the boundary of the river basin as a pre-requisite for the hydrological processing. All of the steps in the terrain pre-processing menu should be performed in sequential order, from top to bottom. Hydrology tools, which are spatial analyses tools describing the physical components of a surface in Arc GIS were used for this processing. Hydrology tool functions in the sequence are; load DEM, fill sinks, determine flow direction, calculate flow accumulation, define pour appoint, delineate the watershed boundary and create stream networks. (Ismael, 2013)

Terrain Pre-processing tools are a set of functions used for processing DEM based data needed for watershed delineation and watershed characteristic extraction.

Table 6.6 Summary of description of functions in hydrology tools

Functions	Description
Fill	Fills sinks in a surface raster to remove small imperfections in the data
Flow Direction	Creates a grid of flow direction from each cell to its steepest down slope neighbor.
Flow Accumulation	Creates a raster of accumulated flow to each cell by accumulating the weight for all cells that flow into each downslope cell.
Stream Shape	Converts a grid representing a raster linear network to a shapefile
Snap Pour Point	Snaps selected pour points to the cell of highest flow accumulation within a specified neighborhood.
Watershed	Determines the contributing area above a set of cells in a grid

6.7.2 Crop Water Requirements

The way in which land and water resources are used is essential to the challenge of improving food security around the world. Demographic pressures, climate change and increased competition for land and water are likely to increase vulnerability to food insecurity, particularly in Africa and Asia. The challenge of providing adequate food for all around the world has never been greater. (Baas et al., 2008).

The world's population continues to grow. Today, the population of about 7 billion is expected to increase to about 9 billion by the year 2050. By then, another 1 billion tons of grain and 200 million extra tons of animal products will have to be produced each year (Doorenbos et al., 1992). The imperative of this agricultural growth is strongest in developing countries, where the challenge is not only food production, but also ensuring that families reach food security.

Moreover, on a more political point of view, some tensions appear from time to time between Erbil governorate and downstream provinces. Some downstream water users require Erbil release enough irrigation water to avoid an agriculture disaster in the area. For saving food basket in the river basin in 2018 and during future 2050 is one of the main study objectives. Crop water requirement (CROPWAT) used for calculating the quantities of water, the way of irrigation such as water saving technology (sprinkler system drip system) open channel and pipelines, finding the time and duration of irrigation, development of irrigation schedules under various conditions and scheme water supply for the lands. (Kuo, et al., 2006).

Preparation five metrology data (climate/ ET_0, Rain, crop type, soil type and crop pattern) for running CROPWAT module and the output will be the three calculations(CWR, schedule of irrigation and type of schemes), water balance method used for calculation of irrigation schedules in CROPWAT, which means that the incoming and outgoing water flows from the soil profile are monitored.

Table 6.7 Illustrates the Crop Water (CROPWAT) requirement in GZRB

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

Table 6.8 Crop type and duration planting in GZRB

a) winter

			Average irrigation in (month)mm												
	Crop name	**Cropping period**	**Oct.**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual Req.**
Winter	Wheat	1/11-15/6	**83**	**72**	0	0	0	0	8	38	0	0	0	0	201
	Barley	1/11-01/6	83	66	0	0	0	0	0	0	0	0	0	0	149
	Sunflower	1/11-15/5	69	59	0	0	0	0	16	51	0	0	0	0	195
	Trefoil	1/10-20/5	**117**	14	0	0	0	0	9	114	0	0	0	83	337
	Flax	1/11-25/5	56	53	0	0	0	0	28	56	0	0	0	0	193
	Potatoes	16/8-15/12	138	57	0	0	0	0	0	0	0	0	153	139	487
	Bean(seed)	16/10-30/4	57	25	0	0	0	0	50	0	0	0	0	139	271
	Legumes	15/10-15/4	57	17	0	0	0	0	16	0	0	0	0	56	146
	sugar beet	15/10-15/6	72	20	0	0	0	0	37	192	126	0	0	83	530
	Vegetables	1/5-1/12	67	25	0	0	0	0	9	11	0	0	25	85	222
	Onion	16/10-20/5	47	17	0	0	0	0	43	57	0	0	0	42	206
	Cabbage	1/9-20/3	81	22	0	0	0	0	0	0	0	0	42	128	273

b) Summer

Average irrigation in (month)mm															
	Crop name	**Cropping period**	**Oct.**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual Req.**
Summer	Cotton	11/4-15/9	0	0	0	0	0	0	66	104	307	393	306	61	1237
	Sesame	11/4-25/8	0	0	0	0	0	0	39	92	236	357	264	40	1028
	Soybean	25/8-11/4	0	0	0	0	0	0	39	110	288	357	186	0	980
	Corn(sp.)	16/3-15/7	0	0	0	0	0	39	0	190	281	99	0	0	609
	Corn (su.)	11/7-30/10	**125**	0	0	0	0	0	0	0	83	128	236	267	839
	Grain	15/4-20/8	0	0	0	0	0	0	39	88	294	372	143	0	936
	Sunflower	1/4-15/8	0	0	0	0	0	0	39	115	281	382	96	0	913
	Peanut	4/6-20/9	0	0	0	0	0	0	43	126	254	368	299	88	1178
	Mung Bean	5/6-20/9	0	0	0	0	0	0	0	39	75	332	328	89	863
	Haricot Beam	10/4-31/8	0	0	0	0	0	0	0	64	113	286	160	0	623
	Rice	1/5-20/9	0	0	0	0	0	0	0	390	340	506	432	180	1848
	Tobacco	11/4-30/9	0	0	0	0	0	0	39	126	290	104	310	160	1029
	Watermelon	11/4-25/8	0	0	0	0	0	0	39	115	278	344	210	0	986
	Sugar Beat	1/4-10/9	0	0	0	0	0	0	80	129	307	394	350	64	1324
	Potatoes	16/3-10/7	76	0	0	0	0	39	12	186	288	76	0	0	677
	Corn(fodder)	16/4-15/9	0	0	0	0	0	0	39	97	275	828	319	240	1798
	Grain(fodder)	1/4-30/9	0	0	0	0	0	0	39	135	313	328	285	214	1314
	Vegetables	1/3-1/10	44	0	0	0	0	19	34	124	276	226	188	117	1028
	Tardy	21/4-31/10	81	0	0	0	0	0	59	107	278	344	310	192	1371
	early Tomato	11/3-20/7	0	0	0	0	0	39	36	175	346	100	0	0	696
	Egg plant	5/4-30/9	0	0	0	0	0	0	45	142	307	364	299	122	1279
	Okra	28/3-10/10	21	0	0	0	0	39	1	149	317	393	303	147	1370
	Green paper	21/4-25/10	**68**	0	0	0	0	0	39	96	274	356	292	174	1299

c) Permanent

Average irrigation in (month)mm															
	Crop name	**Cropping period**	**Oct.**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual Req.**
Permanent	Grapes	15/3-5/11	81	1	0	0	0	80	0	53	283	321	249	147	1215
	Fruits	1/1-1/12	133	36	0	0	0	0	9	154	283	321	303	226	1465
	Jet	1/1-1/12	**154**	50	0	0	0	0	0	0	70	168	300	240	982
	Average Req.		**1710**	**534**	**0**	**0**	**0**	**255**	**952**	**3625**	**6863**	**8247**	**6388**	**3523**	

6.7.3 Water Evaluation Analysis and Planning (WEAP)

The Stockholm Environmental Institute developed WEAP Model in 1988 and it is help plan and manage water supply, software package. (SEI, 2005)

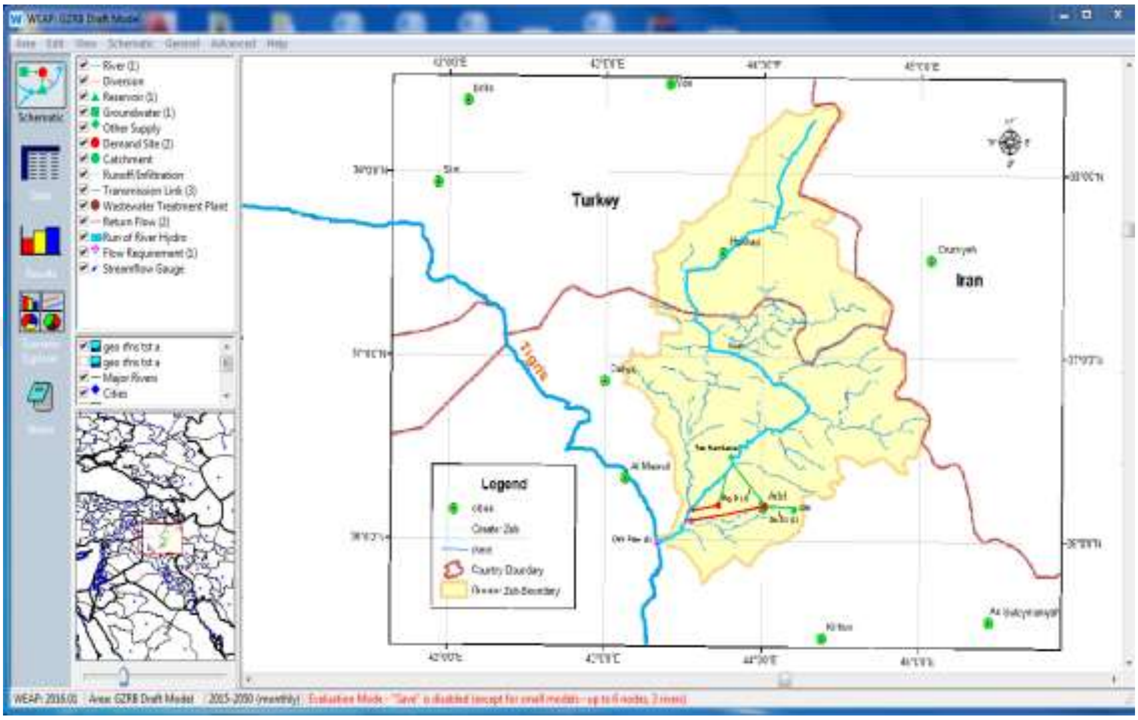


Figure 6.3 Schematic for the GZRB WEAP Model

The principle of mass- balance operates by (WEAP), the priorities specified for the system components, such as the reservoirs, demand sites, environmental flows and allocate water based on (SEI, 2005).

A water resources study throughout the world has used by WEAP in numerous. in this study use WEAP to represent inflows, demand sites, reservoirs, transmission links (diversions), return flows, reach gains and losses, and to simulate the effects of these system components on deliveries to demand sites Figure 6.3

Water put value and system (WEAP) The water evaluation analysis planning design to be copied developed by the Stockholm conditions of Institute in 1988 and is a software parcel to help map and manage water supply. water evaluation analysis planning operates on the principle of mass- balance, and puts on one side water based on the things by right coming first given details of for the system parts such as the request building lands, reservoir, conditions of moves WEAP has been used in great number of water resources studies throughout the earth, the upper Chattahoochee River Basin, Georgia South Africa Levite and Al 4. 2003); Sacramento River, California Austin, Texas; Portland, Oregon; and Philadelphia, Pennsylvania (Alfarra, 2004)

Complete the WEAP model for the GZR, then, specify three scenarios. The first scenario represents past historical conditions (2000-2015); the second scenario re-prioritize water use among agricultural and urban users; and the third scenario add a new reservoir in Bekhme upper Ifraz location. Finally, simulate each scenario to determine the effects on deliveries and unmet demand to the GZRB and new urban users in Erbil Governorate.

Addressing the goal and research questions required an analytical framework capable of accounting for the water and agriculture systems of the region in an integrated manner. The Water Evaluation and Planning (WEAP) system used for this analysis and is an integrated modeling tool that can track water resource stocks and flows associated with extraction, production, and consumption, including surface water, groundwater pumping, and the transmission of water.

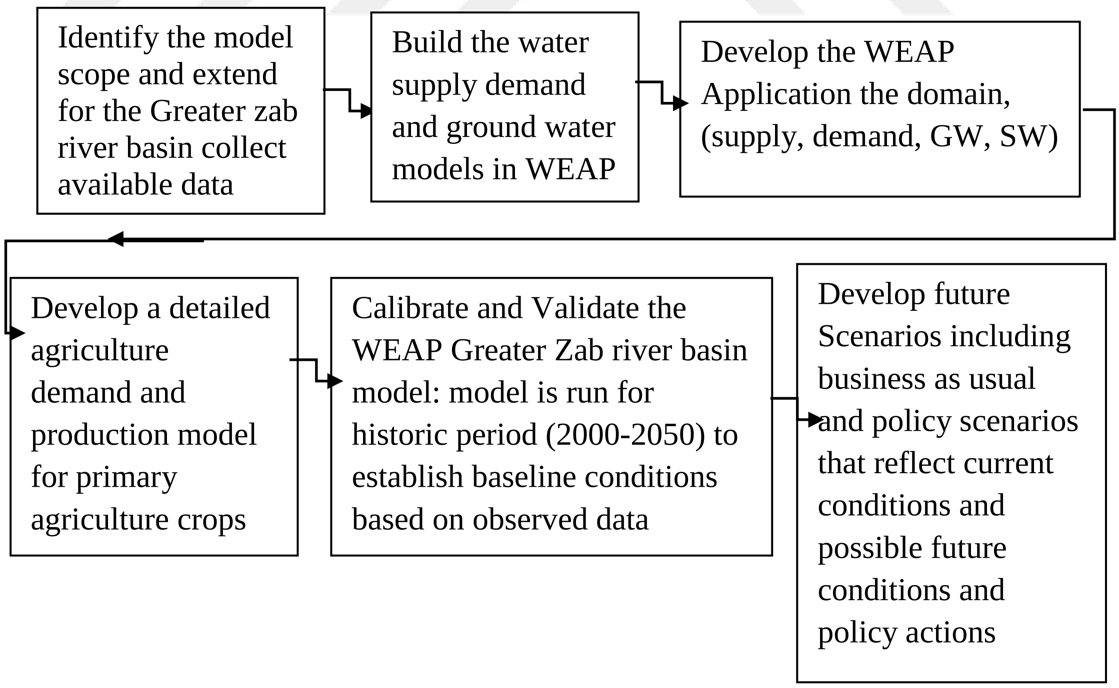


Figure 6.4 Working steps and installation WEAP software

The development of a valid and credible water and agriculture systems model for the GZRB is the final component of the analytical approach.

The Water Evaluation and Planning (WEAP) system, used in the study for analysis and is an integrated modeling system that can cover water resource stocks and flows connected with extraction processing, production, and consumption, including groundwater pumping, surface water, and the water supply. The development of a valid and credible water and agriculture systems model for the GZRB is the final component of the analytical approach.

The following steps followed during the works.

1- Build up the WEAP model: Developing the water system model in WEAP required a comprehensive estimate of the water supply/demand characteristics of the GZRB. Once the baseline data were established, such as the regional population, the per-capita indoor water demand, the extent of outdoor irrigation for amenity, garden, and agricultural uses, the water supply sources including fresh groundwater, surface water, technologies used, etc. were configured into the model to facilitate mass balance calculations on a daily time step.

2- Build the water resource model: The ground and surface water model included a representation of the water supply systems of Erbil governorate, using of WEAP's catchment objects

3- Calibrate the water resource model: After building the water resource model and calibrated according to predevelopment, steady-state conditions that maintained a level groundwater table and quantities of surface water flow across the representative area, from the center of Erbil and the model used to explore current and future water use conditions.

4- Development of a detailed agricultural demand and production model. Making use of crop water requirement model (CROPWAT), and developed a detailed model of the primary crops in production in the region (fodder, vegetables, and orchards). This model can be used to explore the water demand and the production of agricultural outputs under current and future climate conditions.

5- Calibrate the WEAP model: Once the water supply and demand models were developed, they were run for the historic period 2000 to 2016 to establish baseline conditions based on observed data with regards to water supply and use. This can be considered a calibration phase.

6- Develop Business-as-Usual (BAU) or Reference Scenario RS scenarios that reflect current conditions growth ratio 3.4%, that continue into the future, but that consider changes in future climate. In addition, we have developed a future policy scenario that assumes a reduction in the forestry and fodder areas, and an increase in land under agricultural cultivation for higher valued crops such, orchards and vegetables.

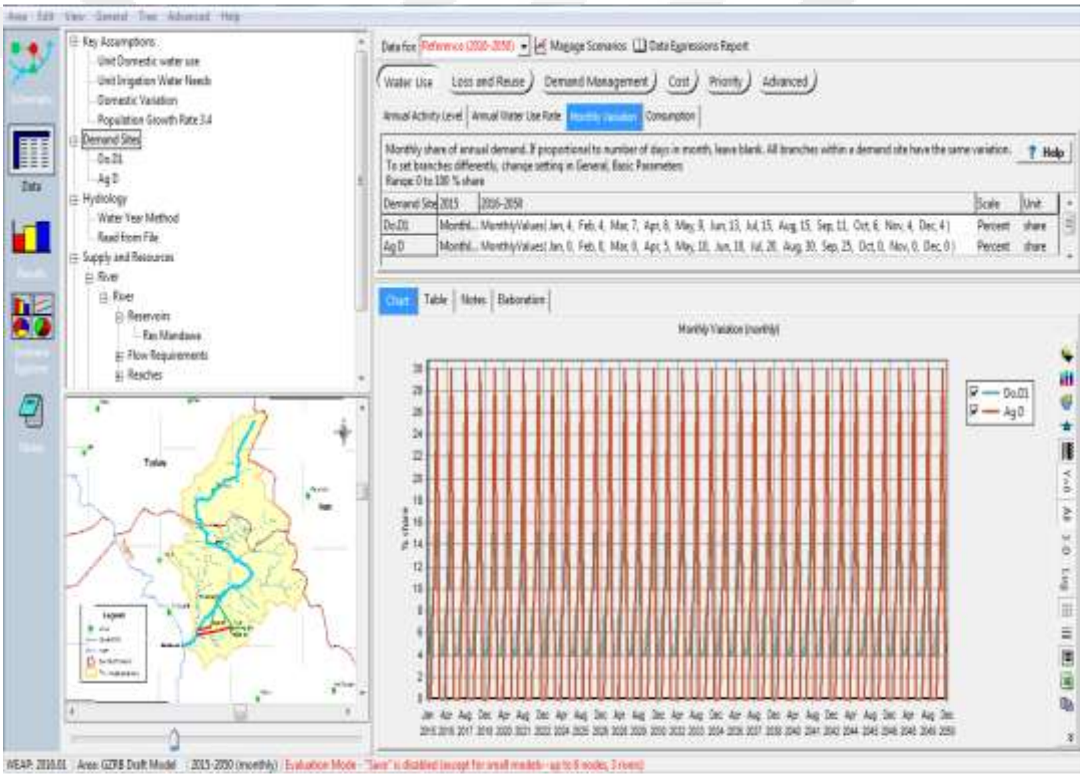


Figure 6.5 WEAP-GZRB model and its geographic scope.

A model development period using historic data from 2000 – 2016 was used for model setup and configuration. Once the GZRB WEAP model calibrated and validated against the historical period, it was used to project forward under different assumptions of resource use and climate. A future planning period of 2016 through 2050 was considered in the analysis.

The model captures system characteristics like agricultural areas, populations, water demand for human consumption and irrigated amenity areas, wastewater plant capacities, water production capacities, irrigation demands, and groundwater availability/recharge. The model developed in a daily time step to examine water supply and demand balances in the GZRB, and encompasses an area of approximately 26,307 km^2, illustrative schematic view of the model shown in Figure 6.5. The schematic demonstrates the aggregated nature of the GZRB model's representation of water supply (green lines) and demands (red and green dots). A final version of the GZRB water system model, after receiving and incorporating all stakeholder feedback, will be available for download.

6.7.4 Data Input Sources and Assumptions

The water and agriculture systems model uses a host of data assumptions that influence water supply and demand. These data assumptions have been carefully assessed, and incorporated into a working version of the water system model that adequately simulates historical conditions. After a review and vetting process by stakeholders of the current version of the model, a final version will be developed that incorporates all feedback.

The representation of water supply and demand characteristics within the water system model was as "granular" as possible. While there was ample local data to construct a modestly granular water system model, there was not enough detailed data to develop a highly granular water system model. This has consequences for the level of detail that can analyze during the policy scenario analysis. That is, the water system model can analyze high-level (i.e., sectorial level) policy scenarios and offer first-order indications of alternative development pathways. However, the model cannot analyze the interactions between water supply/demand policies at lower levels of disaggregation (e.g., level of enterprises, households, precincts). (Jamieson & Fedra, 1996)

The water system model built in WEAP is fundamentally data-driven. Hence, there is a large amount of data, which needed to build the model. The data collection effort has benefitted from collaboration across relevant Erbil province institutions, which have granted access to necessary data. As of this writing, this process has satisfactorily completed.

There were several differing types of modeling assumptions, which incorporated into the water system model. Background for each of the major assumptions is providing in the subsections below regarding water supply, water demand, and wastewater treatment.

6.7.5 Model Structure

The WEAP software model used to build a water system model for the GZRB. The WEAP provides a sector-specific integrated approach to water resources planning by linking quantification of water availability and water allocation routines, hydrologic processes, system operations and end-use quantifications within a single analytical platform (SEI, 2005) , (Yates, et al,.. 2005)

The modeling software incorporates the multiple dimensions critical to water resources management, including surface water and groundwater hydrology, water quality, water demands, population growth, reuse, system losses, and consumption. WEAP represents water supply and demand centers in a spatial way because its focus is the flow of water from the river to the users.

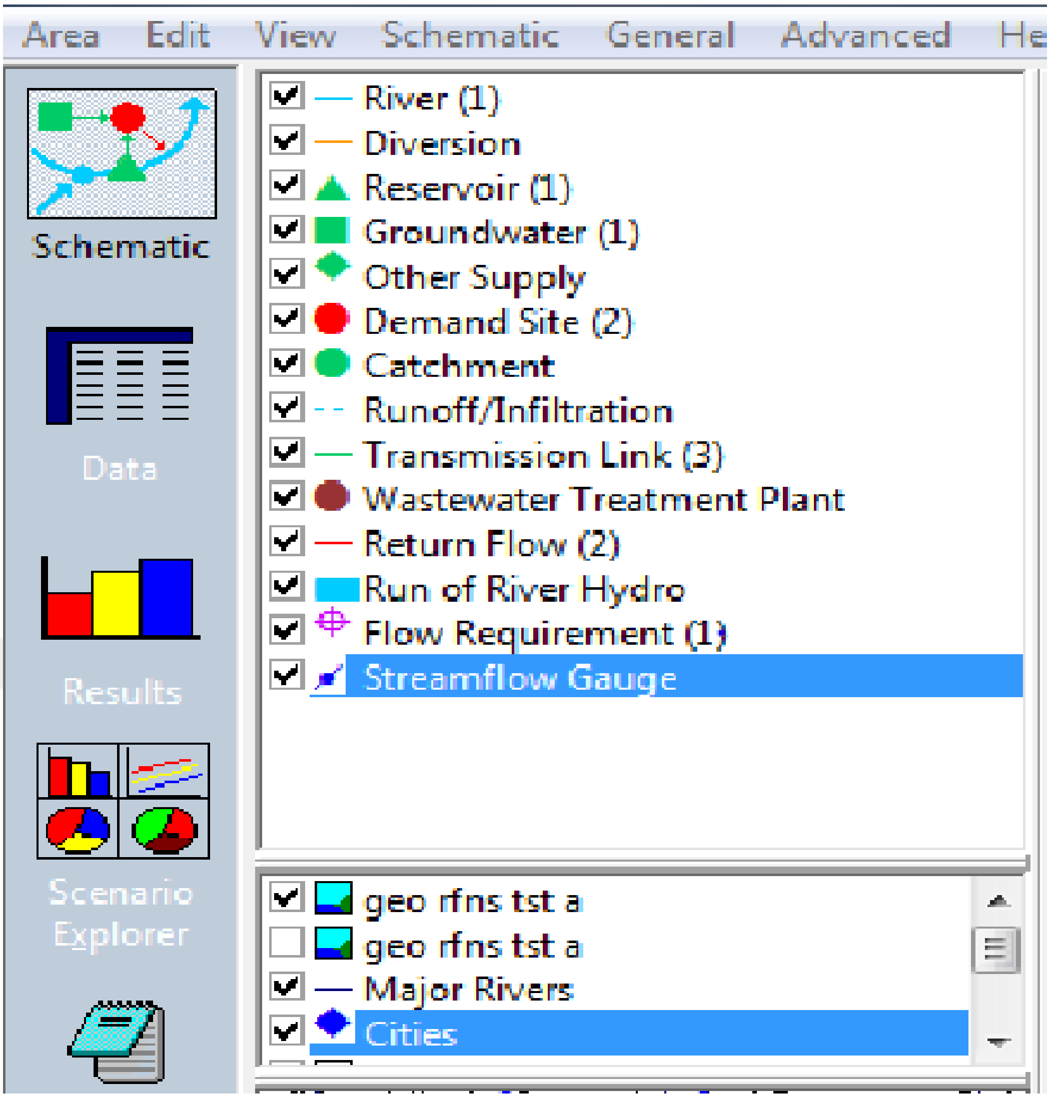


Figure 6.6 Illustrate model structure and activities

The water system model structure accounts for the locations of all water supply sources and the magnitude of current and future demand for water. The nomenclature of water system components, as illustrated in the WEAP modeling figures, is outlined below:

1) Green squares represent groundwater aquifers. These three aquifers receive influx from the system and mountain front recharge and assumed to contain 100 BCM at the start of the simulation in 2015 (MOA&WR 2016).
2) Red dots represent indoor water consumption per capita; the annual indoor and outdoor water use is calculated 179 m^3/year to represents the GZRB municipality demands.
3) Maroon dots represent wastewater treatment facilities.

4) Green dots represent catchment water demands associated with different types of land covers that require irrigation; 22 catchment objects are used to represent the Mountains, comprising around (117000 ha) in 2017. This object was also use to represent agriculture, amenity, and outdoor irrigation and water demands.
5) Green lines represent water transmission flow; a set of transmission links define how water was allocate among the various supplies and uses.
6) Red lines represent water return flow; Return flow water is water that was pass back to the environment or recharges to an aquifer.
7) Dashed blue lines represent connections of hydrologic processes, including the transmission of recharge water to the alluvial aquifer or the flux of water from the alluvial aquifer to the steady-state aquifer.

On the other hand, during working, there are several activities within WEAP.

6.7.6 Modeling Water Demands in WEAP GZRB

Water demands include indoor and outdoor municipal use, amenity water use, forestry, and irrigated agriculture. The WEAP's catchment object used to represent "Outdoor water use" corresponding to irrigation for private outdoor household demand. "Amenity water use" corresponds to irrigation for public forests and amenity use (recreational or green areas such as public parks, green areas along roadways and freeways, turfs mainly representing golf courses, and trees in urban areas). "Agricultural water use" corresponds to land area used for crop cultivation (plantations, fodder, agricultural vegetable crops, and other agricultural crops). The annual agriculture water required used by model is (3500 m^3/ha) and the irrigation land in Erbil Governorate for the year 2015 calculated is (117110 ha) as shown in previous table 6.1

The GZRB includes the demand centers of the city of Erbil and surrounding districts and sub-districts. Demands include indoor, outdoor and amenity uses. The model uses a single demand object to represent the forestry uses and assumes average water requirement about, (3500 m^3/hectare per year). A single demand object also used to represent amenity water use, where we assume that (99745 ha.) are under active irrigation, using (506 MCM) per year.

The domestic water demand for each household in rural area used by model assumed (533 m^3/ year) including (each household (4) persons) and shows in the previous table 6.3

Domestic water requirement data, in this study show, that the province has to reduce, individual water uses. In the future DWR using reduce from (490 liter /capita/day) which include indoor (365 l/ c/ day and outdoor 125 l/ c/ day), to (375 l /c /day). The water use which calculated, (375 liter/c/day), accordingly the annual water use by household (354 m^3) in year 2015 as well as the annual water uses by household (375 l/c/d) in 2050 that by using technology and decreasing losses in system water supply and increasing the price of water supply for the city. Regarding the key assumptions, both units of domestic water needs and irrigation water requirements, annual unit domestic water use per capita (179 m^3) and the annual unit irrigation water needs 3500 m^3 used by WEAP

Table 6.9 Illustrates unit water needs for irrigation

Year	**Annual unit irrigation water needs (m^3)**	**Year**	**Annual unit irrigation water needs (m^3)**
2015	3500	2035	3200
2020	3400	2040	3150
2025	3300	2045	3100
2030	4300	205	3050

And the domestic variations during the year used as shown in table 6.10

Table 6.10 Illustrates domestic variations during the year

Month	**Variation**	**Month**	**Variation**	**Month**	**Variation**	**Month**	**Variation**
Jan.	0.9	Apr.	1.0	July	1.15	Oct.	1.0
Feb.	0.9	May	1.0	Aug.	1.15	Nov.	0.9
Mar.	1.0	June	1.1	Sep.	1.0	Dec.	0.9

The last date of Census is 2015, the population at 2015 was (1981013) people and the proposed (Normal) growth rate (3.4%) by the time unit of irrigation water needs will decrease due to decreasing losses in the system by using new technology and new irrigation systems, the data of irrigation water needs used in model as shown in table 6.9. This data used in the proposed scenario where the population growth normal and it is 3.4 % as a reference scenario, then the model creating running scenarios. The second scenario to model account high population growth, this scenario looks impact of increasing population growth from the value of 3.4 % to 5%.

From the past history of hydrological cycle in the GZRB selecting the water year sequences and estimated for next 33 years as shown in table 6.11, were after every 8 dry years (dry years minimum rain in the basin).

Table 6.11 Water year sequences (normal, dry, very dry, wet and very wet year)

Year	Sequences	Year	Sequences	Year	Sequences	Year	Sequences
2015	Normal	2024	Very Wet	2033	Wet	2042	Wet
2016	Normal	2025	Normal	2034	Very Wet	2043	Very Wet
2017	Dry	2026	Normal	2035	Normal	2044	Normal
2018	Very Dry	2027	Dry	2036	Normal	2045	Normal
2019	Normal	2028	Very Dry	2037	Dry	2046	Normal
2020	Normal	2029	Normal	2038	Very Dry	2047	Dry
2021	Normal	2030	Normal	2039	Normal	2048	Very dry
2022	Wet	2031	Normal	2040	Normal	2049	Normal
2023	Wet	2032	Wet	2041	Wet	2050	Normal

Note: (Very Dry = 0.7, Dry = 0.8, Normal = 1.0, Wet = 1.3, Very Wet =1.45)

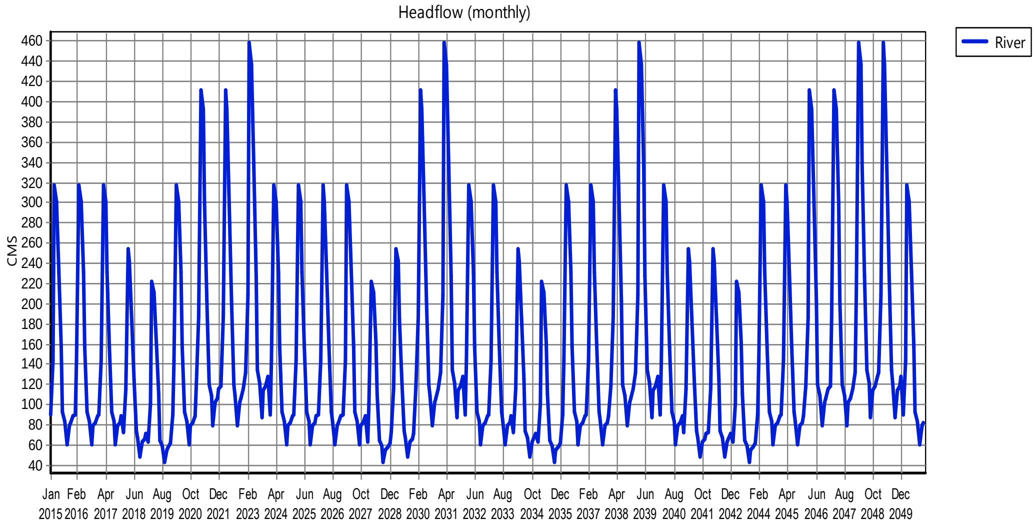


Figure 6.7 Forecast River flows for GZR calculated by model

According to the previous climate, change data damaged the sources of surface water and many water springs dried during the past 50 years. Moreover, causes like a decrease in the snow, rainfall and river flows, and high population growth all together result in increased water needs for agriculture and for domestics, therefore, the Erbil province, focus on construction reservoir on the GZR called Bekhme reservoir.

Bekhme dam with a reservoir capacity of 17.1 BCM, dam height (210 m), and power production (1500 MW) planned to be constructed but due to financial crises, the construction postponed. This research has created to establish in 2035, then run the model and calculate all water demands (Domestic, Agriculture, Environment, and Industrial).

The minimum water releases for the environment from GZRB to the Tigris estimated by minimum GZR water flow and flow requirement by Iraqi government were calculated (50) m^3/sec. The total annual environment flows (1577) MCM for the year 2030. The Table 6.4 illustrates GZR environment water flows to the Tigris River.

Industrial sector water demand generally depended on groundwater due to located in the different area and far from the riverbanks, the total annual amount estimated by 50 MCM for the year 2050 from 389 industrial deep wells.

Table 6.12 Illustrates the water deep wells uses in industrial sector

Year	Number of Well	Av. discharge of one well m^3/sec	Annual Industrial Water Requirement	
			m^3/Sec.	MCM
2010	40	0.005	0.2	5.26
2015	140	0.005	0.7	18.40
2020	140	0.005	0.7	18.40
2025	180	0.005	0.9	23.65
2030	220	0.005	1.1	28.91
2035	260	0.005	1.3	34.16
2040	300	0.005	1.5	39.42
2045	340	0.005	1.7	44.68
2050	380	0.005	1.9	49.93

CHAPTER 7

RESULTS AND DISCUSSION

7.1 Overview

This part of the research includes discussions and result of the thesis. The distribution of authorities responsibility of water resources and management are too wide in general terms the chapter discuss, the appropriateness of the different options to cover the water requirements of different areas and for different users in GZRB.

The poor management of water resources by Iraqi government caused several big problems regarding water resources such as problems in operation of dams and reservoir and water flow of the main rivers. So that, every year, Iraq has faced a big problem in terms of the shortage of water and water losses in the agricultural field and hydropower generation from dams.

Moreover, financial crises after 2014 play an important role in damaging the water resource and its projects in Erbil. Therefore, the Iraqi government refuses plan and funding to establish a new reservoir on the GZR or complete the Bekhme dam. This means that the Iraqi government interested in water flows from the river to the downstream (med and south) and the river working as a free flow river so that the GZR working as an uncontrolled river. It is worth for the river to flow directly to the Tigris River for recharging downstream basins instead of building a dam on the GZR.

It stresses the limited access to drinking water in rural areas. The province authority's alone well supply, but the quality of the water distributed is poor. Sanitation services are practically non-existent. Besides the environmental challenges (lower groundwater levels, more frequent use of surface water), the study highlights several institutional weaknesses:

The lack of human resources, the poor performance of monitoring (including operation and maintenance), the related to the extremely low prices; the inappropriate funding method, the lack of cooperation between Erbil agencies and the inadequate awareness among beneficiaries.

During the research, uses of data and models as well as the organization to set management rules for future water resources development as well as strategy orientations for the next 33 years in GZRB.

As discussed before the aim of the data collection system is enable the different stakeholders to access share information and a general overview of GZRB management. During the research, this information system used mainly included four sectors; the first sector is agriculture and irrigation, second domestic water (drinking water and sanitation), third environment and heritage and the fourth is energy production.

This research stress on the fact that the knowledge of this flow is a capital information to establish a High technical committee between the Turkey and Iraq**:**

I. A good relationship with the upstream users (in Turkey),
II. The discussions with the Turkish government,
III. A good calibration of the global model of the river basin.

As these demand figures are only used to provide weight factors for a distribution of the total consumption value, as discussed and defined for each load case, it does not matter which nominal per capita consumption value is used at this stage.

7.2 Demand Management and Water Reuse

As discussed in previous chapters GZRB water resources are limited and shared and it has been shown that this can still be covered by the available resources provided that a number of large dams and reservoirs are built.

However, there are limits to the further increase of water use, and there are signs of rising concern downstream in central Iraq.

The analyses of water demand, the water balance scenarios, and the above discussion possible strategies have shown that:

A. Demand and pressure on GZRB water resources are growing;

B. There are clear signs of over-exploitation of the groundwater resources in particular in the Erbil area;
C. The sectorial water uses have to be closely coordinated to avoid future conflicts and uncontrolled competition for the same resource;
D. Water resources are shared with upstream and downstream neighbor's, hence the need to agree on water allocation to prevent future conflicts.

Iraq rebuilding and its economic and demographic growth, especially in Greater Zab river basin, will result in increasing pressures on the water resources. Guaranteeing a sufficient supply of quality water to meet the needs of the different uses, in a context of overall sustainable development, must become a major aim for local authorities.

The total land to be irrigated by Greater Zab River flow in Iraq is around (400,000 ha) in the year 2030 and (500,000 ha) during 2050. Most of the agriculture sector water use occurs in the basin assumed that the agriculture sector within greater Zab watershed that has been mentioned in this study.

The extern relations towards upstream countries like Turkey and Iran and downstream federal government are a second major challenge for GZRB. Both Turkey and Iran have already the technical means and the technical knowledge of their resource. Iraq in general needs methodological and technical tools and knowledge to be able to discuss, negotiate and develop water uses in a win-win configuration. The aims to support Erbil authorities in starting integrated water resources management using River basin as a unit for decision-making.

The average coefficient of annual precipitation variation in a drought year is around 30%. Any water management and water use infrastructure should be plane and designed taking drought probabilities into account, including the occurrence of the cluster of dry years. Each parameter influencing the water availability and repartition has been estimated and analyzed per sub-basin: rainfall efficiency, provision of water from snow thaw, infiltration, evaporation, and runoff. Details of the calculations will be presented in the notice for the WEAP hydraulic model.

The estimation permits to determine surface water quantity available per year, the groundwater recharge and its natural discharge through springs, the demands of water per year.

Results of those estimations for our main agro-climatic zones are presented in the following table. The chart underlines the seasonality of the demand for irrigation in the different zones.

7.3 Impacts of Climate Change on GZRB

A full discussion of the phenomenon, in particular downscaling of regional predictions to analyses local effects in Erbil Province, is beyond the scope of this study. However, the length of some of the available meteorological records allows analyzing whether any trends can be detected.

Two relevant questions that can be analyzed in this way:

1. Is precipitation generally decreasing?
2. Is there a change in the seasonal pattern of water availability?

Whether precipitation is generally decreasing in GZRB has been widely discussed, in particular after the exceptional drought period from 1989 and 1999 to 2001 which caused a significant depletion of water resources.

However, clusters of dry years are a normal statistical phenomenon in regions with high climatic variability and are not necessarily an indication of climate change as shown in the table 7.1 and figure 7.1.

Monthly water flow reduced by the time due to climate change to the worst on the other hand demand increased compare to the past river flows data, so that the average water flow reduced

Table 7.1 Average monthly discharge at Kalak (m^3/s) for (dry, wet) year 2014

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Dry year 1989	67.2	83.4	102.6	82.2	60.9	242.1	312.9	246.5	96.1	38.1	33.8	35.1
Wet Year 1969	168.7	308.3	836.5	603.6	554.2	1,646	1,781	1,632	698	351.5	227	180.4
Year 2015	202	233	265	242	250	412	393	338	239	182	154	138

Figure 7.1 Monthly water flow (m^3/sec) at Kalak station (flood and drought)

However, Erbil governorate's water resources are exposed to a number of risks and threats, in particular:

I. A fast-growing demand caused by urbanization, economic development and in particular the planned extension of irrigated areas;
II. Lack of regulation of groundwater use, resulting in overuse in particular around Erbil;
III. Increased water use in upstream countries, resulting in reduced inflow; and
IV. The expect impacted of climate change on the area.

7.4 Results

The main results of the model have presented hereafter. These results are enough accurate for the IWRM at the level of the river basin. They should not use for project design or other studies without further analysis and measurements. The model and its results can be used to simulate the behavior of the GZRB in case of modification of the current situation:

I. Evolution of water needs and requirements
II. Evolution of resources availability (linked to climate change for example)
III. New water projects dams, reservoirs, hydropower plants, etc.…

The detailed analysis of this specific result shows that this is mainly due to the lack of rain and high demands between July and September. Some conflicts around water availability (in quantity, quality) and environmental degradation progressively arose during recent years in GZRB, due to, among others:

1) Over-exploitation of ground water in various areas,
2) Urban water pollution that creates some difficulties during dry seasons;
3) Gravel mining that damages natural river courses or even some irrigation schemes.

These conflicts mainly result from the conjunction of sectoral approaches and from the lack of Integrated Water Resources Management. There is no real operational tool to solve the conflicts. These conflicts can only increase in link with on-going economic development, which generates more and more pressures on the resource (water withdraws, pollutions, environmental degradation)...

The information concerning the regulatory and legal context of water resource management in Erbil makes it possible to draw up a diagnosis and a set of proposals for easier implementation of IWRM principles.

The particular aims are as follows:

1- To have an overview of the current legal context concerning water;
2- To assess the work required to adopt the statutory and institutional context for IWRM Implementation;
3- To implement new tools of governance;

As mentioned previously, water management in GZRB has evolved over the years in response to the isolated needs of each sector rather than through a careful balancing of overall needs. The resulting vertically divided administrative functions in water use and management have made effective water management quite difficult.

As a result, most Iraqis now have limited access to clean water supplies, sanitation, and waste collection. Serious environmental and health risks associated with contaminated water supplies, improper handling of solid waste and sewage disposal threaten to add to the burden of the already overloaded health system.

The result is a specific peak day demand of490 l/c/d included (365 l/c/d indoor and 125 l/c/day outdoor). The peak day demand is the base on which the following components are designed: transmission mains, reservoirs, booster pumps, etc.

Erbil average daily usage of water in liters per capita per day (l/c/d) is 490 according to general directorate of water and sewerage water planning report (2015). The model calculated water requirement per person per day 365 l/c/d for indoor use and 125 l/c/d for outdoor use with a total of 490 l/c/d. The average daily forecast 270 l/c/day for the year 2050 reduced by several ways included increasing the population training on water using and save water, technology development and etc.…

The table 6.4 illustrate average monthly environment water requirement by Iraqi government from GZR, flow to Tigris River. The annual EWR in 2035 estimated by 2208 MCM flows to the Tigris River and required flow from Erbil governorate estimated by 2208 MCM. These rivers may require different forms of study to determine the higher flows required for operations such as channel maintenance and flow, fish breeding and employment, and the health of wetlands and estuaries.

Deep wells are additional area distributed proportionally to the number of existing wells (all wells). Estimation of abstraction per well based on the following estimates: D.G. of Agriculture – estimate that about 30,000 to 40,000 Hectare are irrigated from 4,000 wells. This is equivalent to an area of 7.5 to 9.4 ha Irrigated per well or, assumption an irrigation need of 4,500 m^3 per ha per year, to a water abstraction of 205 to 257 m^3/day per well. On the other hand, abstraction can estimate from the wells database: The average yield of all deep wells used for irrigation is 6 l/s, with an average daily pumping time of (6 hr.) This results in average daily abstractions of (38 m^3/day) water, the annual irrigation day is 57 days, hence a very similar value. Assuming that 20% of the water used will rein filtrate to the aquifer the estimate of (50 m^3/day) net abstraction has finally used for the calculations.

The river flow variable from wet season average Monthly River flow around 2500 m3/Sec. during the flood year 1969 and in the dry season around 50 m3/Sec and it was the year 1989, table 3.11 shows annual average river flow for GZR. (MOA&WR, 2016)

7.4.1 Create Scenarios and model Run

The data arrangement required by software after the difficulty of data collection from several directorates, then installed GIS raster map for GZRB, inserted to the WEAP system program and created two big demands the agriculture and domestic water use as well as linked to the river system.

1. Scenario Reference

In this scenario the annual population growth ratio calculated as a normal case 3.4% after insert all data required by software, ran model as a current situation which called scenario reference, the output result is the water supply cannot cover the demand during the year 2046 to 2050 in both months august and September it means the basin facing problems regarding to water resource availability and the government has to think and establish strategy plan carefully for future generation, the unmet water demand, water supply delivered and total water requirement for both users agriculture and domestic in august and September as shown in table 6.2

Table 7.2 Illustrates water supply required, demanded and sufficient water

1. Supply water requirement in August and September from 2046 -2050

Water Use	**Supply water requirement in August and September from 2046 -2050 (MCM) Million m^3**									
	2046		2047		2048		2049		2050	
	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Agriculture	280.3	233.6	288.1	240.1	295.8	246.5	303.5	252.9	311.1	259.3
Domestic	57.7	50.2	58.4	50.8	59.2	51.5	59.9	52.1	60.6	52.7
Total	338	283.8	346.5	290.9	355	298	363.4	305	371.7	312

2. Unmet Water Demand in August and September from 2046 -2050

Water Use	**Unmet Water Demand in August and September from 2046 -2050 (MCM) Million m^3**									
	2046		2047		2048		2049		2050	
	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Agriculture	2.7	3.1	9.8	9.1	16.9	15	23.9	20.8	30.9	26.6
Domestic	0.5	0.6	1.9	1.9	3.3	3.1	4.7	4.2	6	5.4
Total	3.2	3.7	11.7	11	20.2	18.1	28.6	25	36.9	32

3. Total Water Supply Delivered in August and September from 2046 -2050

Water Use	**Total Water Supply Delivered in August and September from 2046 -2050 (MCM) Million m^3**									
	2046		2047		2048		2049		2050	
	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Agriculture	277.6	230.4	278.3	231	279	231.6	279.6	232.1	280.2	232.6
Domestic	57.2	49.5	56.5	48.9	55.8	48.4	55.2	47.8	54.6	47.3
Total	334.8	279.9	334.8	279.9	334.8	280	334.8	279.9	334.8	279.9

The water supply deficient to cover and met demand in dry months (August and September) which the water demand very big and the maximum around 37 MCM in the year 2050, figure (7.2) shows output and result from run scenario reference, included the water demand and water supply in two months during the unmet years according to the model run, therefore the government has to give priority and plan for completing Bekhme dam and its very important for water resources management in GZRB.

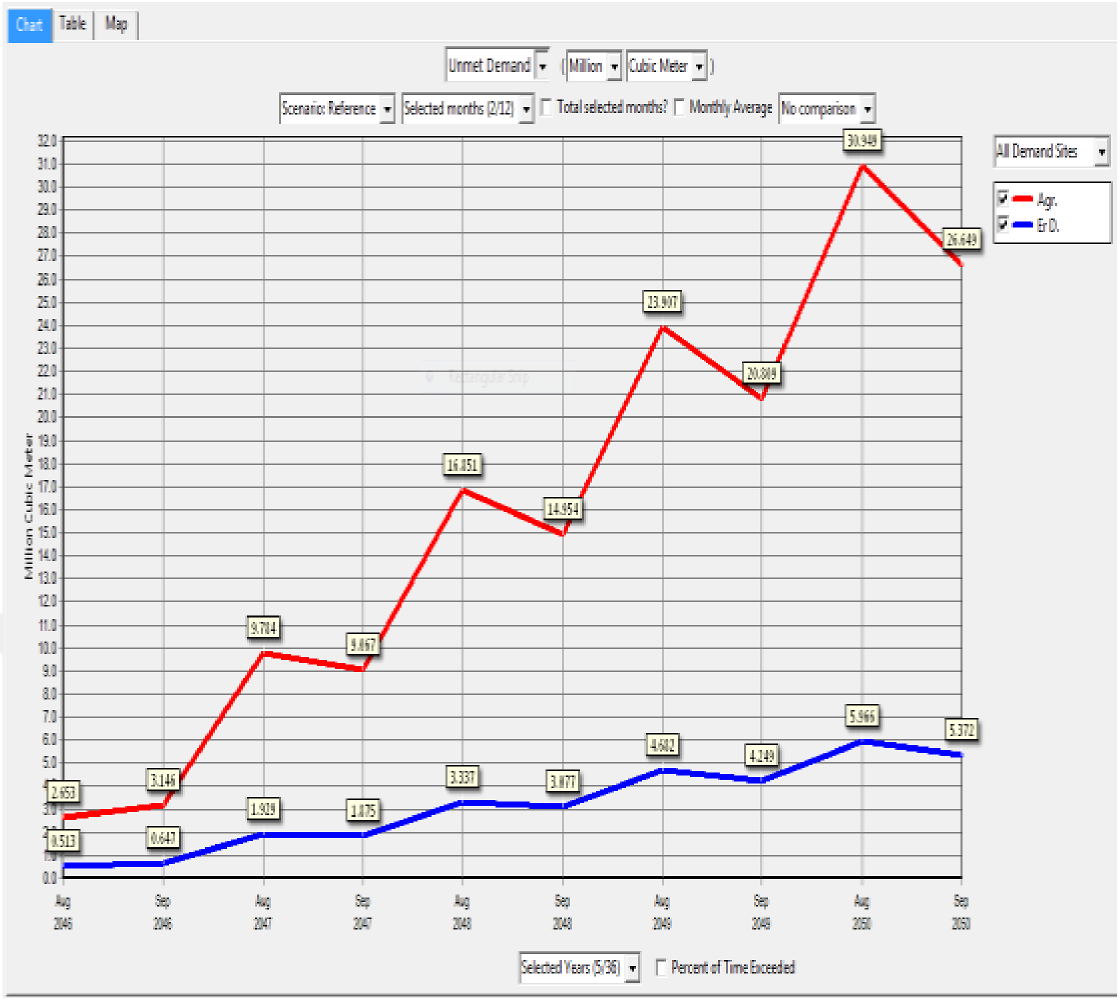


Figure 7.2 Aug. and Sep. 2046-2050 unmet Dem. for Agri. and Dom. water uses

2. Scenario High Population Growth

The scenario of high growth population is one of the opportunity to happen in future, for this scenario the annual growth ratio calculated as a high ratio 5%. In this case the population in 2050 closed to 10 million people, after insert all data required by software, run model takes account future growth population called scenario high population growth, the output result is the water supply can't cover the demand during the year 2032 to 2050 in both months august and September it means the14 years before the scenario reference the river facing problems basin regarding water resource availability and the government has to think about this challenges will happen in case the number of population reach 10 million, therefore, government should take account this probability and establish strategy plan starting from 2030 carefully for future generation, the unmet water demand, water supply delivered and total water requirement for both users agriculture and domestic in august and September as shown in table and figure (7.3)

Table 7.3 Illustrates the unmet water Damen started from 2032 -2050

Water Use	**Total Unmet Water Demanded in August and September from 2032 -2050 (MCM) Million m^3**									
	2032		2033		2034		2035		2036	
	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Agriculture	28.6	24.5	56	47.3	83.7	70.3	111.4	93.4	131	109.7
Domestic	4.7	4.2	8.8	7.8	12.7	11.1	16.2	14.2	18.8	16.5
Total	33.3	28.7	64.8	55.1	96.4	81.4	127.6	107.6	149.8	126.2
	2037		2038		2039		2040		2041	
Water Use	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Agriculture	150.6	126	170.1	142.2	189.6	158.4	208.9	174.6	237.7	198.6
Domestic	21.5	18.7	24.1	21	26.7	23.3	29.4	25.6	33.2	28.9
Total	172.1	144.7	194.2	163.2	216.3	181.7	238.3	200.2	270.9	227.5
	2042		2043		2044		2045		2046	
Water Use	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Agriculture	266.4	222.5	295	246	323.6	270.1	352	293.8	378.1	315.5
Domestic	37	32.2	40.9	35.7	45	39.2	49.1	42.8	52.1	45.4
Total	303.4	254.7	335.9	281.7	368.6	309.3	401.1	336.6	430.2	360.9
	2047		2048		2049		2050		2051	
Water Use	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Agriculture	404	337.1	429.8	358.6	455.5	380	481	401.2		
Domestic	55.2	48.1	58.2	50.7	61.2	53.2	64.2	55.8		
Total	459.2	385.2	488	409.3	516.7	433.2	545.2	457		

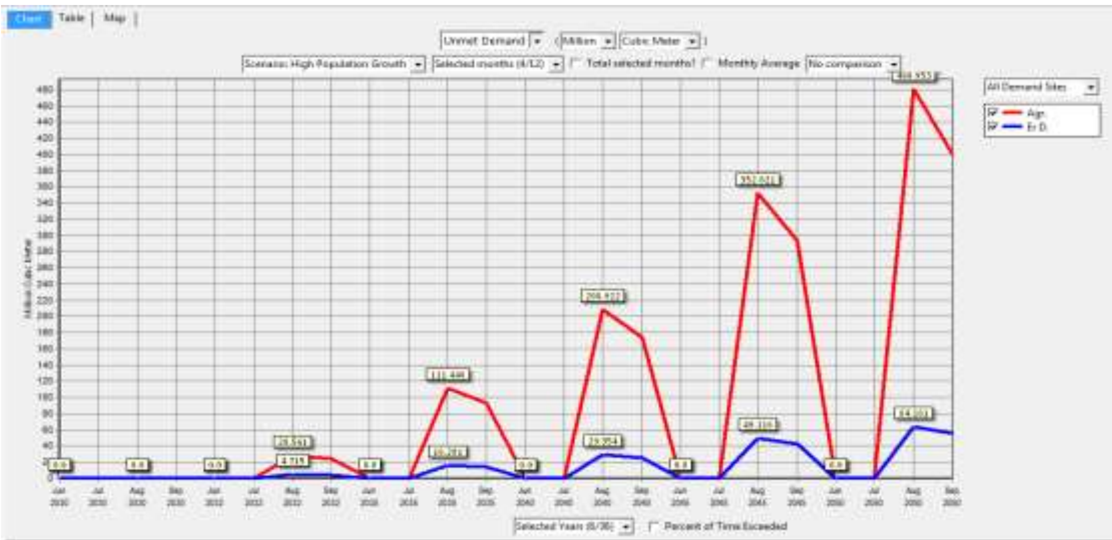


Figure 7.3 Illustrates the unmet quantity of water during 2032 to 2050

Table 7.4 Total water supply in August and September from 2032-2050

Water Use	Water Supply Requirement in August and September from 2032 -2050 (MCM) Million m³									
	2032		2033		2034		2035		2036	
	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Agriculture	315.4	262.8	344.9	287.4	374.4	311.9	403.5	336.3	423.5	353
Domestic	52.7	45.8	54.7	47.6	56.8	49.4	58.9	51.2	61.1	53.2
Total	368.1	308.6	399.6	335	431.2	361.3	462.4	387.5	484.6	406.2
	2037		2038		2039		2040		2041	
Water Use	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Agriculture	443.5	369.5	463.2	386	482.9	402.3	502.3	418.6	531.4	442.9
Domestic	63.4	55.1	65.8	57.2	68.2	59.3	70.8	61.5	74.3	64.6
Total	506.9	424.6	529	443.2	551.1	461.6	573.1	480.1	605.7	507.5
	2042		2043		2044		2045		2046	
Water Use	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Agriculture	560.3	466.9	588.9	490.4	617.4	514.5	645.7	538	672.2	560.1
Domestic	77.9	67.8	81.8	71.2	86	74.7	90.2	78.5	92.8	80.7
Total	638.2	534.7	670.7	561.6	703.4	589.2	735.9	616.5	765	640.8
	2047		2048		2049		2050		2051	
Water Use	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept	Aug	Sept
Agriculture	698.5	582	724.6	603.8	750.5	634.4	776.3	646.8		
Domestic	95.5	83.1	98.2	85.4	101	87.7	103.7	90.1		
Total	794	665.1	822.8	689.2	851.5	722.1	880	736.9		

3. Scenario environment flow (SEF)

In this scenario, the environment flows calculated into account monthly river flow 50 m^3/sec. flow release to downstream Tigris River. This scenario the monthly water flow mandatory release to downstream by the Iraqi government. That proposed as a minimum river flow during the dry season.

The scenario SEF is one of the opportunity to happen in future, for this scenario the annual growth ratio calculated as a proposed 3.4% and high ratio 5%.After inserting all data required by software, model run take account future growth population for both scenarios SR and SHP, on the other hand, the river flow mandatory release environment, then the output result is the water supply cannot cover the demand during the year 2030 to 2050 in both months August and September it means the16 years before the scenario reference when the environment flow required and in SR .

But in this case and when the calculation is done for SHP the water unmet will happen start from 2021 and the river facing problems regarding water resource availability and the government has to think about this challenges will happen in case the number of population reach 10 million, therefore, province should take account this probability and establish strategy plan starting from 2021 carefully for future generation, the unmet water demand, water supply delivered and total water requirement for both users agriculture and domestic in August and September as shown in figure 7.4 to 7.7

	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045	2050	Sum
Agr.	0.0	2.0	5.6	9.4	16.6	25.3	56.3	284.2	434.9	685.2	930.5	2,449.9
Er D.	0.0	0.1	0.9	1.6	2.6	4.1	10.3	41.7	61.4	97.0	127.5	347.2
Sum	0.0	2.1	6.6	11.0	19.1	29.3	66.6	325.8	496.3	782.2	1,058.0	2,797.1

Figure 7.4 Unmet Demand table for SHPG, environment flow mandatory

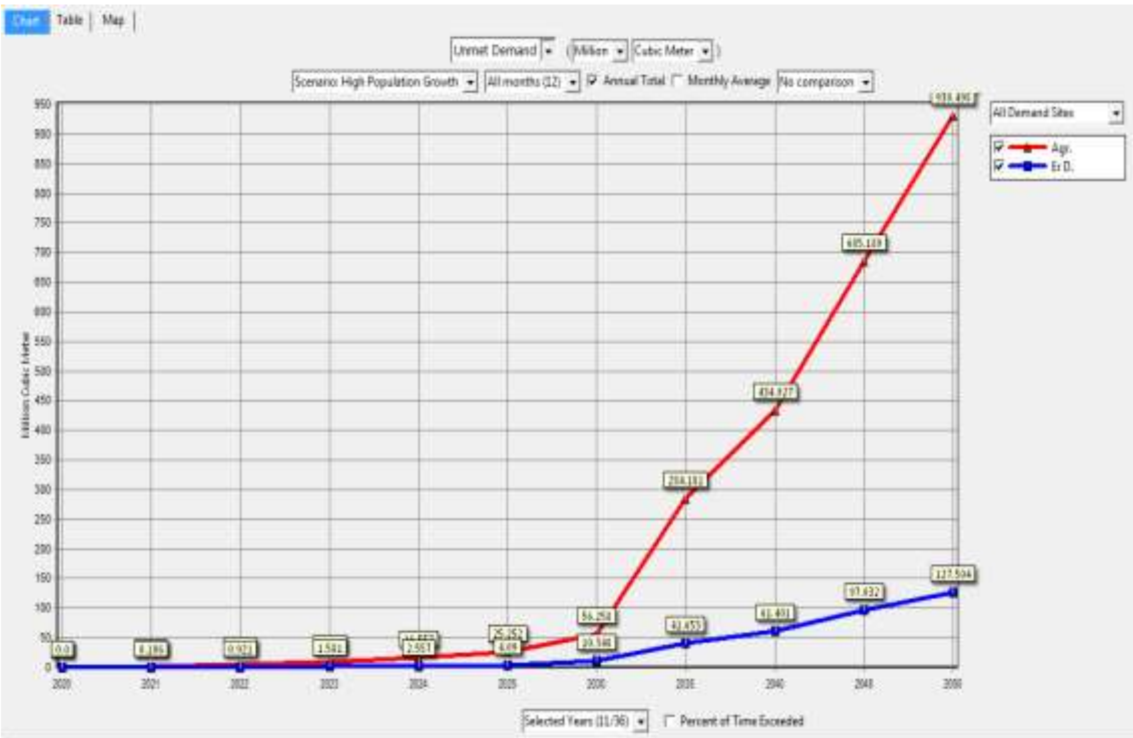


Figure 7.5 Unmet Demand chart for SHPG, environment flow mandatory

	2022	2023	2024	2025	2030	2035	2040	2045	2050	Sum
Agr.	0.0	0.0	0.0	0.0	0.0	32.4	65.1	131.1	180.2	408.9
Er D.	0.0	0.0	0.0	0.0	0.0	6.3	12.9	27.4	34.9	81.4
Sum	0.0	0.0	0.0	0.0	0.0	38.7	78.0	158.5	215.1	490.3

Figure 7.6 Unmet Demand table for SR, environment flow mandatory

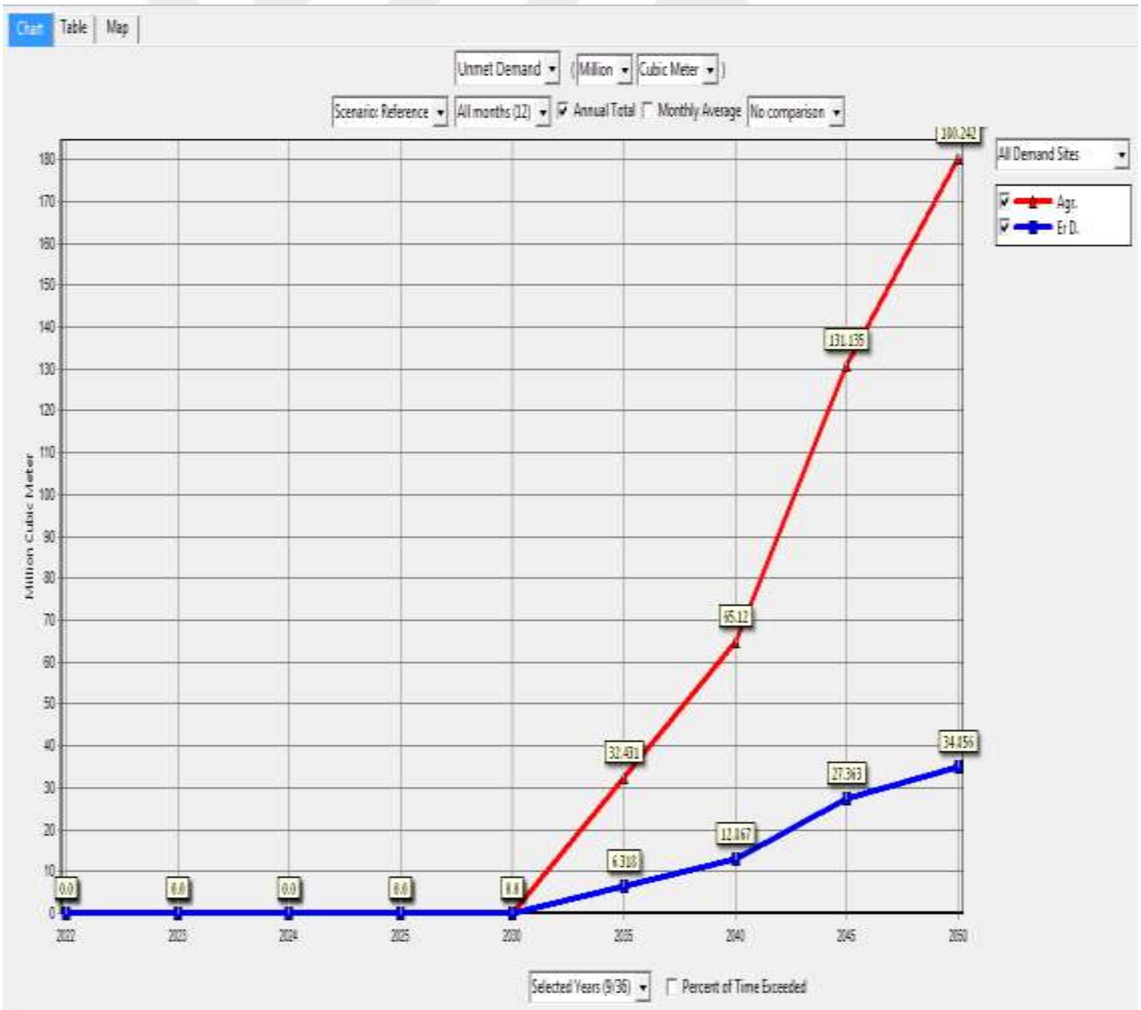


Figure 7.7 Unmet Demand chart for SR, environment flow mandatory

The result for three scenarios (SR, SHPG, and SEF) demonstrated us below figures, in addition to the comparison of the above three scenarios will find in figures

Chart | Table | Map

Water Demand (not including loss, reuse and DSM) (Million Cubic Meter)

Branch: Demand Sites | Scenario: High Population Growth | All months (12) | Annual Total | Monthly Average | No comparison | All Branches

	2015	2020	2025	2030	2035	2040	2045	2050	Sum
Agr.	409.50	634.24	766.01	852.07	1,345.04	1,674.53	2,152.28	2,587.48	10,421.16
Er D.	354.59	391.88	435.62	510.67	614.97	737.91	941.78	1,081.78	5,069.20
Sum	764.09	1,026.12	1,201.63	1,362.74	1,960.01	2,412.45	3,094.06	3,669.26	15,490.36

Figure 7.8 Water Demand per demand sectors for SHPG, environment flow mandatory

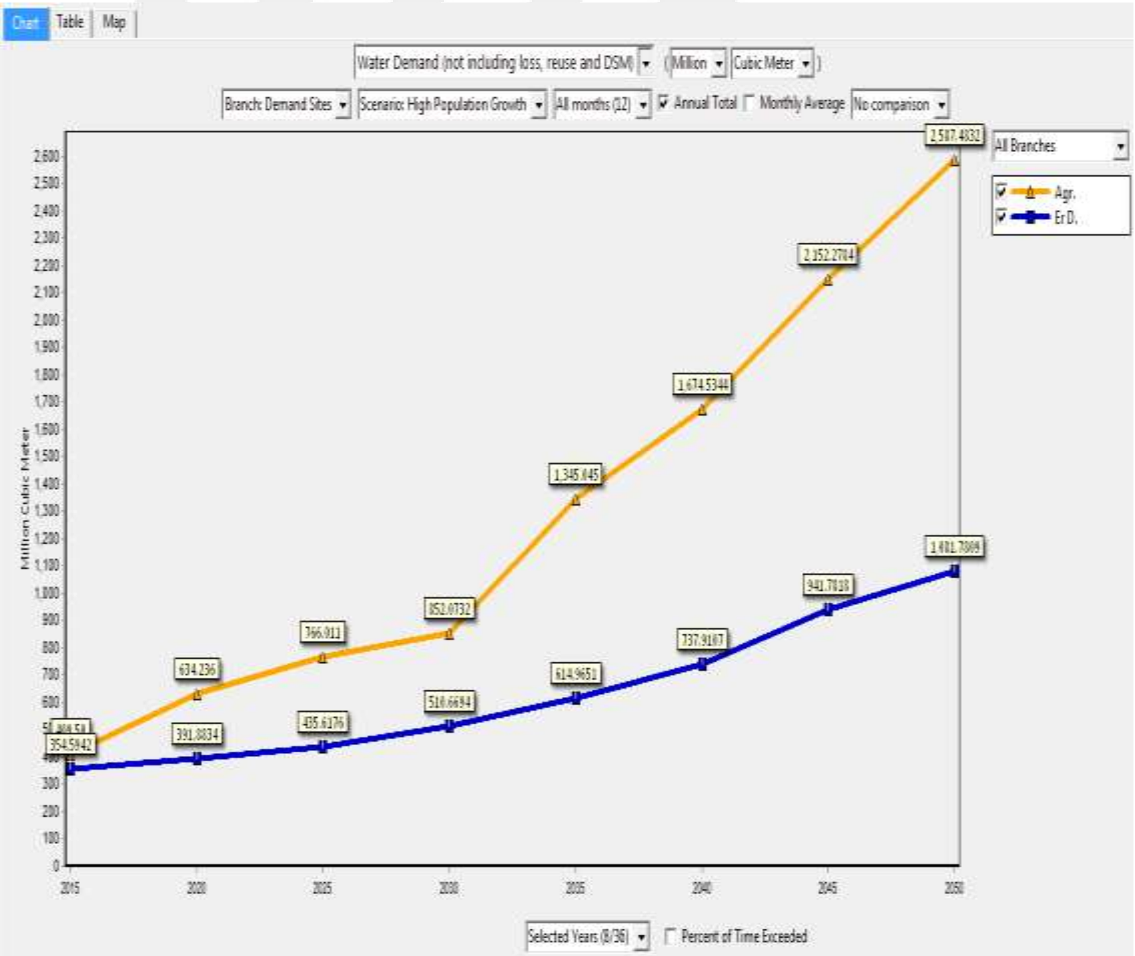
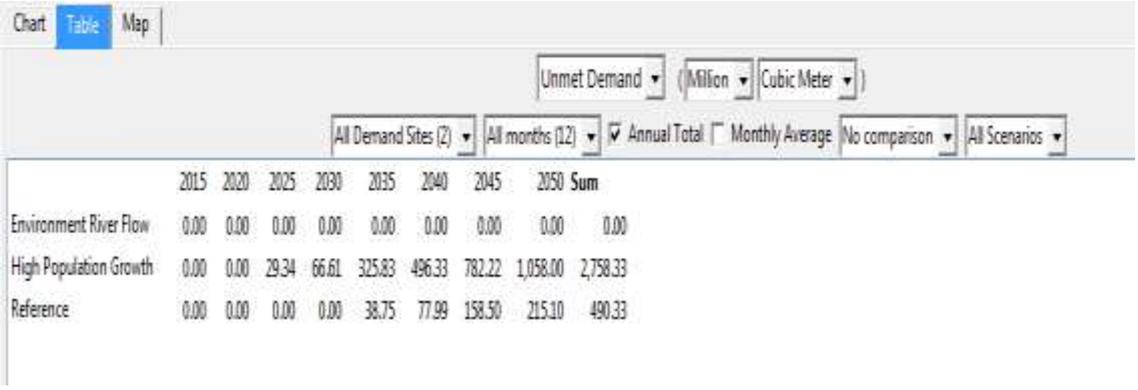


Figure 7.9 Water Demand chart per demand sector (Agr. and dom.) for SHPG, and environment flow mandatory



	2015	2020	2025	2030	2035	2040	2045	2050	Sum
Environment River Flow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
High Population Growth	0.00	0.00	29.34	66.61	325.83	496.33	782.22	1,058.00	2,758.33
Reference	0.00	0.00	0.00	0.00	38.75	77.99	158.50	215.10	490.33

Figure 7.10 Unmet Demand table the three scenarios (SR, SHPG, and SEF), environment flow mandatory

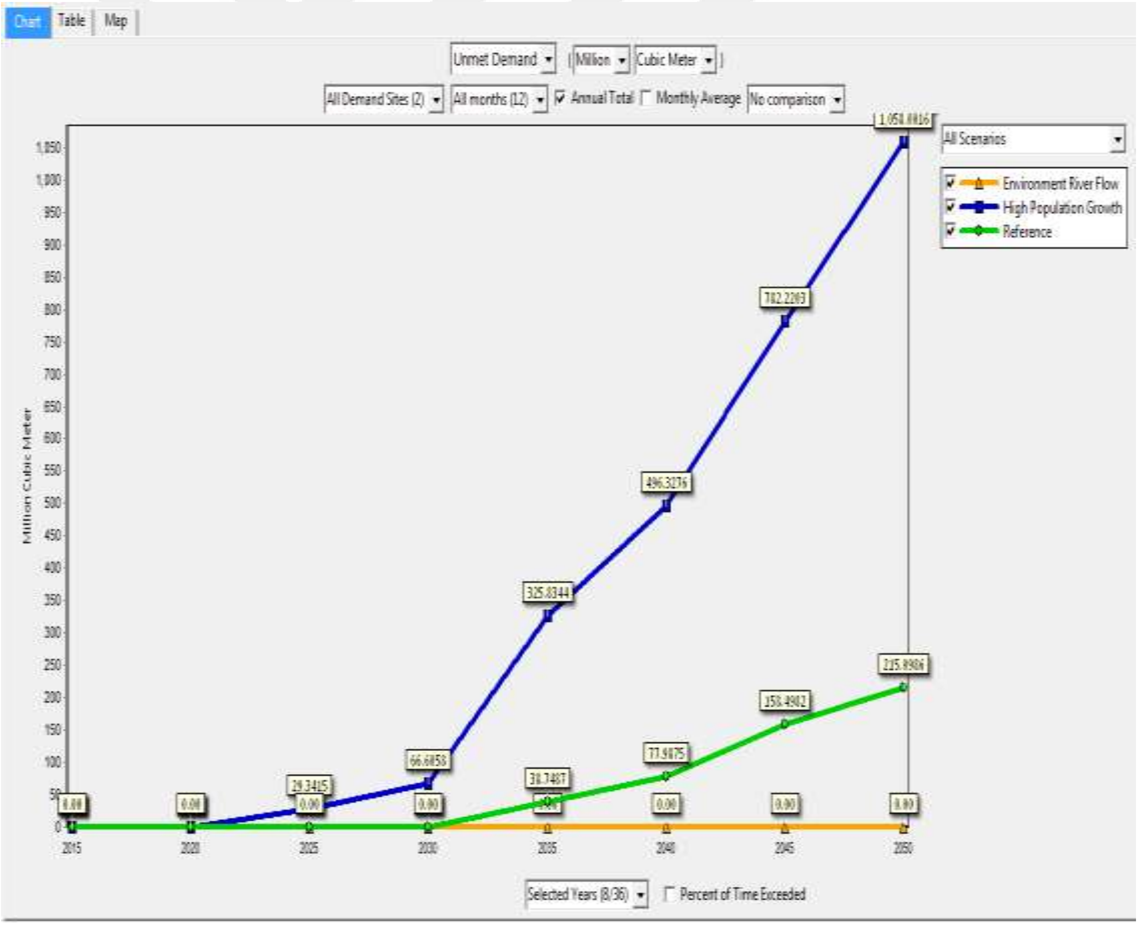
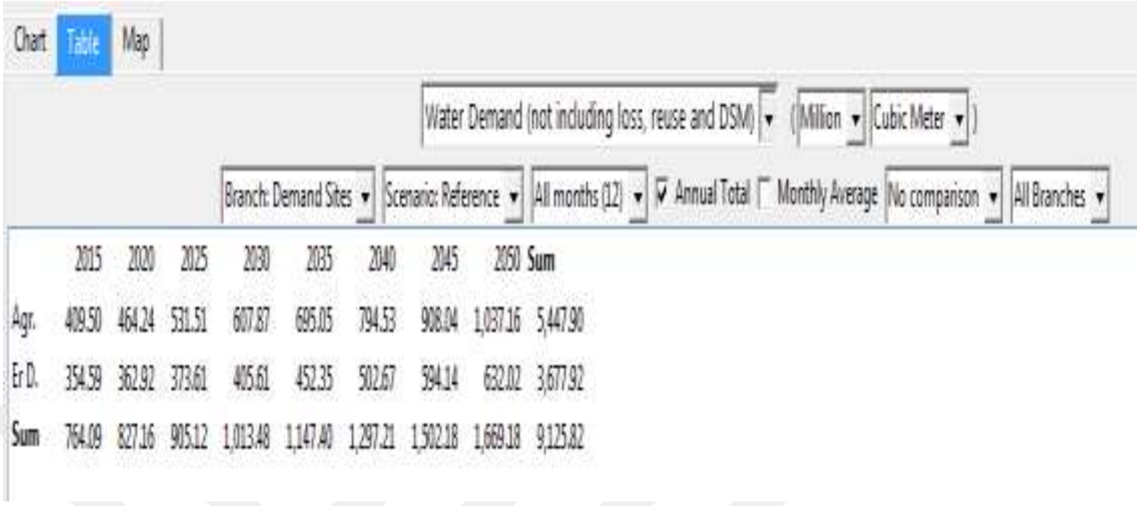


Figure 7.11 Unmet Demand chart the three scenarios (SR, SHPG, and SEF), environment flow mandatory



	2015	2020	2025	2030	2035	2040	2045	2050	Sum
Agr.	409.50	464.24	531.51	607.87	695.05	794.53	908.04	1,037.16	5,447.90
Er.D.	354.59	362.92	373.61	405.61	452.35	502.67	594.14	632.02	3,677.92
Sum	764.09	827.16	905.12	1,013.48	1,147.40	1,297.21	1,502.18	1,669.18	9,125.82

Figure 7.12 Water Demand table per demand sector (Agr. and dom.) for SR and environment flow mandatory

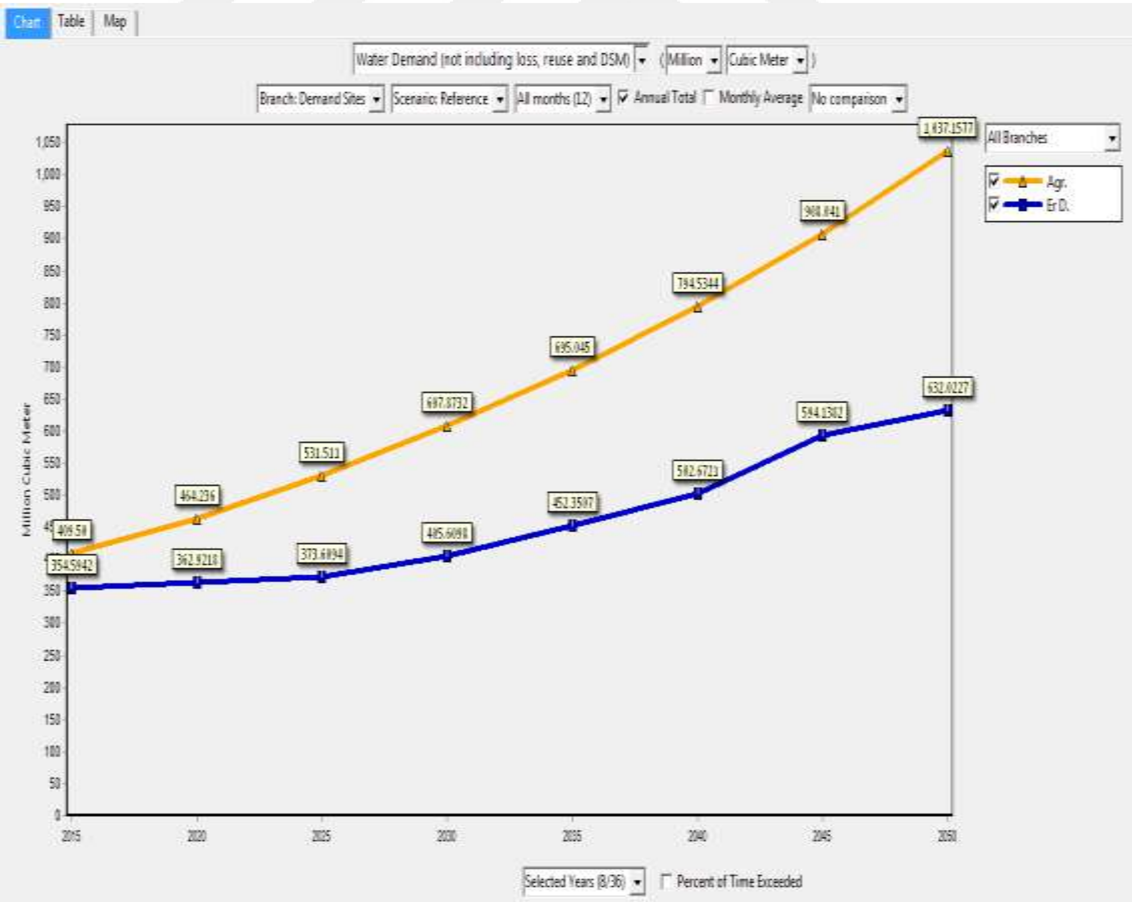
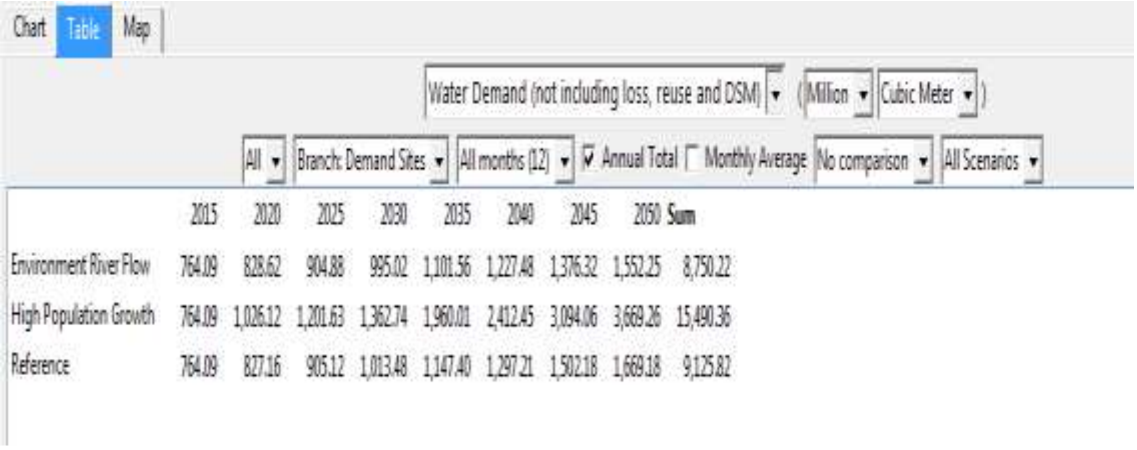


Figure 7.13 Water Demand chart per demand sector (Agr. and dom.) for SR and environment flow mandatory



	2015	2020	2025	2030	2035	2040	2045	2050	Sum
Environment River Flow	764.09	828.62	904.88	995.02	1,101.56	1,227.48	1,376.32	1,552.25	8,750.22
High Population Growth	764.09	1,026.12	1,201.63	1,362.74	1,960.01	2,412.45	3,094.06	3,669.26	15,490.36
Reference	764.09	827.16	905.12	1,013.48	1,147.40	1,297.21	1,502.18	1,669.18	9,125.82

Figure 7.14 Water Demand table the three scenarios (SR, SHPG, and SEF), environment flow mandatory

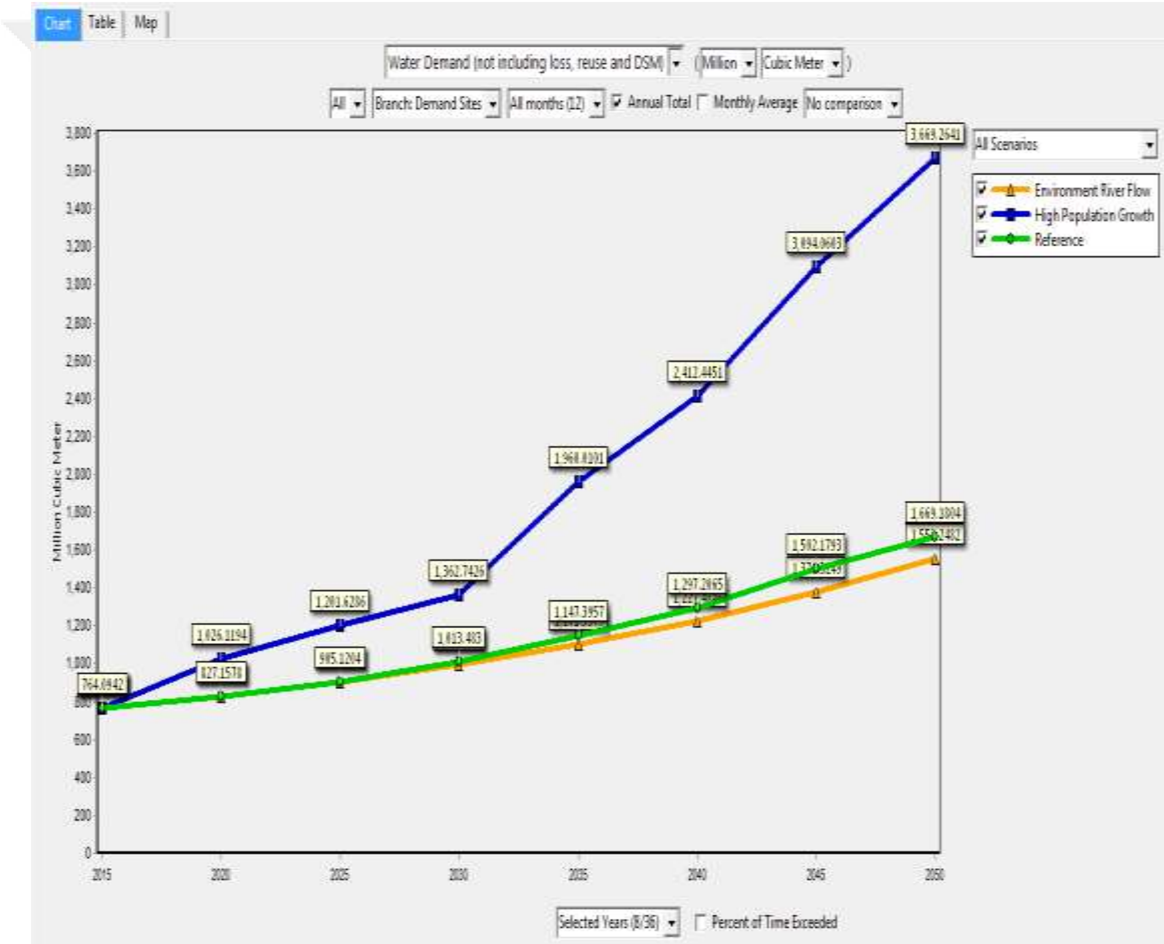
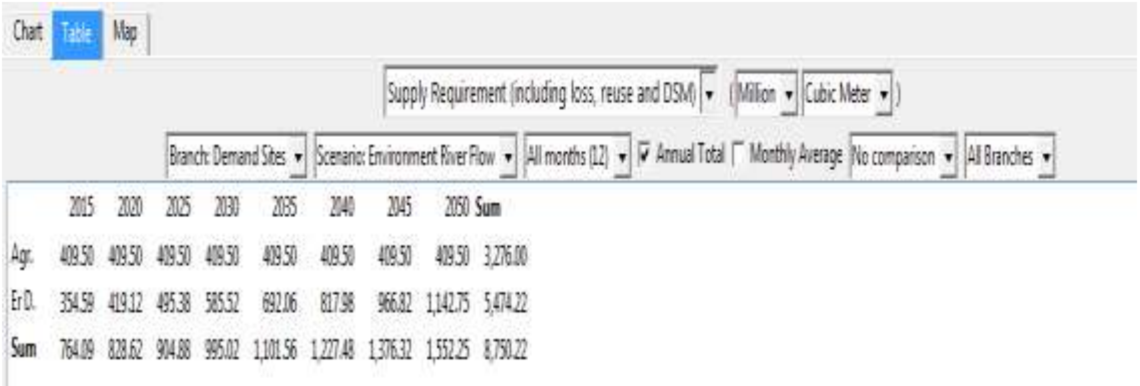


Figure 7.15 Water Demand chart the three scenarios (SR, SHPG, and SEF), environment flow mandatory



Supply Requirement (including loss, reuse and DSM) (Million Cubic Meter)

Branch: Demand Sites | Scenario: Environment River Flow | All months (12) | Annual Total | Monthly Average | No comparison | All Branches

	2015	2020	2025	2030	2035	2040	2045	2050	Sum
Agr.	409.50	409.50	409.50	409.50	409.50	409.50	409.50	409.50	3,276.00
Er D.	354.59	419.12	495.38	585.52	692.06	817.98	966.82	1,142.75	5,474.22
Sum	764.09	828.62	904.88	995.02	1,101.56	1,227.48	1,376.32	1,552.25	8,750.22

Figure 7.16 Water Demand table per demand sector (Agr. and dom.) for SEF and environment flow mandatory

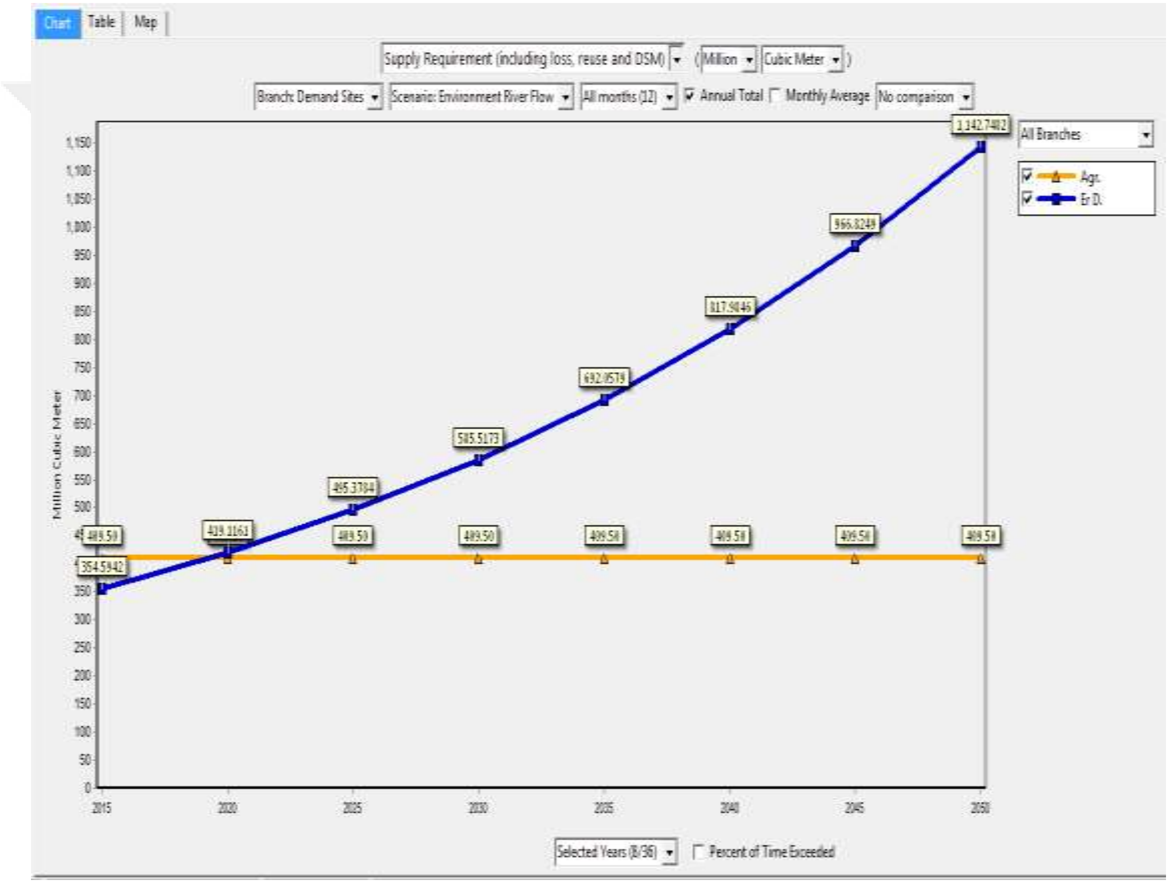


Figure 7.17 Water Demand chart per demand sector (Agr. and dom.) for SEF and environment flow mandatory

Table 7.5 Scenario SR illustrates (Arg. and Dom.) Sectors in case Monthly Ave. Env. Flow 50 MCM

Scenario SR Sector of Domestic (Monthly Ave. Environment Flow 50 m^3/sec.)							
	Year / Annual Water Volume MCM						
	2021	2025	2030	2035	2040	2045	2050
Water Requirement	364	373.6	405.6	458.62	514.1	621.6	666.9
Water Supply	364	373.6	405.6	452.3	502.7	594	632
Water Unmet	0	0	0	6.32	11.4	27.6	34.9

Scenario SHPG Sector of Domestic (Monthly Ave. Environment Flow 50 CM)							
	Year / Annual Water Volume MCM						
	2021	2025	2030	2035	2040	2045	2050
Water Requirement	396	435.6	510.7	615	738	942	1082
Water Supply	395.9	431.5	500.4	573.3	676.6	845	954.5
Water Unmet	0.1	4.1	10.3	41.7	61.4	97	127.5

Table 7.6 Scenario SHPG illustrates (Arg. and Dom.) sectors in case monthly average environment flow 50 MCM

Scenario SR Sector of Agriculture (Monthly Ave. Environment Flow 50 m^3/sec.)							
	Year / Annual Water Volume MCM						
	2021	2025	2030	2035	2040	2045	2050
Water Requirement	400	531.5	607	727.4	859.6	1039.1	1217.2
Water Supply	400	531.5	607	695	794.5	908	1037
Water Unmet	0	0	0	32.4	65.1	131.1	180.2

Scenario SHPG Sector of Agriculture (Monthly Ave. Environment Flow 50 m^3/sec.)							
	Year / Annual Water Volume MCM						
	2021	2025	2030	2035	2040	2045	2050
Water Requirement	652	791.7	908.4	1629.3	2105.4	2837.5	3518
Water Supply	650	766.4	852.1	1345.1	1670.5	2152.3	2587.5
Water Unmet	2	25.3	56.3	284.2	434.9	685.2	930.5

CHAPTER 8

CONCLUSION AND RECOMMENDATION

8.1 Conclusion.

The information concerning the regulatory and legal context of water resource management in Erbil makes it possible to draw up a diagnosis and a set of proposals for easier implementation of (IWRM) principles. Environmental, human and agricultural water pressures often occur in transboundary river basins, leading to competition for water between sectors and between countries.

The threat to freshwater biodiversity is global. The risk of extinction is medium to very high in 70% of the area of transboundary river basins. However, solutions are needed at the local level to address the risk of species extinction.

As mentioned previously, water management in GZRB has evolved over the years in response to the isolated needs of each sector rather than through a careful balancing of overall needs. The resulting vertically divided administrative functions in water use and management have made effective water management quite difficult.

As a result, most of Iraq now has limited access to clean water supplies or sanitation and garbage collection, in the three Northern provinces, where it has developed in recent years but also under an acceptable proportion of sewage, garbage collection and recycling. Serious environmental and health risks associated with contaminated water supplies, improper handling of solid waste and sewage disposal threaten to add to the burden of the already overloaded health system. In addition, the concentration of economic and social activities in Iraq's major urban centers has also led to the prevalence of underserved neighborhoods in major Iraqi cities.

A full discussion of the phenomenon, in particular downscaling of regional predictions to analyses local effects in Erbil Province, is beyond the scope of this study. However, the length of some of the available meteorological records allows analyzing whether any trends can be detected.

The loss of water within the water supply systems and the technologies used are inefficient and not qualify. Recalculations of water per capita are reviewed. For per capita water supply becomes more stringent. Governments need to implement strategic planning that can increase water use efficiency and improve the allocation of scarce resources between agricultural, industrial and local areas. Thus, there will be provision for future water use.

Whether precipitation is generally decreasing in GZRB has been widely discussed, in particular after the exceptional drought period from 1989 and 1999 to 2001 which caused a significant depletion of water resources.

As discussed in previous chapters GZRB water resources are limited and shared and it has shown that this can still cover the available resources provide that a number of large dams and reservoirs can build. However, there are limits to the further increase of water use, and there are signs of rising concern downstream in central Iraq.

The river basin prior estimated of the natural hydrology to any human uses. Hydrology will be estimated in two different scenarios:

1) A mean year is representative of a usual weather.
2) A drought year with low precipitation intensity

For the moment, no large industrial projects, planned. Depending on the crude oil prospection results, the situation may change rapidly in coming years.

Follow up optimal operation for river basin is not easy especially the rivers which flowing free or uncontrolled by dams or reservoirs and for international rivers such as GZRB

The GZRB is a Transboundary River Basin. Part of the flow generated in Turkey and the rest of water generated in Erbil governorate mountains flow to downstream Iraq. The GZRB is very important river basin for Iraq country, due to it is the biggest tributary feeds the Tigris River flow. The annual water flows around 13.3 BCM, during the wet season the flowing river more than 2500 m^3/s and causes several floods, on the other hand during the dry season the flowing river very low and its annual average amount is around 50 m^3/sec.

The management and establish a long-term strategic plan for GZRB is very important for Iraq and Erbil governorate, due to the growth of abnormal population, in this case, the population increase causes to prepare water and foods. According to the MOP data, the population at 2050 will meet 6 million people as proposed mean three-time increasing (normal growing), on the other hand the climate change to the worst(drier) causes to decreasing the water resources, therefore this research is highly important to find operation system for the next 33 years for GZRB.

At very earlier steps of research activities, find the programme, model, and software for start has done as a priority works for the action plans of this research. Searching for the previous works by researchers who have worked on river basins analysis and planning or, related activities works to the same topic of this study, has been done, and the result, for example, some researchers have used MAT LAB, others WAFLEX, and also some researchers have used WEAP. For this study, the WEAP has been selected for analysis and long-term planning for the GZRB, because this program deals with the different size of river basins, and depending on GIS and other water and agriculture programs.

For learning WEAP is not easy due to dealing with several water, agriculture, hydraulics, hydrology, power generation, and cost data, especially the Stockholm Environment Institute were producer of the program doesn't have offices in the area, therefore after changing email with the institution received the key license for using the WEAP and it is for free for students.

The tutorials have been reading and practicing and it is available on the website. Data requirement by the model collected from different government offices and arranged in a new format to be entered into the model. The data collection was noted easy due to the thinking of government that the data has a cost and not to give to the private sector, but by using relations the data collected.

Three scenarios taking in to account:-

The first, reference scenario, the ratio of population growth 3.4% as a normal case were proposed by MOP taking into account, and the result shows that water supply can't cover the water requirement in Aug. & Sep. at the year 2046.

The second scenario, high population growth, also the ratio 5 % identified by the MOP and model run done, the result shows the water supply can't cover the water requirement and deficit in Aug. & Sep. at the year 2032

The third is environment scenario, in this case, the monthly environment river flow requirement 50 m^3/sec. required by Tigris River and the result shows that unmet demand in Aug. and Sep. at the year 2021.

8.2 Recommendations

During the study especially during the data collection, cooperation and coordination with the all directorates working on water resources within GZRB, founded that and also recommended following measures:

A. Better coordination between the MOM&T and the governorates for implementation of the projects;

B. The setting up of an appropriate pricing system and the establishment of a program for restructuring the water and sanitation sector;

C. Improved management of the water resources sector through:

(Improved systems and procedures. Standard operational procedures. Maintenance plans, strategies to reduce leaks and inspection programs (at Directorate level). The installation of water meters. An accounting system. A performance monitoring system).

D. Participation of the private sector;

E. Elaboration of a multi-annual action plan and its funding;

F. Setting up a tariff system and recovery of costs;

G. Regulations concerning connections;

H. Finalization of the quality standards and protection of the resource;

İ. Communication, information and capacity building.

On the other hand, the study recommends to starting the setting up of an appropriate pricing system and the establishment of a program for restructuring the water and sanitation sector.

The study also recommended that future the strategies take following advice into account:

1) Demand management should be one of the main axes for sustainable management of drinking water in the future in parallel to any supply-oriented project. The target is to reduce per capita demand from 365 l/d to 180 l/day. At this, moment the Erbil government managing water as supply management.
2) Renovation of urban networks is a priority to reduce leakages (although infiltrated water is a good opportunity to recharge aquifers).
3) Priority for infrastructures should be given to wastewater treatment to avoid dramatic consequences on both human health and environment

4) Also recommended in this study, due to unmet demand for the different users in future therefore, restart of Bekhme dam with capacity 17 BCM and arranging fund for that to control the water flow and continuing supply water to the users within GZRB and for downstream area (Tigris River)

5) Applying such model in all river basins as it has faced many problems in terms of operation such as lack of river basin management, unorganized water flow. By applying WEAP the integrated water resource management will improve the operational management of the Iraq reservoirs, and give real understanding of all strategies;

The below main points also are recommended in the research:

I. First, establish a high river basin commission **(**decision maker level) very important, acting as a "Water parliament" for the completely Iraqi government, gathering all water actors in an impermanent assembly (3 to 5 meetings per year). This high commission would tackle with river basin management, making key-decisions regarding planning, concrete priority actions in the basin and ways of funding.
II. Establish a new directorate for river basin management (executive level) placed within the Ministry of Agriculture and Water Resources. This directorate would

act as the operational arm (preparation/execution of decisions) for high river basin commission.

III. Establish sub-river basin committees that would bring together water actors at the local level and would be responsible to prepare a sub-basin, water scheme.

IV. Continued commitment to improve the guidelines for the development and construction of new dams, the design of dams for multiple purposes, the optimization of dams to maximize human benefits and the reduction of adverse ecosystem impacts and sediment capture. This is particularly important in transboundary river basins, where dams are often in the upstream countries and more than 50% of the imports of the GZRB in the territory of Erbil Governorate. Therefore, winter water flow can be stored and then released in the dry season

V. Drainage and water scarcity are currently occurring in the future, increasing in the next 15-30 years, especially for the GZRB should take action now to reduce costs and future impacts where the amount of water becomes very low compared to the growing population

VI. Preparation plan, program and fund for restart construction of Bekhme dam with capacity 17.1 BCM due to the water availability unmet demand in future and can be controlled by big reservoir such as Bekhme reservoir were already 30% constructed and stopped in1990.

VII. The total land to be irrigated by Greater Zab River flow in Erbil Province is around (184204 ha) in the year 2030 and (334678 ha) during 2050. Most of the agriculture sector water use occurs in the basin assumed that the agriculture sector within GZRB that has been mentioned in this study.

VIII. Finally, the preparing new operation strategies for operation both Greater Zab River Basin and Lesser Zab river basin together. Works for an official link between HKU and Erbil province to approving the water resources management in river basins in the region.

IX. Regarding GZRB, Iraq has to take two strategies for negotiation as below:-

The First is fixing the annual amount of water release by Tukey government, for example, 5.3 Billion m^3 that is according to the historical annual data flow for GZR. On the other hand, restart and complete of Bekhme dam reservoir, then control the release amount of water from reservoir capacity 17.1 billion m^3 to Tigris river, for using in med and south of Iraq by the implement of special action plan approving from both sides Erbil province and the Iraqi government.

The Second is, paid a portion of dam reservoir project cost. Iraq has to negotiate with the upstream country, which is Turkey, and signing an agreement for construction big dams and reservoirs inside of Turkey, sharing a portion of the cost (for example 30 %) according to the agreement, has to paid by the Iraqi government and it will be fixed. On the other hand, the daily water release from Turkey to Iraq will fix the same agreements. In this case, Iraq will note lose the lands at the same time Iraq will receive a good amount of water from Turkey to control scarcity in the med and south of Iraq

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