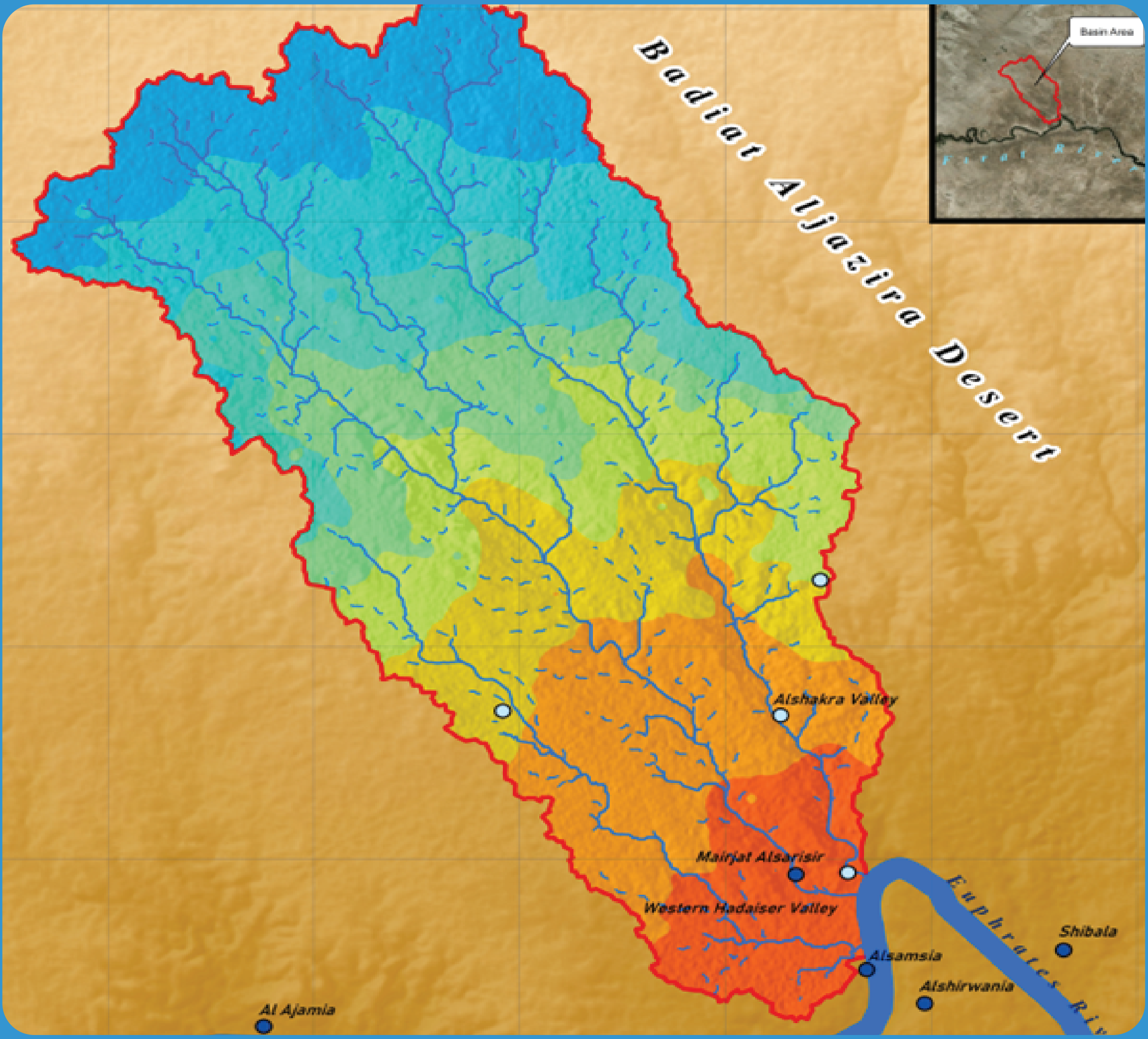

MORPHOMETRIC ANALYSIS OF THE AL-AUQOOD, AL-SHAKREA, AND AL-SAMTHEAI STREAM BASINS IN IRAQ USING GEOMATICS TECHNOLOGY

Taha Saadi AHMED   Öznur YAZICI

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PREFACE

With the increase in population on earth, freshwater balance and water management have become even more sensitive. In recent years, planned and systematic studies have been carried out and precautions can be taken to evaluate water resources holistically by taking advantage of the measurable characteristics of basins and to reduce risks such as drought, flood, and overflow within the framework of climate changes. This research aims to contribute to the results of the dynamics in water resources.

This book was created from the master's thesis titled "Morphometric Analysis of the Al-Auqood, Al-Shakrea, And Al-Samtheai Stream Basins in Iraq Using Geomatics Technology" prepared by Taha Saadi AHMED under the supervision of Assoc. Prof. Dr. Öznur YAZICI, and successfully defended on 14.01.2022.

The research consists of an Introduction and then 4 sections. In the First Chapter, geographical features such as geology, climate, natural vegetation, soil, stream drainage, and land use, which are effective on the applied hydrography of the selected basins, are included. In the Second Chapter, geomorphological processes shaped by the cooperation of mainly stream and secondarily wind factors that are effective in the region are emphasized. Chapter Three includes morphometric analyses and interpretations of studied basins. In the Fourth Chapter, the findings were discussed and evaluated, and the research was completed by listing the main results and suggestions.

We would like to express our sincere gratitude to Dr. Salah Al-Ani for his support in basin determination and field studies in Iraqi geography. Also, we would like to thank the Ministry of Industry and Minerals, the Ministry of Geological Survey and Mining Research, the Ministry of Transport and Communications, General Authority for Meteorology and Seismic Monitoring in Iraq for providing data.

We hope that it will be an inspiration for future studies.

Taha AHMED & Öznur YAZICI
October 2023-KARABÜK

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ABBREVIATIONS

DEM - Digital Elevation Model
GIS - Geographical Information Systems
km - Kilometer
m- Meter
cm - Centimeter
mm- Millimeter
max- Maximum
min- Minimum
N- North
S- South
W- West
E- East
° - Degree
C-Celsius

INTRODUCTION

Analysis means division and separation in contrast with the synthesis in logic. It varies according to the goal and purpose of the study and usually starts from general to specific (from the whole to part).

Quantitative divisional analytical geomorphology depends on the inductive method based on the sequence of facts with the logical arrangement so that each fact leads to understanding the following one to reach the result using all of the field and unfiled conclusion expressed by quantitative digital pattern which helps to strengthen the relationship between geomorphology and some of the other scientific sections which use those methods like using modern technology, GIS unit **(ARC GIS 10.8)**, chemistry and natural sciences.

Following the quantitative method by all its means in geological and geomorphological analysis and using modern technologies and (ARC GIS. 10.8) to get out digital data and morphological analysis lead to emphasis the facts to be closed to field reality depending on quantitative and digital data which its sources distribute between detailed topographic maps, aerial photos and satellite visuals besides the climate and geological data to be able to confirm to field measurement.

Digital language has become a feature of the modern age. This language is not new to geography, which used it to confirm its position by the unique and developed method, keeping geography and its sciences at the top of all practical sciences. This makes it easy for geographic to enter into field studies successfully using different means using devices and showing a remarkable ability to deal with it using advanced statistical and mathematical methods.

The quantitative method is the most accurate and comprehensive way to communicate the facts. It also considers tools to compare the theoretical and the practical things, then find the formulas for compatibility between them by approximation and giving a specific idea about features of the study area. It is very important as well as its role in abbreviation and finding comparison and given the development in the use of computers and its great ability to record data, the speed of its memory and the speed of its calculations, which has a significant impact in shortening the time, effort and costs of completing the required calculations, drawings, analysis, and interpretation.

The study area is one of the critical areas in the western hills of Iraq since it has primary and semi-dry valleys (Watershed and basins). It gives water to the Euphrates River in the west between Haditha Dam and Haroun Valley. Its significant role in transferring different sediments during rainy days, stripping operations, and forming different geomorphological surface features varies in its geographical distribution within the terrestrial perspective.

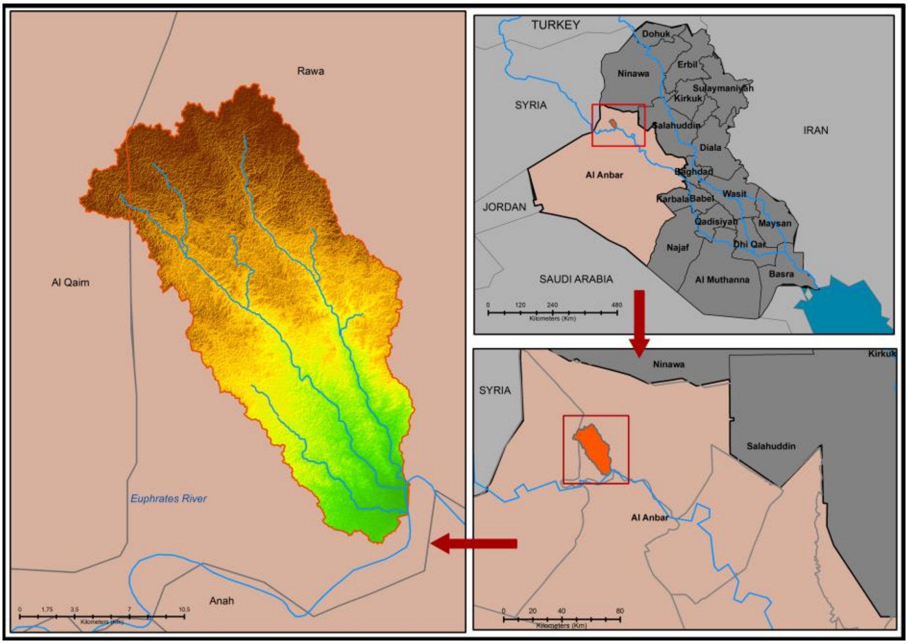
This study focuses on the regional visits and using modern techniques and the program **(ArcGIS 10.8)** to probe information, especially in geomorphological analysis, basin features, drainage patterns, soil types, and natural plants of the area that led to conclusions of new data that was very useful about the unstudied areas with interest and available means used today.

Morphometric analysis is important in determining the geomorphological features of river basins of different shapes and lengths.

This research is considered one of the recent trends in applied physical geography to study stream basins. Each of them is an area through which the properties and data are digitally and quantitatively measured. So, it can be an objective, comparable basis.

I. Location of the Study Area

The study area is located in the west part of Iraq especially in the northwest of Al-Anbar inside the Iraqi Desert. It is boarded by Ninawa from the north, and Haditha Dam from the west **(Map 1)**. As Mathematically, the region is located between latitudes of 34° 29' 42" N and 34° 45' 01" N, and also between longitudes of 41° 31' 18" E and 41° 46' 29" E. The research area covers an area of 303.38 km^2.



Map 1. Location Map of the Study Area

II. Research Problems

The main problem of the study is ‘What are the morphometric properties of the basins of Al-Auqood, Al-Shakrea and Al-Samtheai streams, their applied deliberation, and their effects on geomorphological development?’ This question is the focus of the study, and depending on this goal, and there will be answers to some sub-problems. It can be given some minor questions as follows:

- What are the physical properties of the study area?
- What are the morphometric properties of the study area basins?
- How do the natural factors and qualifications of the study area affect its morphometric systems?
- Can the terrestrial aspects, geomorphological and morphometric properties be used for human investment?

- How do the morphometric analysis results relate to flood, overflow events, or drought in the risky parts of the study area?
- How valid are the digital data using modern techniques and GIS programs in morphometric analysis of the study area?
- What is the impact of natural resources in the study area on the concentration of population?

III. The Study Hypothesis

The hypothesis was a general concept that shows and explains the relationship between the changes of the studied phenomenon. In addition to that, it was as an answer to the questions and problems as follows:

- It can be trusted to the Arc GIS 10.8 Program to study the morphometric properties of the basins of the Al-Auqood, Al-Shakrea, and Al-Samtheai stream, which are considered dry basins. The properties of extracted visuals differ by executing the primary basins modeling orders.
- Some steps should be applied algorithmically so that no step can be advanced or delayed over the one that proceeds to prepare rules of geographical data of the morphometric properties of the basins of dry valleys in the study area to have ultimate trusted and credible results. And so, it can be relied upon in the development mapping in the study area.
- ArcGIS 10.8 was provided with large numbers of each country's local and national coordinate systems, classified according to continents as the five Iraqi national systems. They are then converting from global coordinate systems to national ones to match with topographic maps issued by the Ministry of Water Resources and the general directorate of the Iraqi survey. The values of morphometric properties calculated from remote sensing agree with the importance of Iraqi topographic maps.
- The morphometric factors and the terrestrial, climatic, hydrographical and other factors affect the variation of the morphometric properties of dry basins and valleys in the study area.

IV. Objectives of Study

This study aims at:

- Explaining proper steps to prepare geographic databases for morphometric properties of the basins of Al-Auqood, Al-Shakrea, and Al-Samtheai streams, which considered one of the dry basins, using remote sensing which leads to extreme accuracy in outputs so that it can be trusted and relied upon on the development planning of the study area in the future.
- Practical application of measurements and mathematical calculations of morphometric properties of the basins of Al-Auqood, Al-Shakrea, and Al-Samtheai stream using modern technologies as GIS unit and remote sensing visuals, including automated modeling, and direct interaction with the user through dialogue, inquiry, and ultimate analysis of these properties in space, so that this study will be the applied basis for researchers based on the application of morphometric properties to any area.
- Applying the cartographic foundations in the output maps that represent the morphometric properties of the dry valley basins in the study area making them achieve the goals for which this was set. On the other hand, it reaches its goal of being an effective direct means of communication to deliver the most considerable amount of information to the readers with less effort and less time.

V. Significance and Limitations of Study

It shows the applied steps in studying the morphometric properties of the basins of the Al-Auqood, Al-Shakrea, and Al-Samtheai streams using GIS units and remote sensing visuals. So, this study can be an applied guide of the stages of automated modeling of morphometric properties, its problems, and the proposed solutions to avoid them, so it can be relied upon by workers of the GIS unit to study the morphometric properties of any other region.

The importance of this study is due to the study of national coordinate systems, as well as being an applied guide for the use of national coordinate systems in GIS unit to prepare unified geographical databases in their geographical references with Iraq topographic maps, in addition to the way of converting global coordinate systems, remote sensing visuals into national coordinate systems. Thus, it can be the applied basis for using national coordinate systems for workers in the field of geographic information systems in the future.

The study also focuses on studying the morphometric properties of three basins in contrast with the classical studies, which examine these properties of only one basin because of the many geomorphological and hydrological studies of the basin areas. The morphometric analysis proposes to improve and exploit these areas. It also can be helpful for the country and the reclamation of these areas. These studies can also be used in development planning and supporting decision-makers with sufficient information to make suitable decisions for projects, such as building dams and planning the land. It also provides theoretical and applied evidence for moldering morphometric properties.

Various limitations were encountered while examining the study area, which is located in the Euphrates River Basin, one of the most important and largest rivers in the world and consists of seasonal streams.

Unfortunately, due to the security threat in the region, which has been under the harsh conditions of war for many years, the field studies could not be carried out at the desired level and a small number of photographic archives could be used in the thesis.

Due to the lack of flow stations in the region, annual, seasonal or monthly water flow and water levels in the river basins are not measured and recorded. Accordingly, drawing and revealing the hydrometric characteristics of the basins, especially the flood or recession periods, could not be discussed.

VI. Study Methodology

It consists of general rules that determine the scholar’s study plan from the beginning to the end to reveal the unknown facts or prove the known ones.

This study considered more than one method that suits its problems and objectives as follows:

1. The inductive and descriptive method philosophizes ‘let facts speak’ by describing the morphometric instructions and properties of the study area.

2. The regional method studies the whole morphometric properties of the basins of dry valleys in the region in order to provide geographical bases for these properties to make suitable decisions for redrawing the region.

3. Objective method which studies the morphometric properties of the basins of dry valleys in the study area in order to classify the basins according to the variety of its morphometric properties in the study area using advanced statistical analysis.

4. Modern pragmatic method which shows the applied steps used in the basins, watercourses and valleys in the study area as remote sensing using a **(GIS unit)** which is one of the most famous geographical information systems in the world **(Bedewi, 1963, p. 5)**.

5. Relying on the applications of geographic information systems (GIS) and using the ArcMap 10.8 Program to derive the basin, mapping, derive the water network, Information systems are defined as systems that consist of a group of people, data records, and some manual and non-manual operations of maps, etc., and these systems generally address data and information for each system, and it can also be defined as a set of elements that overlap among themselves to collect, process, store and distribute information About a specific topic systematically, in order to support the organization, control it, analyze, and form a clear current and future perception of the topic under research, which we used in mapping and data extraction for morphometric analysis. Analyze the data and use the **Global Mapper Program**, as well as make use of the **Google Earth Program** to determine some aspects in the study area, as well as the reliance on visual images (DEM) and visual images, were used at a distance of 30 * 30 m because there were no images closer to the study area.

6. Thornthwaite’s climate classification **(Dönmez, 1984)** was also used in the study.

7. The study relied on several approaches to give an integrated analysis interconnected with ideas. The inductive and analytical method was counted on as basic methods in the study. Quantitative mathematical methods and a set of equations and statistical analyses are required to make the results more accurate and realistic and express spatial phenomena accurately. The analysis and extraction of data and mathematical equations were relied on in the section of the morphometric study that was addressed in the third chapter of the research based on the equations of **[Gravelius (1914) - Horton (1945) - Strahler (1952, 1958, 1964) - Schumn (1956, 1963) - Hadley and Schumn (1961)]**. Among the most critical numerical methods related to the stages of bifurcation, the bifurcation ratio, and the arrangement numbers of river tributaries. The Strahler method was applied to determine bifurcation data in this paper. According to the method of Strahler, the bifurcation stages are the minor canals formed in the source part of the basin. The first order, the tributary created by combining two orders of the first order. Then comes the second order by connecting the two tributaries, the third order is accepted, and in this way, the sorting system is revealed up to the main branch. On the other hand, the mainstream creates the last row and the most essential numbered series.

VII. Study Stages and Tools

The study went through several stages as follows:

1. The stage of collecting data and information

It is represented by reading books and valuable research for natural geography studies in general and morphometric analyses in particular. It also considered geological and geomorphological studies through visiting the organization of water resources and looking at topographic maps and the Iraqi geological survey to get geological reports and using it to draw geological, geomorphological, and hydrographical maps of the region, in addition to visiting the organization of weather and earthquake monitoring to get climatic data from the Al-Qaim Station between 1980-2019 years.

2. The fieldwork stage

It is one of the most critical stages of the study since it represents the primary and accurate source to get the information and data related to the region and giving the field measures of some geomorphological landforms and taking explicit photos of the earth surface, and the use of the area assisted by experts and some of our professors and their instructions.

3. Writing stage

It is the outcome of the two previous stages and formulating the information and data in varied ways and with geographical style through drawing tables, maps, and figures in addition to clarifying results related to the natural properties of the region, analyzing and evaluating the samples according to the criteria described by world organizations as the Food and Agriculture Organization (FAO) and American Soil Conservation.

VIII. Study Structure

This study includes sections structured with an introduction, theoretical framework, findings, conclusions, and recommendations. The introduction clarified the importance of the pragmatical studies in general and which are related to the human life as water resources and how to preserve it by defining the region problems and finding solutions through several hypotheses in addition to giving justification for the chosen title, methodology, and the stages of this study. The first chapter included analyzing the natural and human factors of the region represented by (geology of the region, climate properties, water sources, soil, natural plants, and the residents of the region). The second chapter explains the most critical geomorphological processes and indicators of tectonic activity in the study area. The third chapter has been divided into three sections: Linear Morphometric Characteristics of the Basins, Areal Morphometric Characteristics of the Basins, and Relief Morphometric Characteristics of the Basins. In the fourth chapter, the results were evaluated and discussed.

IX. Previous Studies

1. In **T. Buday**'s **(1980)** research called **'The Regional Geology to Iraq Stratigraphy and Paleontology**', the researcher expressed that Iraq was tectonically divided into major ambits; the study area is located within the settled pavement and in the sub part and western sub part of Abo-Algabr ambits and Al-Kaara.

2. In **Al Basrawy and Naseer Hassan Mohammad (1989)** research called '**The Tectonic of Western Desert by Remote Sensing and Geophysical Information**', researchers emphasized the effect of Al Kadesiah Dam on the ground and surface water. They also stressed that storing caused changes to surface and ground water ingredients and showed new paths of the ground water.

3. In **Al Kobaisy and Sahar (1993)** research called '**Geomorphology of the Nothern Badia**', the researcher classified the geomorphological units in the study area into the shapes of the earth's surface and its rocky nature. She also specified the rocks and divided the area according to its geomorphological nature.

4. In **Hatem and Maher Tahseen (2005)** research called '**The Study of the Geology and the Structure of North of Zakho Using Remote Sensing Techniques**', researchers also reveal the expansions of the stratigraphic column in the study area. It extends from the Ordovician (Khabur) period to the Quaternary period. A significant change in the thickness of the Cretaceous and Jurassic period formations was also observed between the east and west of the area. This study also revealed that Cubic and Orthogonal Drainage patterns are the most prevalent in the study area. And this effects on the rock installation and its factors in the area since this type of Drainage is seen above the rocks that varies in solidity and separated with orthogonal fractures.

5. In **Al Maarawy (2010)** research called '**Ground Water and the Possibility of Investing in the Island Area, Al-Anbar Using GIS Unit**', researchers showed the presence of four reservoirs of groundwater in the region and its directions towards south and southeast with some minor trends due to structural phenomena and the different aspects of the earth's surface. And using **GIS Unit** to extract data on the area and measure the accuracy of the data extracted from **GIS**.

6. Özşahin (2010), in his research titled **'Morphometric Analysis of Neighboring River Basins: Sarıköy and Kocakıran Streams (Gönen Basin, South of Marmara)'**, calculated and interpreted the morphometric properties of the basins of Sarıköy and Kocakıran streams with indices. The results were presented comparatively.

7. Özdemir (2011) examined the morphometric characteristics of the basins in the occurrence of floods in his study named **'Basin Morphometry and Floods'.** He tried to reveal the effect of the linear, areal, and relief features of the river basins in the basins and their connection with the floods. In addition, he emphasized the importance of utilizing morphometric analyzes in order to take strong measures on how to prevent the flood risk.

8. In **Rayan and Wafaa (2014)** research called **'Morphometric Properties of the Basin of Al-Fareaa Stream in Palestine Using GIS UNIT and Digital Elevation Models'**, researchers showed the morphometric properties of the basin of Al-Fareaa stream in Palestine using **GIS UNIT** and digital elevation models. This study concluded that the basin is more elongated than round, the value of the relief in the basin is high, and that the basin is going through the stage of geomorphological youth, and that the tributaries of the first and second rank constituted 94% of the total tributaries of the basin, and that the natural geological factors climate and topography varied despite the area of the basin. It also affected the basin's spatial, morphological, and topographical properties.

9. In the master's thesis named **'Morphometric Analysis of Marmara Sea River Basins'** prepared by **Emre Elbaşı (2015)**, Geographical Information Systems was also used. In this thesis, the morphometric parameters reflecting the drainage characteristics of the river basins discharging their waters into the Marmara Sea were calculated and evaluated. The results obtained were supported by field studies. With these results, it was thought that data could be provided for future research such as erosion, tectonism, and flooding.

10. In **Al Forqan and Abdullah (2015)** research called **'The Study of Morphometric Properties of the Basin of Gaza Stream and Water Harvesting of its Upper Basin Using GIS UNIT'**, researchers focused on the study of morphometric properties of the basin of Gaza stream in Palestine and water harvesting of its upper basin using **GIS UNIT.** This study showed that the basin ends at the seventh level, indicating that the basin has crossed a significant stage of erosion, and it seems to be more rectangular than round. The terrain features showed that the basin is located within the soft texture, and it was proposed to build three dams as the best first-class sites and six as second-class sites.

11. In **Abd Al-Hadi and Kareem (2015)** research called **'Geomorphological Analysis of the Basin of Al-Haira Stream, Geomorphological Study'**, researchers prepared a geomorphological study of one of the Libyan valleys, it showed that morphometric properties of the basin are different according to the area of the basin, structural conditions in the faults and differences of kinds of rocks in addition to the climatic changes. The erosion of the basin is still in the youth stage which has not yet been completed due to the lack of running water. The morphometric properties also showed that the basin is not round.

12. Mehmet Üzülmez (2015) carried out metric measurements and sampling in his master's thesis named **'Morphometric Analysis of Suat Uğurlu Dam Surroundings'.** The researcher also evaluated the 2014 Google Earth images of the land. Many deposits were formed around the dam and a settlement was established on the largest of them. Morphometric analyzes were made in the region and the results were interpreted.

13. In their paper named **'Evaluation of Beyazçay Basin (Hatay) by Geomorphometric Analysis'**, **Geçen and Ölmez (2017)** reported stream length ratio (Rl), drainage density (Dd), stream frequency (Fs), basin relief (Bh), ruggedness value (Rn), texture ratio (Rt), valley width-height ratio (V), hypsometric curve, hypsometric integral (Hi) were used. The researchers determined that the structural and lithological differences in the basin were effective on the drainage system and interpreted their results.

14. A study named **'Morphometric Analysis of River Basins Using GIS and Remote Sensing of an Andean Section of Route 150, Argentina: A Comparison Between Manual and Automated Delineation of Basins'** was prepared by **María Yanina Esper Angillieri and Oscar Mario Fernández (2017)**. In this study, morphometric analyzes in Agua Negra River basin in the Central Andes of Northwest Argentina were carried out using the GIS and Remote Sensing tools via the digital method and traditional manual method. Well-defined basin analyzes provide numerous benefits such as flood assessment, water use, watershed protection, planning, and resource management. In the current study, digitally derived polygonal sub-catchment areas were identified shorter than the traditional manual method to identify 17 watersheds. The absolute difference between the basin area definitions averaged 5.29% (range 0.50 – 13.83). According to the research results, the traditional manual method of identifying basins and measuring morphometric parameters requires time, precision craftsmanship, and expert judgment. In contrast, automated techniques for the same analysis reduce the computation to just a few minutes. However, the researchers stress that the automated procedure is not foolproof and that a degree of judgment and subjectivity may also be required.

15. In their article named **'Morphometric Analysis of the Marmara Sea River Basins'**, **Elbaşı and Özdemir (2018)** aimed to reveal the morphometric inventory of the river basins of the Marmara Sea. The morphometric indices of the determined river basins were calculated and evaluated. As a result of the evaluation, they determined that the basins in the north of the Marmara Sea are younger than those in the south, as they are shorter, longer lengthwise, have lower drainage density and higher hypsometric integral value.

16. In the study of **Aytekin Erten and Alper Gürbüz (2018)** which named **'Determination of the Hydrological Characteristics of the Dalaman Stream Drainage Basin Using Morphometric Indices',** the morphometric and hydrological characteristics of the Dalaman Stream basin were emphasized. The effects of the lithology of the basin on the characteristics and development of the drainage network were determined by hydromorphometric analysis. As a result of the study, it was seen that the age of geomorphological evolution of the research area is close to the maturity stage. It has been stated that the landforms are high due to the presence of Neogene and Quaternary permeable rocks and dense vegetation.

17. A study was conducted by **Şakir Fural (2018)** to analyze the drainage features of Acısu Stream in the Mediterranean Region in the south of Turkey using morphometric methods and to determine the geographical factors that cause the stream to acquire its current geomorphometric features. As a result of the study named **'Morphometric Analysis of Drainage Characteristics of Acısu Stream (Serik–Antalya)'**, it was determined that Acısu Stream, which has a dendritic and disordered drainage network and bifurcation in 5 stages, is a young basin far from equilibrium profile, and geomorphological development continues.

18. Müsteyde Baduna Koçyiğit and Hüseyin Akay (2018) presented the characteristics of the drainage system according to the Strahler method in their article titled **'Estimation of Potential Flash Flood Risk in a Basin Using Morphometric Parameters: A Case Study of Akçay Basin'.** The flood risk in the basin was investigated by calculating various parameters. It has been determined that the Yunuslar Hydroelectric Power Plant reservoir in the region carries a high flood risk.

19. Halil Zorer and Saadettin Tonbul (2019) evaluated the factors affecting the relief of the field with morphometric analysis in their article named **'Investigation of Basin Development in Başkale Basin with Geomorphometric Analysis'**. Researchers examining the effect of neotectonics in the region in detail determined that the basin is a pull-apart basin, tectonic activity continues and it is an asymmetrical basin as a result of the calculation of many parameters.

20. Ahmet Öztürk (2020), in his master's thesis named **'Evaluation of the Applicability of the Holistic Watershed Management Approach in the Example of the Ermenek Stream Basin',** made morphometric analyzes both to establish the quantitative basis of physical properties and to suggest a useful method in watershed management studies. The researcher calculated the linear, area and relief morphometry of the basin over 23 parameters. In the study, the envisaged holistic management of the Ermenek Basin was evaluated by taking into account the field studies, interviews with the relevant people, and the physical-human structure of the national and international protocols of the basin. In his thesis, Öztürk also evaluated the 'river basin regions' and 'transboundary basins', which are important problems in watershed management practices.

21. Zeydin Urar (2020) made morphometric interpretations using GIS and remote sensing in his master's thesis named **'Geomorphometric Analyzes of Sortkin Stream Basin (Çatak, Van)'.** Some traces of glaciation were encountered in the study area located on the Bitlis massif. Sortkin Stream Basin, which has a very high elevation, was found to be circular as a result of morphometric analyzes. It has been observed that river erosion is also a strong factor depending on the altitude in the basin.

22. Şaziye Arslantaş Dik (2021) prepared a master's thesis named **'Applied Hydrography of the Ulus Stream Basin'.** In addition to the hydrographic properties of Ulus Stream Basin, the sub-basin of Bartın Stream and located in the Western Black Sea Region, morphometric properties have also been revealed in the study. For this, 23 parameters of linear, areal, and relief properties were used. The most significant number of indexes calculated according to the Strahler Method is 5 (the mainstream), and the bifurcation rate is 3.2. According to the research results, the age of the basin shows that it is approaching the maturity stage. In the study, SWOT analysis was made, the strengths and weaknesses, opportunities, and threats of the basin were also discussed.

23. Tuğçe Bilgin (2021), in her master's thesis titled **'Geomorphology and Morphometric Analysis of Çanaklı (Mamak) Polje',** used morphometric analyzes to interpret the geomorphology of the West Taurus Mountains (Mamak) Polje. At the end of the research, it was seen that there is no active river in the polje today and excess water passes underground through sinkholes in rainy seasons. If the sinkholes are clogged, temporary lakes emerge at the base of the polje. Polje is very suitable for agriculture.

24. Safiye Yüksel Öztekin (2021), in her master's thesis titled **'Vegetation and Hydrography of Devrek Stream Basin',** examined the vegetation and hydrography features in the Devrek Stream Basin, which has rich forests. As a result of the morphometric and hydromorphic analyzes applied in the study, a total of 30 sub-basins were determined and it was seen that the largest of them was the Bolu Stream Basin. In the study area, which is located within the Anatolian Ecotone, the shaping effect of the NAFZ-related tectonism was found to be very high.

CHAPTER ONE

1. NATURAL PROPERTIES OF THE STUDY AREA

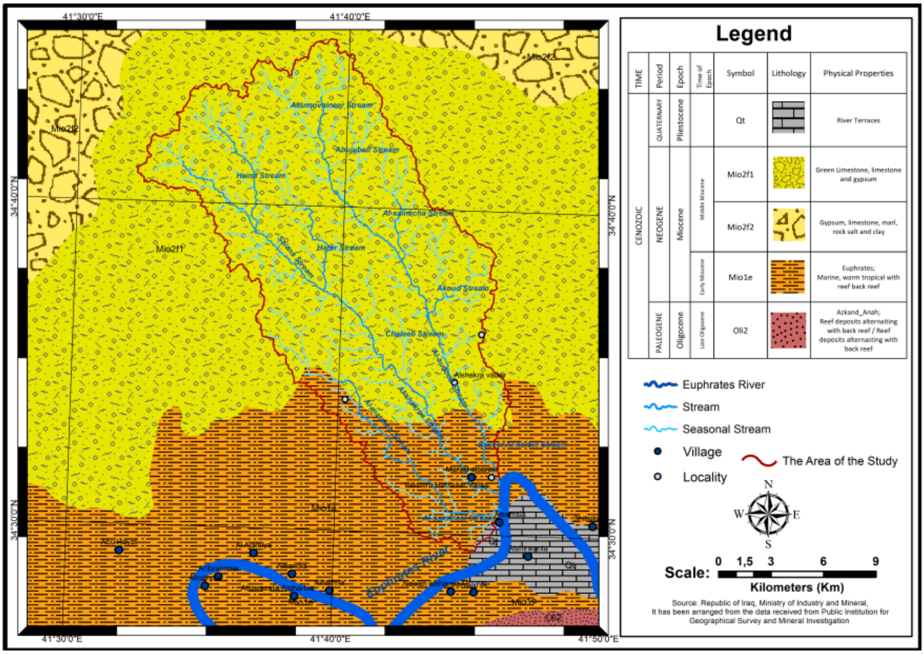
1. 1. Geological Structure

A report has been published to plan the Upper Euphrates area, re-home the people of the Haditha Dam basin **(Ministry of Regional Planning, 1975, p. 1)**. The western desert of Iraq is flat land with a moderate slope extending from the borders of Jordan to the Euphrates River at a decreasing rate of a mile m^2/1 km, and the study area occupies part of this desert. It contains ancient crystalline rocks covered with a thick layer of limestone from the Mesozoic and the Tertiary geological periods. This cover of some parts of the hill was removed due to erosion. To study the rock layers was essential to study the geological formation of layers which was made according to its sequence time and the geological age **(Ministry of Regional Planning, 1975, p. 1)**, as shown in **Map 2**.

1. 1. 1. Limestone Formation of Euphrates (Lower Miocene)

It is not a very common formation in the study area. It is about 48.89 km^2 of the whole area of the region, which is about 303.38 km^2. This formation appears as a cliff overlooking the west and east of the Euphrates between the Lower and Middle Miocene.

The ideal thickness of the limestone formation of the Euphrates in the Al-Auqood, Al-Shakrea, and Al-Samtheai streams (the study area) is 12.5 m which contains many fossils breccia of identical dolomitic limestone. The Euphrates formation has veins of solid coral limestone and basal calcareous aggregates whose thickness is between 2.5-9 m, with a layer of scalloped limestone at the top to be 18 m. It is also topped with a layer of chalkstone and white limestone. The upper layer of this formation contains the jutting and rolled surfaces, which is the unique characteristic of the formation and its incompatible existence above the ancient formations with thin and lumpy layers **(Al-Ghariri, 1985, p. 17)**. This formation is found confined to the Euphrates River and at the mouth of the valleys in the Euphrates River in the southern sections of the study area, as shown in **Map 2**.



Map 2. Geology Map of the Study Area

A. The lower section is characterized by chalk limestone of the oldest formation with an insulating layer of primary conglomerate and breccia. It also contains colored limestone that contains breccia and clay materials. The appearance of Oligocene erosion deposits is evidence of the presence of sediments in a regional environment. This formation is located in the northeastern and northwestern part of the study area, as shown in **Map 2 (Ministry of Irrigation, 1989, p. 27)**.

B. The middle section consists of dolomite and chalks, limestone, the upper part of which is characterized by stratigraphic compatibility and overlap with marl. And it appears on some parts of the surface consisting of dolomite and impure dolomite, and fine-grained crystalline limestone. The thickness of this formation reaches 17-25 m. This formation is located in the northeastern and northwestern part of the study area, as shown in **Map 2 (Ministry of Irrigation, 1989, p. 27)**.

C. The upper section: This section is characterized as dolomitic and has successive solid limestone rocks, soft marl and breccia (broken pieces of rocks) mudstone successive with and stone and silica. One of the most important characteristics of the limestone is being hollow and crossed due to the possibility of changing the deposition environment. This formation is located in the northeastern and northwestern parts of the study area, as shown in **Map 2**. *"The Euphrates. center for studying irrigation projects, the proposal of the study of the groundwater of areas adjacent to Al Qadisiyah lake, the hydrological report"* **(Ministry of Irrigation, 1989, p. 27)**.

1. 1. 2. Fatha Formation (Middle Miocene)

It occupies a large area of the study area, about 254.04 km^2 of the total area, one of the most extensive formations. This formation extends from east to west and from the center of the study area to its northernmost part, covered with Quaternary deposits as shown in **Map 2 (Sisakian and Hafiz, 1994, p. 7-8)**. The formation was divided into two members:

A. The lower member

It consists of green shale, solid gray limestone, and lead gypsum mixed with green and pink impurities. Three depositional courses in the region can be seen with thicknesses between 75-80 m.

B. The upper member

It has the same characteristics as the lower member, with a difference in the appearance of a layer of red mudstone thickness between 55-75 m.

1. 1. 3. Quaternary Sediments

It is one of the essential deposits in terms of economic importance. It represents the surface layer of the earth's crust on which humans practice economic, industrial, and agricultural activities. *"It is also a source of gravel, sand, and clay. In addition, it represents the soil on which various other activities are carried out. Quaternary sediments are divided into the*

Pleistocene and Holocene periods, and each section is classified into several types, depending on the quality of the sediments" **(Sissakin, 2000, p. 12-13)**.

A. Pleistocene River Terraces: These sediments can be easily distinguished in the study area due to:
1. Its presence is limited to the Euphrates River.
2. It is higher than the surrounding land.
3. The application in it is contrary in the sense that the layers that make up these balconies differ with the layer that follows it or above it.

The height of the river terraces ranges from 5-25 m above the river surface. It occupies an estimated area of 0.99%, one of the study area's lowest formations. It is almost limited to the areas adjacent to the Euphrates River in the southern part of the study area, as shown on Map 2. These terraces consist of gravel consisting of limestone and flint with some igneous rocks **(Sisakian and Hafiz, 1994, p. 11)**. This made the river terraces resistant to some erosion and weathering.

1. 2. Climatic Properties

Climate is one of the most critical factors affecting the formation and development of landforms in any region from past to present. The climate of the study area is directly affected by the Mediterranean climate. The climatic properties and phenomena will be studied in a detailed image as follows:

1. 2. 1. Climate

Climate, especially temperature and humidity, is the leading cause of the physical disintegration of rocks and chemical weathering **(Türkeş, 2010, p. 4)**. The climate, which characterizes the weather, largely determines the amount of water carried by the streams in a region, the drainage density, the regime, and the water potential of the basin **(Arslantaş Dik, 2021)**.

Firstly, the data of the climatic stations has been gained to study the current climate of the study area.

However, since there is no meteorological station within the boundaries of the study area, as shown in **Table 1**, the climate data for the years 1980-2019 were obtained from the two closest stations, Anah and Al-Qaim.

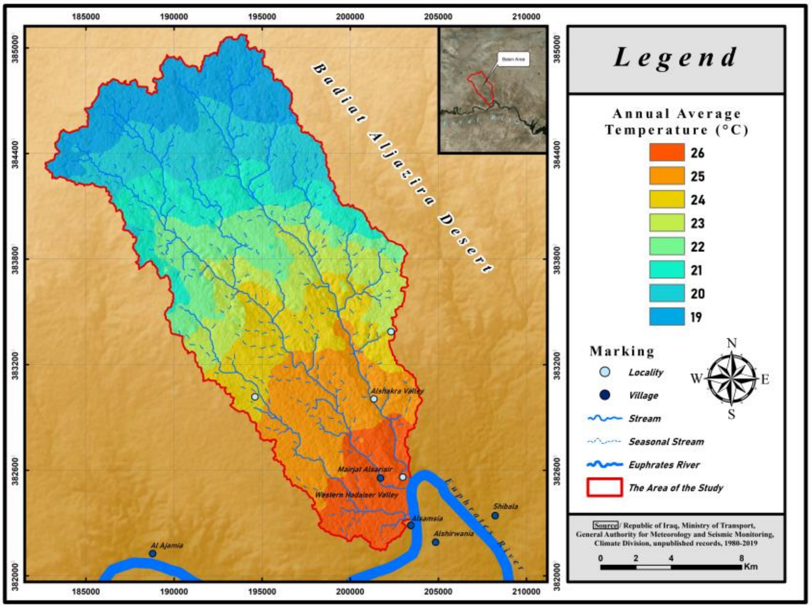
Table 1. Coordinates of Climate Stations

Station	Station number	Latitude (North)	Longitude (East)	Altitude above sea level
Al-Qaim	627	23° 34'	41° 01'	177 m
Anah	629	22° 34'	57° 41'	138 m

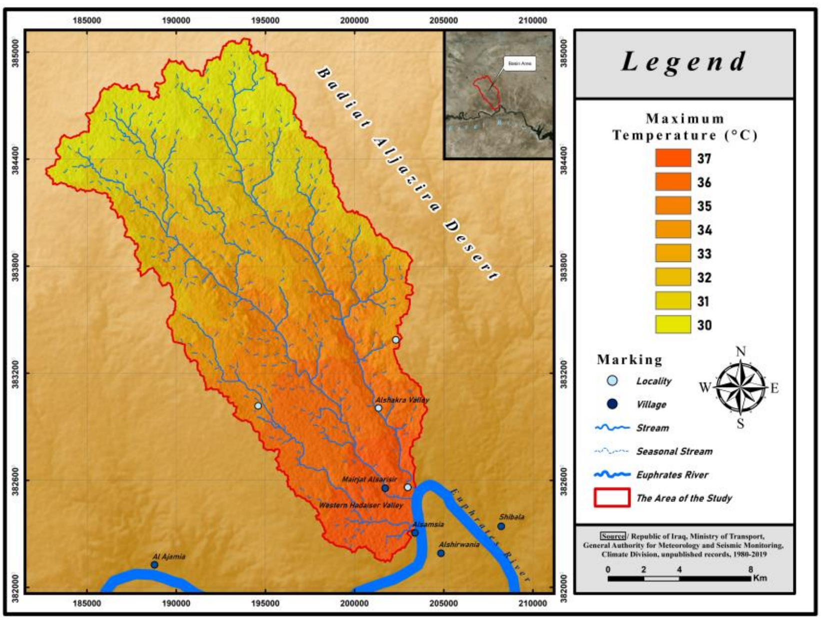
1. 2. 1. 1. Temperature

It is one of the most important climatic elements due to its direct and indirect effect on the other climatic elements. For example, the rise of the temperature leads to an increase in the evaporation in the water bodies and the groundwater close to the earth’s surface, in addition to the increase of wind erosion. The low temperature causes the water to freeze inside the cracks and increases its volume by about 9%, leading to the pressure inside the cracks and the voids in the crocks, which leads to its disintegration. When temperature rise, the chemical weather increases by speeding up chemical reactions and decomposing organic chemical materials **(Al-Jumaily, 1990, p. 44)**.

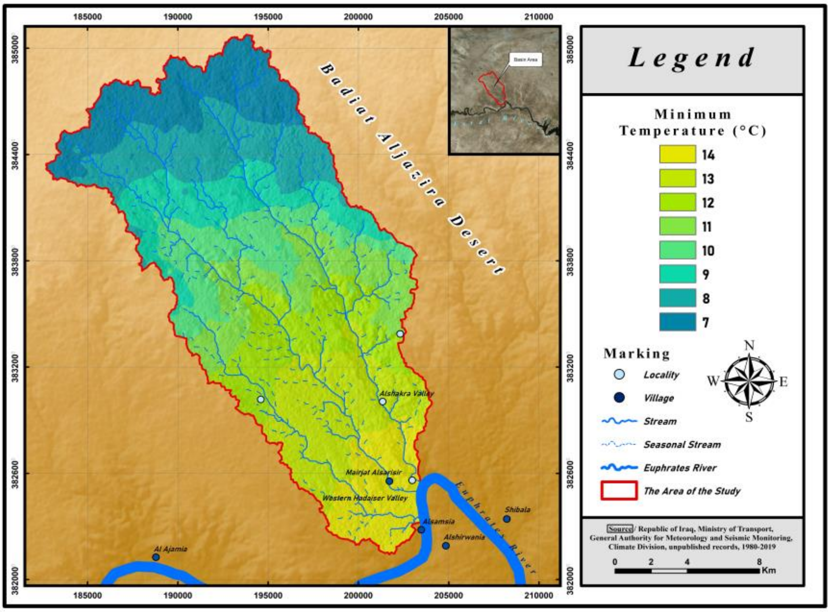
The difference in the season temperature is evident in Table 2 and Table 3. June recorded the highest average temperature, reaching 31.3°C in Al-Qaim Station, while July recorded the highest temperature in Anah Station, reaching 32.5°C. The lowest temperature was recorded in January in Al-Qaim Station, which amounted to 8.6°C, and the Anah Station recorded the lowest temperature in December, reaching 8.1°C. The decrease in temperature rates is due to the lack of hours of solar radiation in winter. On the contrary, in summer, the temperature rises, and the hours of solar radiation increase.



Map 3. Annual Average Temperature (°C) Map of the Study Area



Map 4. Maximum Temperature (°C) Map of the Study Area



Map 5. Minimum Temperature (°C) Map of the Study Area

Table 2. Monthly Average Temperature of the Al-Qaim Station (1980-2019)

Seasons	Months	Al-Qaim				Semester average
		Max	Min	Thermal range	The average	
Winter	Dec	13.3	4.0	9.3	8.6	11.1
	Jan	15.3	4.4	10.9	9.8	
	Feb	21.5	8.3	13.2	14.9	
Spring	March	27	13.4	13.6	20.5	25.4
	Apr	31.9	18.6	13.3	25.2	
	May	38.5	22.6	15.9	30.5	
Summer	June	41.2	25.8	15.4	33.5	31.3
	July	40.9	23.4	17.5	32.1	
	Aug	36.6	20.3	16.3	28.4	
Autumn	Sept	31.2	15.9	15.3	23.5	16.7
	Oct	25.7	9.2	16.5	17.4	
	Nov	14.6	4.2	10.4	9.4	
	Annual average					21.1

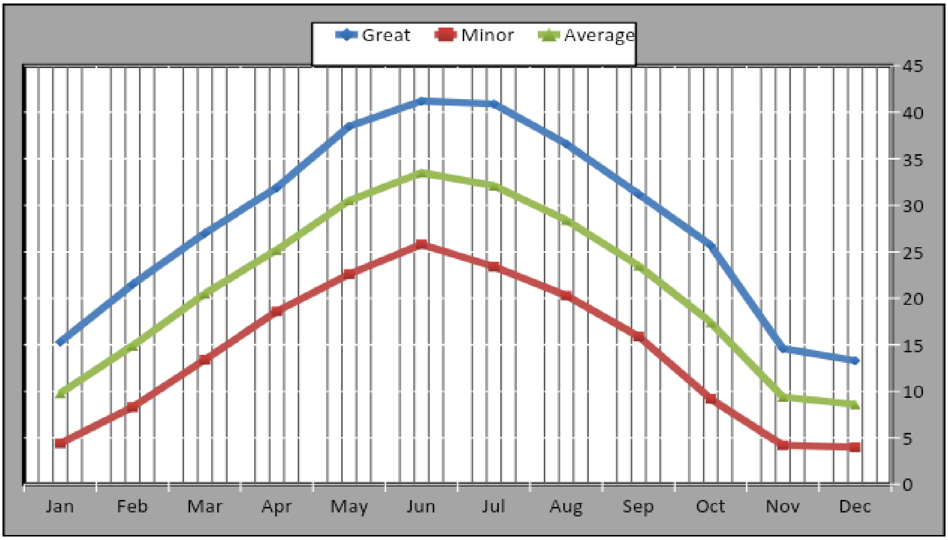


Figure 1. Seasonal and Average Monthly Temperatures of the Al-Qaim Station (1980-2019)

Table 3. Monthly Average Temperatures of the Anah Station (1980-2019)

Seasons	Months	Anah				Semester average
		Max	Min	Thermal range	The average	
Winter	Dec	15.4	4.0	11.4	9.7	9.3
	Jan	13.5	2.7	10.8	8.1	
	Feb	16.8	3.6	13.2	10.2	
Spring	March	21.4	7.6	13.8	14.5	20.3
	Apr	28	12.8	15.2	20.2	
	May	34.1	18.4	15.7	26.2	
Summer	June	39.1	22.2	16.9	30.6	32.5
	July	42.1	25.4	16.7	33.7	
	Aug	41.7	24.8	16.9	33.2	
Autumn	Sept	37.9	19.9	18	28.9	22.1
	Oct	30.7	14.4	16.3	22.5	
	Nov	22.3	7.7	14.6	15	
	Annual average					21.0

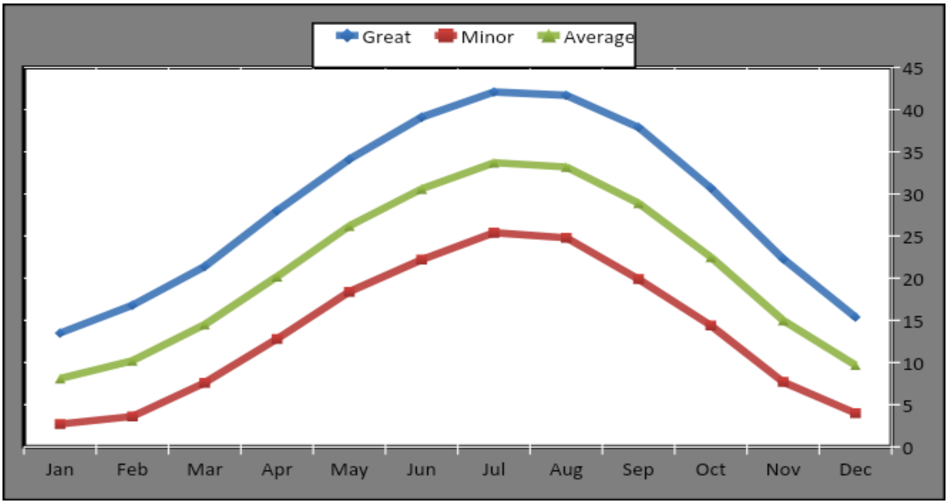


Figure 2. Graph of Monthly Maximum, Minimum, and Average Temperatures of the Anah Station (1980-2019)

The difference in the month temperature is clear in **Table 2** and **Table 3**, and **Map 3**, **Map 4**, and **Map 5** show the annual average, the maximum, and the minimum temperature in the study area. The highest maximum average temperature for June was 41.2°C in Al-Qaim and 42.1°C in Anah for the same month. The lowest maximum average temperature is in December, which is 13.3°C (Al-Qaim), and in January, which is 13.5°C (Anah). The lowest minimum average temperature in Al-Qaim Station is at 4.0°C (in December), and in Anah Station is at 2.7°C (in January) **(Figure 1 and Figure 2)**.

Annual average temperature values are minimum in June at 33.5°C (in Al-Qaim Station), and in December at 8.6°C (in Al-Qaim Station). And also, annual average temperature values were recorded as maximum in July 33.7°C (in Anah Station), and in January 8.1°C (in Anah Station). The differences between summer and winter in the temperature values recorded at both stations clearly show that physical disintegration processes are effective.

As for the lowest temperature, it was in January in Al-Qaim Station, and it was estimated at 10.8°C. The Anah Station was recorded at 10.9°C in the same month. It is clear from the temperature difference that the temperature range increases to be 13.5°C and 15.3°C in both stations, which increases physical weathering processes.

1. 2. 1. 2. Relative Humidity

It is significant for the morphometric process since it is a climatic element that has its role in weathering especially chemical weathering. It also contributes to abrasion and wind transport prevailing in dry areas. The relative humidity is low with a rate of 45% due to the high temperatures, 'an inverse relationship under the constant pressure'. The air is dry if the humidity is less than 50%, moderate between 60-70%, and very wet above 70% **(Abu Aleata, 1985, p. 188)**.

Table 4. Monthly and Seasonal Relative Humidity (%) of the Al-Qaim (1980-2019)

Al-Qaim												
Seasons	**Winter**			**Spring**			**Summer**			**Autumn**		
Month	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Aver.	72.8	74.7	63.2	53.9	46	35.6	30.4	27.8	32	38	46.8	62.6
Semester average	70.2			45.1			30			48.8		
Annual average	48.5											

Table 5. Monthly and Seasonal Relative Humidity (%) of the Anah Station (1980-2019)

Anah												
Seasons	**Winter**			**Spring**			**Summer**			**Autumn**		
Month	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Aver.	75.3	68.1	65.4	54.8	43.7	32.9	26.9	26.5	27.5	32.7	44.6	63.1
Semester average	69.6			43.8			26.9			46.8		
Annual average	46.7											

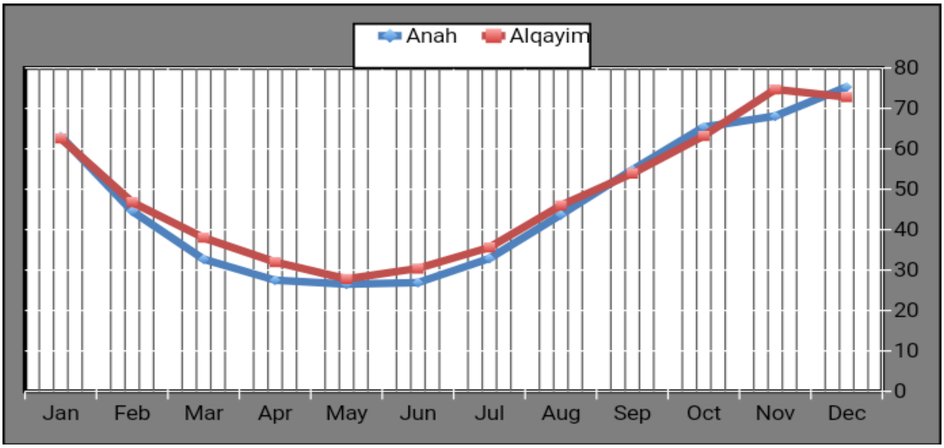


Figure 3. Monthly Relative Humidity (%) of the Al-Qaim and the Anah Station (1980-2019)

Table 4 and **Table 5** show an inverse relationship between temperature and relative humidity, which rises in winter to be 70.2% in Al-Qaim Station because of the large amount of rains in this season, as mentioned above, which is accompanied by a decrease in temperature. On the contrary, the relative humidity decreases 26.9% in summer in Anah Station. In general, the rise of temperature is not the only reason for the high rate of evaporation in surface water in summer, but also the decrease of relative humidity, which reaches less than 30% in summertime. **Figure 3** shows that January is the wettest month in Al- Qaim Station, with a rate of 74.7%. At the same time, December was the wettest month in Anah Station, with a rate of 75.3%, while June was the least humid month with 26.9% **(Al-Dazniu, 2020, p. 24)**.

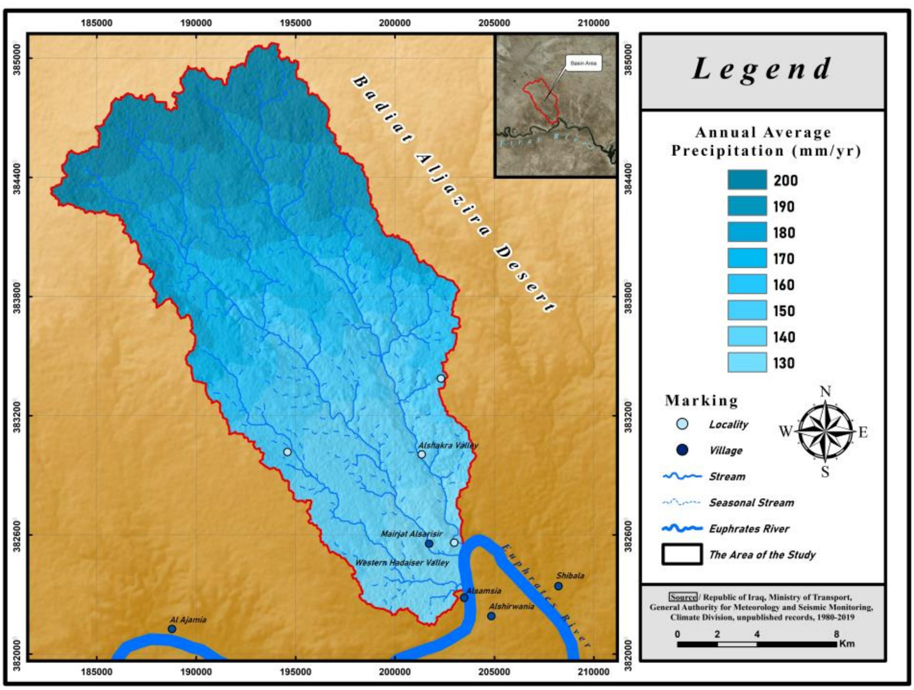
1. 2. 1. 3. Rain

Rain is one of the effective elements on the figuration of earth's surface features and geomorphological ones in dry and semi-dry regions. It is the primary source of the flow. The condensation of the water vapor, which forms the fog and clouds in the air, causes various condensation products **(Yazıcı, 2019a, p. 173)**. The study area is one of the arid regions since it seldom rains, so it remains dry all the year **(Al-Saamaraayiy and Al-Rayhani, 1990, p. 97)**.

Due to the significance of rain and its role in the formation of the features of geomorphology, in addition to its effect on increasing the number of floods and the resulting changes in the study area and its reflection on the amount of surface runoff, and to know the climate balance, it is vital to know the amount of rains and the rainiest areas in the study area as shown in **Map 6**.

Table 6. Monthly Average Rainfall of Al-Qaim Station (1980-2019)

Al-Qaim												
Seasons	**Autumn**			**Winter**			**Spring**			**Summer**		
Month	**Sep**	**Oc**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Av.	0	0	7.4	17.3	17.5	22.7	22.4	21.6	12.7	5.8	0	0
Quarterly total	7.4			57.5			56.7			5.8		
Annual total	127.4											



Map 6. Annual Average Precipitation Map of the Study Area

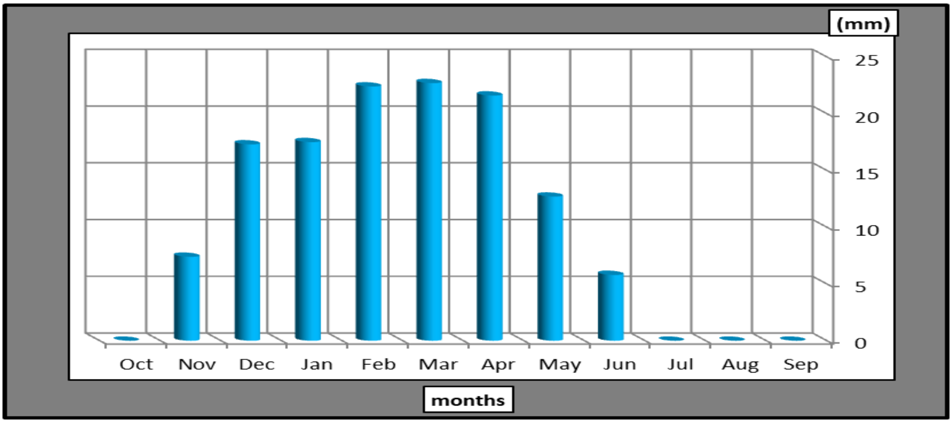


Figure 4. Amount of Rains of the Al-Qaim Station (1980-2019)

Table 7. Monthly Average of Rainfall of Anah Station (1980-2019)

Anah												
Seasons	**Autumn**			**Winter**			**Spring**			**Summer**		
Month	**Sep**	**Oc**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Av.	0	0	14.3	19.3	20.8	26.8	25.6	24.7	14.9	6.6	0	0
Quarterly total	14.3			66.9			65.2			6.6		
Annual total	153											

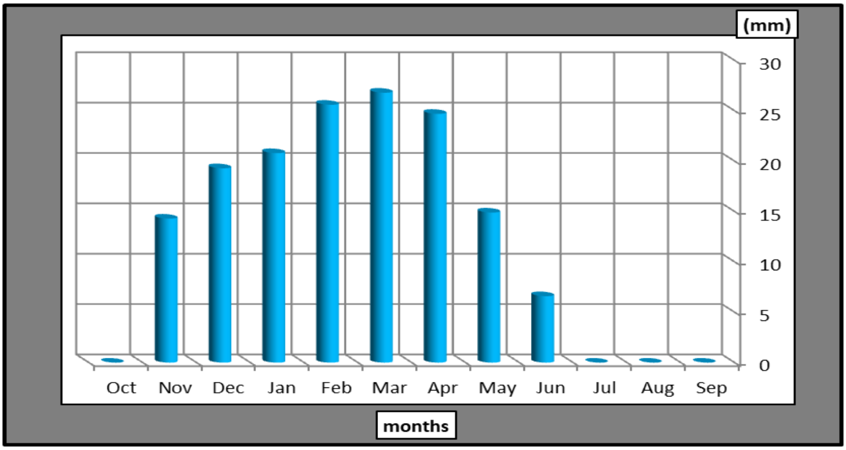


Figure 5. Amount of Rains of the Anah Station (1980-2019)

It turns out in the two tables that there was little rain in the study area for July, August, September, and October, respectively, due to the high temperatures and the increase in evaporation and the high pressure in the area. The presence of depressions in the study area affects precipitation, as precipitation is significantly related to the altitude situation. One of the most influential depressions is the Mediterranean, the closest sea to the study area. The rains are characterized by seasonal and monthly variations in the times and amounts of their precipitation. February is the rainiest month as it recorded 22.7 mm Al-Qaim and 26.8 mm of the Anah stations, as is apparent in **Table 6**, **Table 7**, and **Figure 4**, **Figure 5**. As for the seasonal distribution, winter recorded the most considerable amount of 57.5 mm in Al-Qaim Station and 66.9 mm in Anah Station. It turns out in the two tables that there was little rain in the study area in the summer for July, August, September, and October respectively, due to the high temperatures and the increase in evaporation and the high pressure in the area. The precipitation difference between both stations is 25.6 mm, favoring Anah Station. This is because Al-Qaim Station is located in a depression area.

To find out the adequacy of rainfall in the study area, the **Thornthwaite** equation **(Dönmez, 1984)** was applied to the stations of the study area, which are Al-Qaim Station and Anah Station.

$$E_{121.65}\left(\frac{R}{T+12.2}\right)^{\frac{10}{9}}$$

It turned out that a dry climate characterizes the climate of the study area, and this is clear from the results of the equation, as it reached 4.4 mm in Al-Qaim station and 4.4 mm in Anah Station, as shown in **Table 8, Table 9, Table 10** and **Figure 6**.

Table 8. Thornthwaite Equation Results (Enough Rain)

Stations	Total annual rainfall (mm)	Annual average temperature (°C)	Enough rain (mm)	Climate type
Al-Qaim	127.4	21.1	4.4	Dry
Anah	153	21	4.4	Dry

Table 9. Thornthwaite Water Balance of the Anah Station

Thornthwaite water balance table of Anah Station													
Months	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Monthly average temperature	8.1	10.2	14.5	20.2	26.2	30.6	33.7	33.2	28.9	22.5	15	9.7	21.07
Temperature indice	2.08	2.94	5.01	8.28	12.28	12.53	17.9	17.5	14.24	9.57	5.28	2.7	113.6
Uncorrected	6.8	12.1	29.5	68.2	131.6	194.75	248.4	239.2	168.5	89.6	32.2	10.7	
PET Correction coefficient	0.8	0.86	1.03	1.09	1.19	1.2	1.22	1.15	1.03	0.97	0.88	0.8	
Corrected PET	5.9	10.4	30.4	74.4	156.6	233.7	303.1	275.1	173.6	86.9	28.3	9.2	1388.1
Monthly total precipitation	20.8	26.8	25.6	24.7	14.9	6.6	0	0	0	0	14.3	19.3	153
Water storage change	14.8	16.3	-4.8	-36.3	0	0	0	0	0	0	0	10.07	
Water storage	24.8	41.2	36.3	0	0	0	0	0	0	0	0	10.07	
Actual evapotranspiration	5.9	10.4	30.4	61.04	14.9	6.6	0	0	0	0	14.3	9.2	153
Water deficiency	0	0	0	13.3	141.74	227.1	303.1	275.1	173.6	86.9	14.05	0	1235.1
Water surplus	0	0	0	0	0	0	0	0	0	0	0	0	0
Runoff	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidity	2.4	1.5	-0.16	-0.67	-0.9	-0.97	-1	-1	-1	-1	-0.5	1.09	

Table 10. Thornthwaite Climate Type Interpretation of the Anah Station

Thornthwaite climate type interpretation of Anah Station			
	Symbol	**Explanation**	**Indices**
Precipitation efficiency indice	E	Arid (Desert)	-53.39
Temperature efficiency indice	A"	Megathermal (Climates with high temperatures)	
Humidity and drought indice	D	Little or no water surplus	1388.11
Ratio of PET three summer months	B"2"	Nautical effect	0

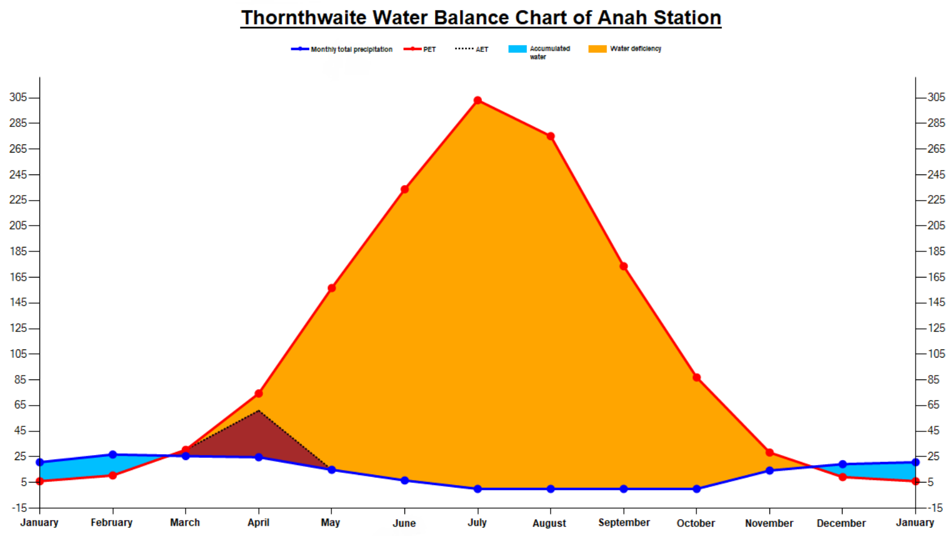


Figure 6. Thornthwaite Water Balance Chart of the Anah Station

1. 2. 1. 4. Winds

It means the horizontal movement of air parallel to the earth's surface, which is an important climatic feature that contributes directly to the formation of the surface geomorphological features. Its influence is apparent in the desert and semi-desert regions as they are active due to the exposed surface and the lack of vegetation cover, which protects the soil from winds. The winnowing, refinement, and sedimentation processes are involved in the sedimentary material, a load suspended in the air **(Al-Raawy and Al-Bayati, 2001, p. 125; Al-Khashab, 1978, p. 219; Dy and Nbry, 1975, p. 395)**.

As for the effect of winds on the area's geomorphology, it is clear through wind erosion which is closely related to its speed. Since the study area is a desert free of mountains with a dry climate characterized by lack of natural vegetation helped to increase the activity of wind erosion. **Table 11** and **Table 12** show the variation in wind speed during the four seasons.

At Al-Qaim Station, the highest seasonal wind speed average value is 3.1 m/s in summer, and the lowest seasonal wind average is in autumn with 1.9 m/s. Similarly, at Anah Station, the highest average seasonal wind speed is seen again in summer with 4.5 m/s, and the lowest average wind speed with 2.1 m/s is again in autumn. As can be seen, the values in Anah Station are higher than those in Al-Qaim.

Table 11. The Rate of Wind Speed (m/s) of the Al-Qaim Station (1980-2019)

Al-Qaim												
Seasons	**Winter**			**Spring**			**Summer**			**Autumn**		
Month	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**
Av.	1.6	2.1	2.5	2.6	2.8	2.8	3.2	3.4	2.9	2.1	1.9	1.7
Semester average	2			2.7			3.1			1.9		
Annual average	2.42											

Table 12. The Rate of Wind Speed (m/s) of the Anah Station (1980-2019)

Anah												
Seasons	**Winter**			**Spring**			**Summer**			**Autumn**		
Month	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**
Av.	2.1	2.2	2.6	3.2	3.2	3.6	4.7	5.2	3.8	2.8	1.8	1.7
Semester average	2.3			3.3			4.5			2.1		
Annual average	3.05											

1. 3. Natural Vegetation

Vegetation has an active role in geomorphological work in river basins in terms of its kind, density, and distribution in any region since it reduces the effect of water and wind erosion. It protects the earth's surface, cements soil particles, reduces the intensity of raindrops, and causes a surface obstruction by intercepting surface water runoff and rain, leading to an increase in groundwater and surface water recharge. In addition to this, the lack of vegetation leads to rapid water flow and obstruction of infiltration into the ground, especially in clay soil. These soils are located near the Euphrates River and Samsiya Village. The lack of natural plants and their distribution in the basin increased the effectiveness and activity of different geomorphological processes and their effects on the earth phenomena. The soil and exposed surface as slopes, surfaces, hills, and the edges of the valley stream are exposed to water and wind erosion, landslide, and rockfall due to the lack of natural plants in these places. Accordingly, the natural plants in the stream basin reflect the dry climate, so the prevalent plant is a kind of desert plant. For example, algreda plants and *Diplotaxis* plants are divided into perennial and annual plants according to their type of growth. As for the perennial plants, the bush dies outwardly. Its branches, leaves, and flowers wither during the dry season and then blooms in the rainy seasons, while the annual plants (short-lived plants living during the rainy season again from October to March). Die, but their seeds remain in the ground until the beginning of the next rainy season, so they bloom and die again **(Lal, 1995, p. 19)**. Natural plants were divided into three areas in the study area as follows:

1. 3. 1. Areas with Very Little Natural Vegetation

They occupy a very small proportion of the northern part of the study area, where only the climate-tolerant bushes can grow in the southern regions of the Wadi Al-Shakrea basin. As well as the lack of plants is due to the nature of the soil in those areas since it is located within large areas of swamps where it is difficult for plants to grow except some types of plants, high salinity resistance, one of the characteristics of these desert soils is that they are highly permeable and have an increase in salinity due to the nature of the area where drought prevails and the abundance of stones in it.

1. 3. 2. Areas with Little Natural Vegetation

These areas occupy the largest proportion of the middle part of the study area. The lack of these natural plants in these areas is due to the drought that repeated in the study area in the varying period and the human factor and its misuse and irregular use of natural pastures **(Mousa, 2018, s. 45)**.

1. 3. 3. Areas with Natural Existing Vegetation

It occupied the smallest proportion of the study area. This means that geomorphological figures in this region were affected by plants since the vegetation cover is a geomorphological factor in the formation and development of the land. The plants of these areas are characterized by the ability to tolerate the salinity of the soil and less need for water **(Al-Nueaymi and Al-Jamili, 2013, p. 256-257; Al-Rabiei, 2017, p. 35)**. We will explain some of the natural plants found in the study area.

Photograph 1. *Salmon bush*, a perennial plant species in western parts are close to the Samtheai Stream in the study area

A. Perennial shrubs: Perennial shrubs mean those shrubs that have been able to remain throughout the seasons of the year resistant to climatic conditions and have the ability to withstand the lack or lack of rain in the study area. Therefore, a few types of these shrubs, such as '*salmon bush*', usually grows in the first year of the vegetation growth and blooms in the second year with the length of 2- 3 m, as shown in **Photograph 1**.

There are other types of plants as '*artemisia plants*', which can be found in the western parts close to Samtheai Stream and outskirts. They can be used as medicinal herbs and perfume '*incense*' at homes **(Abd Al-Salam, 2015, p. 30)**.

B. Seasonal herbs and weeds appear during the spring and winter and disappear in the fall and summer in the northern parts of the Al-Auqood Stream in the study area. And they can be used for animal grazing and as fodder for camels. Some of these weeds are '*Diplotaxis*', one of the desert plants special for its yellow flower, as shown in **Photograph 2**.

Photograph 2. *Diplotaxis* plant in the study area at northern parts of the Al-Auqood Stream basin

These do not appear every year, which means that they appear within a few years, and when they do appear, it is an indication that truffles may be present. These plants occur in the northern parts of the study area, generally in the rainy seasons, as shown in **Photograph 3**.

If the vegetation cover is preserved, the damage to the basin caused by the sediment accumulation due to erosion can be minimized **(Erol Görür and Karadeniz, 2018)**.

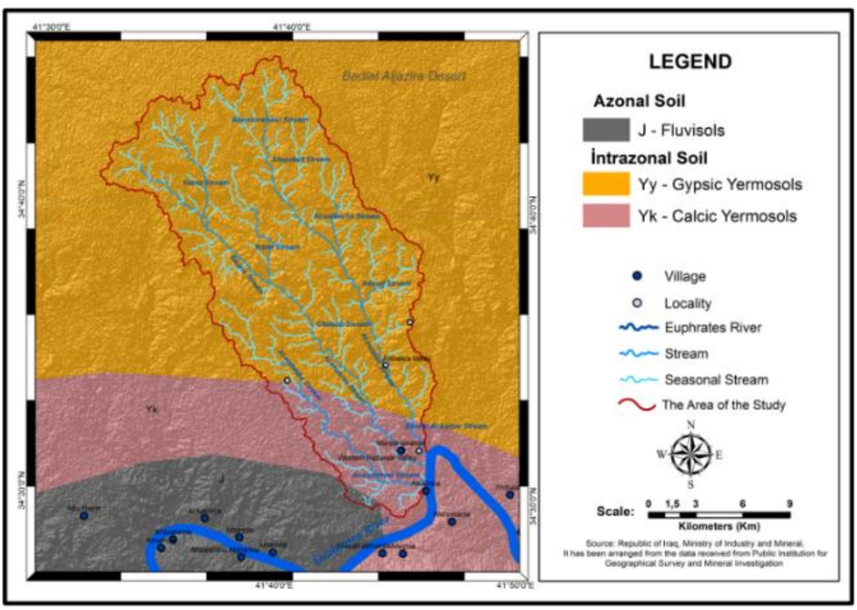
Photograph 3. *Algreda* plants in the northern parts of the study area

1. 4. Soils

It is the natural part and fragile layer which covers most of the land surface with a thickness from one place to another, ranging from centimeters to meters resulting from the varying disintegration of rocks and consisting of mineral and organic elements.

The effect of moist and dry soils on ground temperature differs. The specific heat of the water that has wetted the soil is high, and although it takes a lot of energy, it heats up less and cools down slowly. On the other hand, dry soils have low specific heat and heat up quickly **(Erol, 1988)**.

It is divided into two parts: Transferred soils and local soils resulting from weathering processes **(Al-Dulaimi, 2005, p. 133)**.



Map 7. Soil Map of the Study Area

The soil is some of the most important natural and animal resources for humans after water, resulting from physical, chemical, and erosive processes.

Erosion is affected by the main characteristics of the soil, including the texture (relative distribution of mineral soil grains) and soil structure (the natural arrangement of atoms clumps in small groups). The types of soils vary according to the different factors that influence their formation. The soils of dry regions vary in comparison with wet areas and acidic, alkaline, saline, calcareous, and gypsum soils. Studying the kinds of soils is significant for researching the physical field of geography, especially geomorphology. The essential prevalent soils in the study area are the following **(Map 7)**:

1. 4. 1. Flooded Soils

They are the best soils in the study area since they represent the areas of agriculture activity and the residents centralizing as villages and others close to the study area.

These soils represent a very little part of the study area, with 1 km^2 of 303.38 km^2. The soils can be found in the southern part of the study area, especially those close to the Euphrates River. It is characterized by low rates of electrical conductivity and the amount of dissolved salts, where the lowest rates were recorded at about 1.9, for electrical conductivity 1.258 milliequivalents per liter of dissolved salts. It is also characterized by neutral Al alkaline with a rate ph 7.2. They are also considered organic soils since organic matter was 20-30%, which recorded the highest rate in the study area. In contrast, the intensity recorded was 1.17 cm^3, a low intensity because of the texture of the soil with a mixed and alluvial nature, which is one of the best types of texture **(Almueayni, 1990, p. 438)**. According to analysis, it was clear from above and research that the soil of flooded plain is one of the best types of soil due to its proximity to the Euphrates River. Their sediments represent the primary source of this soil, as is evident in **Photograph 4**. So, this study focuses on the need to take care of these soils, preserve them from other uses such as industrial and urban projects, and use them only for agriculture.

Photograph 4. Flooded soils at Samsiya Village in the study area

1. 4. 2. Desert Soils

The desert climate prevails in the study area and affects soils and plants. Many types of desert soils can be found in the area, which are local soils such as **(Photograph 5)**:

Photograph 5. Desert soils in the northern parts of the Al-Auqood Stream basin

1. 4. 2. 1. Gypsum Desert Soils

These soils spread in the dry and semi-dry regions, forming main layers from gypsum deposits, limestone, and sandstone. And they are shallow soil with little thickness because of their exposure to weather factors and the lack of organic matter, which ranges between 0.1-1.5 % **(Al-Khatib, 1978, p. 25)**. These soils represented the most significant proportion (261.17 km^2) of the total study area (303.38 km^2), as shown in Map 7 **(Aleakaydi and Aleisawy, 1986, p. 54)**.

These soils are characterized by a large amount of calcium compounds (salty) and the lack of rain which made it a natural pasture. The percentage of calcium is more than 15% and with the thickness of more than 15 cm in the form of limestone layers close to the earth’s surface, which are sometimes accessible for the roots of natural plants to penetrate and sometimes they are solid **(Hantoush, 2003, p. 54)**. Some of their characteristics:

- They are greatly affected by erosion due to the lack of vegetation cover.
- They contain a good proportion of calcium carbonate.
- They are shallow, not exceeding 20 cm.
- The lack of humidity due to the lack of rain leads to cracking of the soil and erosion.
- The reduction of the percentage of organic matter to 0.1-1.5%.

1. 4. 2. 2. Carbonate Desert Soils

They extend in the western regions of Iraq and spread in this soil is found in the middle sections and expands in the northern direction of the study area. They consist of limestone and sandstone, as shown in **Map 7**, and cover a good amount of the area, about 40.76 km^2 of the total study area, 303.38 km^2. They may contain stony rocks, where they appear clearly on the surface. Their thickness doesn’t exceed 10 cm. The study area is characterized by poor soil for organic matters, humidity, and vegetation cover. It is a fragile disjointed desert that is greatly affected by external factors of erosion and weathering, which contributed to the formation of surface features. Geomorphological processes significantly contributed to the formation of the surface parts.

1. 5. Hydrographic Features

Due to the conditions of the working area, it has a dry climate dependent on climatic conditions. It is not a hydrographically rich area. Many valleys related to the river’s journey in the basins make up the study area, almost all of which are dry valley features. They are divided into surface water and groundwater resources as follow:

1. 5. 1. Surface Water Resources

The Al-Auqood, Al-Shakrea, and Al-Samtheai streams forming three separate stream basins of the study area are supplied with water from the rainfall system in the Mediterranean basin, which starts in October to the end of March. The rains are characterized by the low amount and different temporal and spatial falls and their heaviness. The basins of the Al-Auqood, Al-Shakrea, and Al-Samtheai streams become dry most of the year. Water may flow into some of its basins or in all of its secondary basins if the rain continues for a long time and the rainstorm covers all parts of the basin during the rainy season as it is evident in **Photograph 6** and **Photograph 7**, **Map 8** shows the hydrography of the study area. To shed light on the amount of annual revenue and the absence of hydrographic stations to measure the amount of water discharge does not appear to modify the subject the mathematical estimates. It was adopted by relying on the two climatic stations, namely Al-Qaim and Anah stations which cover the basins of the study area **(Mohammed, 2000, p. 46)**.

Based on the Barkley method forest impacting the volume of annual water revenues in the basin, which depends on the climate and terrain elements, it is calculated as follows: R=(cis) ½ (w/L) 0. 45 considering that

R: The volume of expected annual flow billion/m^3

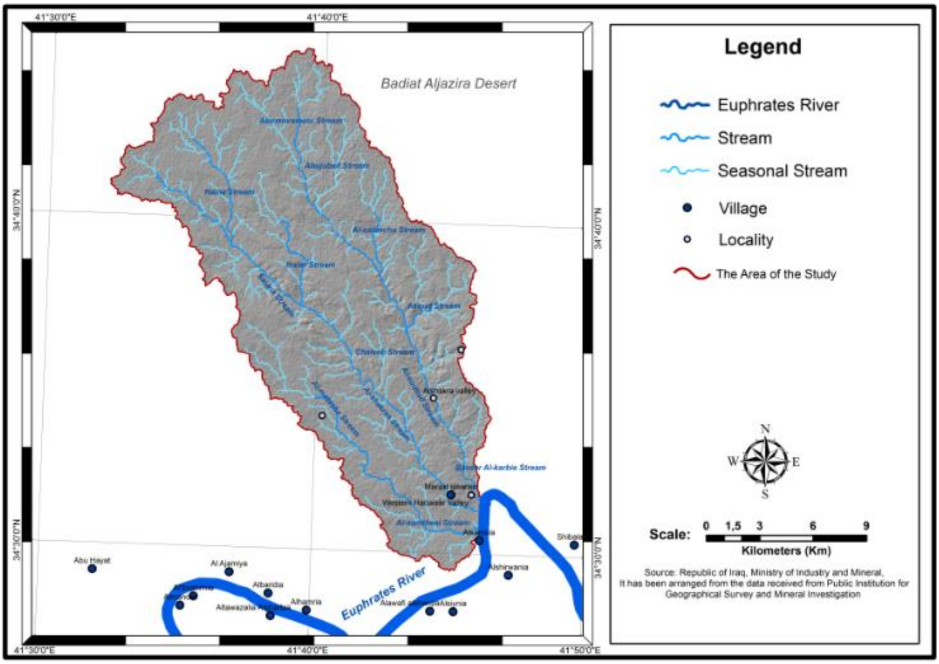
I: The volume of expected annual flow billion/m^3 (it is calculated by multiplying the annual rain rate /mm by the basin area, then dividing the result by 1000000.)

S: The gradient average m/km is calculated in the following way: the difference between the highest and lowest value in the highest of the basin/length of the basin.

W: The rate of stream width.

L: The valley's length from the source to the estuary was measured using Auto Disk Map Program.

C: A constant value estimated in the western desert at 0.10.



Map 8. Hydrography Map of the Study Area

Based on the results obtained from **Table 13**, it appears that the volume of expected annual flow in the study area has reached 0.0571 billion/m^3, as all basins varied separately in the volume of revenues. This depends on the amount of rain falling on the two stations between the basins covered by Al-Qaim Station and basins covered by Anah Station and the variation in the area, the rate of stream width, and the gradient rate.

Photograph 6. Samsiya Village to the west of the study area

The greater the rainfall rate and the area, width, and degree of slope of the basin, the greater the volume of annual flow for this basin. In general, these values ranged between 0. 0089 billion/m^3 in Samtheai Stream basin, 0. 0255 billion/m^3 in the Al-Shakrea Stream basin and 0.0227 billion/m^3 in the Al-Auqood Stream basin. The variation in the volume of these revenues leads to a variation in the rate of erosion and dissolution that occur when the volume of flow increases.

Photograph 7. Rainwater collected south of the Al-Auqood Stream basin

Table 13. Expected Annual Runoff of the Study Area Basins

Basin name	Length of the stream (km)	Area (km^2)	Relative space (km^2)	Perimeter (km)	Average annual rain (mm)	Projected annual runoff
Al-Auqood	148.72	124.13	40.8	81.64	153	0.0227
Al-Shakrea	166.89	132.88	43.7	87.35	153	0.0255
Al-Samtheai	58.66	46.37	15.3	56.42	153	0.0089
Total	373.72	303.38	303.66	105.21		0.0571

1. 5. 2. Ground Water

It has a geomorphological action that is no less important than surface water—flowing or precipitating groundwater because it contains dissolved chemicals and soluble limestone and dolomite. One of the essential rock-dissolving resources is chlorides, sulfates, and carbon, forming many terrestrial phenomena caused by groundwater action. Many factors control the existence and the movement of groundwater. They are represented by the volume and the abundance of rainfall and by ground structure, which is represented by the nature of rocks, linear system, nature of the terrain, nature of gradient, quality of the soil, and its ability to infiltration the density of vegetation cover and the geomorphological history. These unique factors caused two types of groundwater, such as 'oozing water' close to the surface within free rocky reservoirs. Accessible sedimentary reservoirs, whose direct sources are rainwater and the running water in the valleys in the rainy season, are subject to fluctuation in their amount according to wet and dry years. It is characterized by low salinity of less than 1000 mg/liter. It can be found in the study area within valleys and alluvial deposits with a depth ranging between 3-8 m in some hand-dug locations Al-Auqood Stream. Oozing water forms dissolution pits whose density depends on the nature of the rock, formation, and the thickness of cracks and joints.

Free rocky water components are groundwater away from surface recharge sources and are found in rock structures that can carry groundwater. The groundwater table may approach the surface in areas representing water gathering places, represented by subterranean karst corridors and aquifers. This water reduces the thickness of the rocks and works to create collapse craters. *"The nature of the dissolved chemicals depends on the nature of the rocks, structural features, and groundwater feeding, and then running out of water from depth into reservoirs is a factor to specify the quality of water"* **(Aljaburi and Albasrawi, 2002, p. 9-10)**.

One of the most important of these dissolved components in the rock layers, which bear water, is in a group of chlorides, by 50% sulfates by 39% and bicarbonate by 11%. In comparison, the dissolved elements are sodium by 46%, calcium by 33%, and magnesium by more than 20%. The high percentage of chlorides is due to the rock nature and the long time in which the groundwater remains in the interior reservoir resulting in an interaction between the water and the rocks. The nature of water at the beginning of the basin sources is of the bicarbonate type because it is greatly affected by the surface water feeding. As for the movement of the water, it takes the eastern direction, which almost corresponds with the direction of the surface draining of the basin and the general slope of the western plateau. This water can lead to activate the role of chemical weathering processes due to the increase of conductivity values that ranged between (1000-2270/day) and permeability value ranging between (4-5.7 m/day) which reflects the presence of karst channels and gaps within the brock substructures, which are good paths for the passage of groundwater **(Al-Sahaaf, 1970, p. 31)**.

1. 6. Human Uses of the Study Area

There are different practices by inhabitants in the study area based on data registered by government institutions. Based on field study, the lands were divided according to investment into several divisions as follows:

1. 6. 1. Human Settlements

It is located along the Euphrates River and distributed randomly as a result of the topography of the area, which represents a part of the desert of the Iraqi Badyat Aljazira contained several basins as well as some slopes and rocky ledges, which constitute an obstacle to its distribution in other directions. In contrast, settlements take a line style that stretches out along the river from the east to the west, while the distribution decreases as we head north and is almost absent as we move away from the river. The field study showed that the inhabitants of the study area are from the rural areas, which numbered about 100, male and female, who settled in the areas near the river. This requires executive government agencies to find solutions to attract residents to these areas, such as agricultural lands reform and motivating them to invest and contrast them.

1. 6. 2. Arable Lands

Agriculture is considered the main craft for most of the study area population. Now the agricultural activity has started to decline due to the lack of support and the decrease in the arable areas. Agricultural lands have a percentage of the uses the study areas. Still, at the time of the study, they were not exploited because the residents couldn’t cultivate it due to the presence of large unsecured regions due to the remnants of the war (weapon remnants).

This leads to a loss in wheat and barley cultivating, while the years 2015 to 2021 have not witnessed any production. As mentioned previously, the population spread near the river and agriculture as it depends on it in the irrigation. In contrast, the lands far from the river depend on wells, and the drip method is used, as is evident in **Photograph 8**.

Photograph 8. Drip irrigation in the southwestern part of the study area near the Samsiya Village

1. 6. 3. Industrial Lands

This use occupied a very small percentage of the study area as it was almost restricted to some plants such as gravel and sand plants and stone quarries. The region suffers from a lack of industrial activity, so it is necessary to establish industrial sites such as the salt factory, where raw materials are available that are randomly exploited by the population.

1. 6. 4. Road Networks

Roads are considered the main factor in the development process of any region, being the vital artery that feeds cities and connects them with other cities and regions. Roads are divided into two kinds as follows:

1. 6. 4. 1. Paved Roads

It is a single road that passes through the outskirts of the study area in the southern part of it to the outskirts of the Euphrates River and connects the villages of Rawa district to the transit area, as shown in **Photograph 9**.

Photograph 9. Paved roads in the south of the study area on the Euphrates River

1. 6. 4. 2. Unpaved Roads

"These roads occupied more areas than paved ones. This indicates poor quality of the roads and lack of interest from government agencies, as the road that connects Rawa district with the Al-Obour sub-district considers the major artery for the study area residents" **(Falih, 2011, p. 125)**.

1. 6. 5. Abandoned Lands

They include most of the study area at the rate of 80.2%. These lands represent unexploited areas. Therefore, they are considered promising areas for investment and expansion towards the north through establishing the following projects.

1. Establishing roads to facilitate the process of trade exchange between districts, subdistricts, and villages.
2. Establishing oases in the desert by digging wells and encouraging farmers to invest in those lands **(Alhadithiu, 2020, p. 35)**.

CHAPTER TWO

2. GEOMORPHOLOGICAL FEATURES

2. 1. Morphological Processes

Many processes result in a change in the shapes of the surface, depending on the main factor of the ancient climate and geological formation had a prominent impact on forming the region's geomorphology. For the study to clarify the impact of this, the process will be explained in detail for each process, as follows:

2. 2. Morpho-Climatic Processes

The morpho-climatic processes mean the processes of erosion and weathering, which are among the most influential factors in the study area and are continuing until the present, as climate factors are the main factor affecting their occurrence, as temperatures affect weathering through the expansion and contraction of rocks. Rains have a prominent role in erosion processes. As a result of this importance, the processes of weathering and erosion have been studied in detail, as follows:

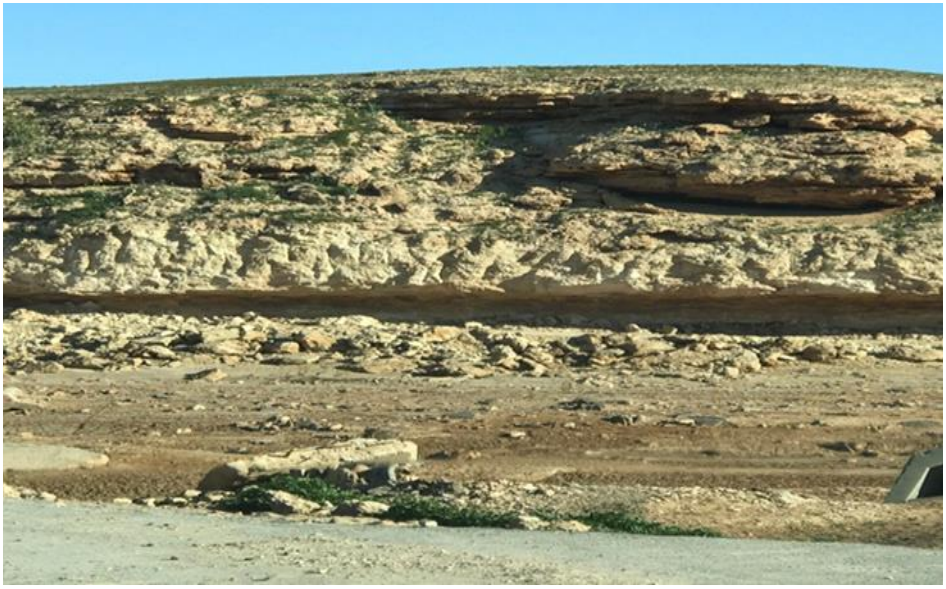
2. 2. 1. Weathering

"The weathering process is defined as the sum of chemical and natural processes that lead to the dissolution and fragmentation of rocks and mineral materials, as a result of the interconnecting influences of the atmosphere, water, and biological, and it represents the first step that paves the way for the processes of erosion, sedimentation, and landslides" **(Salama, 2017, p. 108)**.

It is also one of the most important phenomena for human life for a very simple reason, which is that the agricultural soil without which plants cannot live, and the weathering process represents the basis for changing the shapes of the earth's surface, compared to other processes that leave a slight impact such as erosion and structural movements. There are several types in the study area, the most important of which are:

2. 2. 1. 1. Mechanical Weathering

It is to change the size of the rocks from the original size to a size less than it was in the past, keeping all its characteristics and properties **(Photograph 10)**.



Photograph 10. Mechanical weathering in the north of the Al-Auqood Stream

This weathering occurs through the following:

A- Weathering due to thermal range: Changing in the daily and monthly thermal range results in the expansion and contraction of the rocks, and as a result of the repetition of this process, the process of rock fragmentation occurs, which increases in the desert and semi-desert areas because the rocks are directly exposed to the sun's rays, and this is what happens in the study area because most of the regions are barren desert lands except In some rainy years **(Alhadithiu, 2020, p. 176)**. It is characterized by an increase in the monthly thermal range, as August recorded the highest range of 16.2°C and 17.2°C, and the winter season, specifically in January, recorded the lowest range of 11.2°C and 11.1°C for the two stations of Al-

Qaim and Anah, respectively, **Table 2** and **Table 3**. Due to high ranges, the rock layers are subjected to expansion and contraction processes due to the low temperatures at night and different rates due to the different coefficients of expansion and contraction for each mineral, so cracks of upper rock layers occur taking the cross direction in most times.

B- Salt weathering: Rock salt has come from evaporite basins, the evaporation environments of seas, lakes, or other closed basins in ancient geological periods **(Yazıcı, 2019b, p. 191)**. This type of weathering occurs in areas characterized by a high percentage of groundwater, which appears to the top of the surface due to the capillary property. The water inside the gypsum rocks evaporates and exposes it to pressure due to these grains. The Repetition of dissolving and crystallizing some holes and pores in the stones that were exposed to this type of weathering, the concentration of salts rises, crystallizes, expands, and generates an increase in volume and pressure within the rocks, which causes their weakening and disintegration **(Al-Awadi and Al-Dughairy, 2017, p. 67)**. This type of weathering appears in the western and central parts of the study area near the Al-Samtheai and the Al-Shakrea streams. In the study area, there is a lot of evaporation in the ground due to the prevailing climatic conditions in the area, such as drought and the accumulation of salt from the ground, most of which are not exploited **(Photograph 11)**.

Photograph 11. Salt weathering in the Al-Samtheai Stream basin

C- Weathering by Wetting and Drying: It represents this type of weathering product whose occurrence is concentrated in low areas that contain transported soils that are originally sediments transported by the streams and settled in the depressions, desert bottoms and mudflats are the suitable environments of this type of weathering which affected by the rate of drying and wetting and the lower layer **(Salama, 2017, p. 132)**. This type of weathering is affected by the quality of the prevailing mud and the amount of salt and rain that penetrates these muds, resulting in cracks after they were exposed to the swelling process and then to dehydration due to exposure to sunlight. It is spread in the study area in most of the basins, specifically in the middle, as well as in the flood areas, as the thickness of the cracks varies according to the thickness of the soil, as shown in the middle of the Al-Shakrea Stream basin **(Photograph 12)**.

Photograph 12. Weathering by drying and wetting in the central parts of the Al-Shakrea Stream basin

D- Weathering by Living Organisms (Plants, Animals or Humans): Living organisms are among the factors affecting the formation of landforms, but their impact is limited to a specific area without another, and this distinguishes them from the influence of the climate factor, the most influential factor in the formation of these forms. The role of man is represented as a significant geomorphological factor through the exploitation of some lands as quarries for gravel and sand, digging wells, and plowing and grazing animals by moving the thin layers of soil while the animals pass over them as well as the construction of both types of paved and unpaved roads.

The effect of plants is represented by the penetration of the roots of these plants into the cracks formed by weathering processes as a result of the change in the temperature range. These roots fragment the rocks due to the amount of contained water inside the roots since most of those plants are vegetation growing in rainy seasons. For this reason, these rocks are prepared for their impact on weathering processes. This type of weathering of living organisms is clear at the basin of the Al-Auqood and the Al-Samtheai stream basin of the study area **(Photograph 13)**.

Photograph 13. Weathering by plants in the Al-Auqood and the Al-Samtheai Stream basins

2. 2. 1. 2. Chemical Weathering

"It is the exposure of rocks to decomposition processes and turns into another metal by the interaction of water and oxygen with some of the minerals contained in the rocks, and it is formed as a result of the presence of one or more chemically active substances found in nature" **(Sawalha, 2005, p. 109)**. Chemical weathering is more active in wet areas than in dry areas, so the effect of this type of weathering in the study area is less effective compared to physical weathering, and as shown in map 16 and the processes of chemical weathering that occurred in the previous periods when the area was exposed to glacial periods and the subsequent changes until it appeared as it is at present. The processes of weathering varied, as follows:

A- Dissolution: This type of weathering depends on the interaction of water with some minerals that can unite with water. The dissolution process spreads within the formation of the upper and lower aperture, since the rocks of this formation are characterized by the speed of dissolution, such as the limestone rocks that are present in it, as some openings caused by the dissolution process appear in them and at heights ranging from between 8 to 20 cm. It is found in the Al-Auqood and the Al-Shakrea stream basins **(Photograph 14)**.

Photograph 14. Chemical dissolution processes near the Al-Auqood Stream basin

B- Oxidation: *"The reaction of oxygen with rocks is called the process of oxidation, and it results in changing the black color of basalt to brown. This process leads to the weakening of the metal (iron) and thus leads to the weakness of the rock itself"* **(Salama, 2017, pp. 135-136)**. This process appears in minimal areas, so it is limited to the areas near the Wadi Al-Samtheai Stream basin. The oxidation process increases in sandy, limestone, clay, and red rocks with organic matter and water, while hot and dry areas (study area) weaken the oxidation process, causing organic matter to accumulate on the surface. There are no photographs of oxidation due to the difficulties entering the regions because of the security situation previously mentioned.

C- Erosion: Erosion is one of the processes that result in the change and formation of landforms in dry and semi-arid areas. This is represented by water and wind factors, whose impact varies according to the element's strength and location. Rains that fall on the steep slope regions are more influential than the plain regions, as shown in map 9. The types of erosion in the study area are:

1- Water erosion

Since the study area has a dry and semi-dry climate, the main factor of water erosion is rain.

Splash erosion of rain droplets

"This type of erosion depends on the rain falling on the study area, whose characteristics differ depending on the size and speed of the impact on the surface, as well as the terrain factor, natural vegetation and soil" **(Salama, 2017, p. 140-141)**. Since the region has a dry climate as mentioned before, the surface layer of the soil is dry, and there is little cohesion between the elements, the first periods of rains have a significant effect on the formation of this type of erosion. There is little rainfall in the study area. As explained in the climate characteristics section, January, February and March are when water erosion is most active compared to other months.

Rill erosion

"They are shallow, random strips, formed in the form of bands with the irregular flow that can erode the soil and move it to another place" **(Abu Saada, 1983, p. 88)**. This type of erosion occurs after rain, and in large quantities and by the action of surface runoff, it can be observed in sloping areas because these areas help to increase its activity by increasing the water

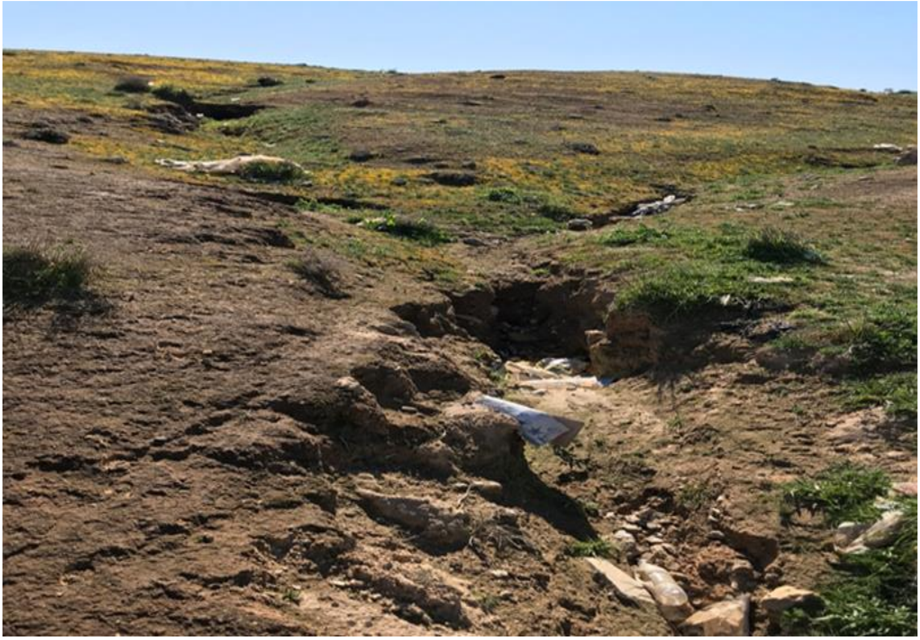
run-off of different lengths ranging from 1 m to more than 3 m **(Photograph 15)**.

Photograph 15. Water streams with little length in the Al-Auqood Stream basin

It can be seen from **Photograph 15** that the nature of the region and the degree of slope effect determine the lengths of the rivers. Most of the valleys in the Al-Auqood basin and other basins in the study area are short and dry, with low slopes.

Groove erosion

"It is the process of removing soil and rocks fragmented by water, as it consists of several channels that transport water during and after rain" **(Almawlaa, 2008, p. 132)**. Groove erosion constitutes a negative factor on the region in which it occurs since it erodes the soil and exposes the natural vegetation at the beginning of the growth period to erosion. Thus, the area becomes more exposed to erosion, as shown in **Photograph 16** and **Map 9**.



Photograph 16. Groove erosion by slope factor in the Al-Shakrea Stream basin

2- Wind erosion

Wind erosion is one of the factors that affects geomorphological forms in areas with arid climate, characterized by low vegetation cover, and increases the effect of this erosion **(Al-Bayati and Mousa, 1989, p. 77)**.

Wind erosion occurs when the pressure generated by the surface increases the ability of the surface components to resist detachment and rolling, which increases as the soil dries out. The study area has a very high degree of wind erosion due to the lack of rain and high temperatures, which was mentioned previously in the first chapter, which was reflected in the dryness of the soil, which made it easy for erosion to affect the ground forms. As shown in **Map 9**, these are more in the northeast part of the study area. Furthermore, ripple marks, which form wave wrinkles with the effect of the wind, are also seen in the study area. An example of ripple marks is the downstream part of the Al-Shakrea Stream basin **(Photograph 17)**.

Photograph 17. Ripple marks near the estuary of the Al-Shakrea Stream basin

2. 3. Morphodynamic Processes

They are the processes that occur due to the overpowering of gravity, such as precipitation and rockslide on the strength of rock cohesion. These processes are affected by the type of rocks and the degree of gradient as they move from higher areas to lower areas. Morphodynamic processes of the study area were classified due to Sharp classification. G.F.S. Sharp's classification **(Sharp, 1938)** is one of the modern classifications, which depends on the difference in the speed and movement of sliding materials, and it has been classified into four groups based on the difference in velocity and movement of materials.

2. 3. 1. Mass Movements

2. 3. 1. 1. Soil Creeping

They are slow movements of rocky crumbs. This movement prevails in areas characterized by the sediments from the soil and at different depths, as dry soils and in the dry season are subject to the process of encroachment by wind and lack of cohesion between them. Still, in the rainy season, materials are within the areas subjected to rain intensities and the slope factor, which is a conducive factor to the creep of the soil. The creeping process is an invisible movement that moves from high ground to low sides **(Al-Khashab, Hadid and Al-Sahaaf, 1976, p. 107)**. *"This movement can be inferred on the surface of the slopes, as the earthy and rocky band affected by weathering slowly moves downwards"* **(Sawalha, 2005, p. 254)**. The height of the rocks exposed to creep in the study area varies between 20-70 cm **(Photograph 18)**. Gravity has a significant influence on the creeping movement.

2. 3. 1. 2. Rockfall

It is the process of moving the disintegrated rocks downwards due to their exposure to weathering processes, such as expansion and contraction due to the temperature change. Crawling processes are activated in the solid rocks of sandstone with joints, cracks, and dense faults that weaken the rock and the ease of its disintegration **(Abu Al-Enein, 1995, p. 320)**.

Photograph 18. Rockfall near the Al-Samtheai Village

2. 4. Landforms

Landforms vary according to the processes they formed. Some forms were created due to inter processes such as tectonic movements and earthquakes. These forms are somewhat stable compared to the forms that occurred due to external processes such as erosion and weathering and are still subject to change. To know the forms in the study area, it relied on the topographic map and the field study, which classify the forms according to the primary process.

2. 4. 1. Erosion Originated Structural Forms

A. Low Plateaus

The Northern Badia is a plateau in the Arabian Peninsula with an undulating surface with some areas of high elevations and about 360 meters above sea level. The surface is also characterized by its gradual slope from north to south towards the Euphrates River **(Al-Dulaimi, 2008, p. 56)**.

From the geological point of view, the study area is an extension of the geology of the Arabian Peninsula, which forms part of the northern section of the front terrestrial pavement of the Arabian Solid Block, which consists of the Arabian Shield and the Arabian Pavement, which is also divided into two parts, the stable pavement and the unstable pavement in which the area is located studying **(Fayyad, 2008, p. 6)**. As is known, limestone dissolves faster than dolomite and both limestone and dolomite have relatively lower porosity. The Miocene age is one of the most widespread formations of the third age in the study area, and its most important components are gypsum, silt, limestone, sand, and gravel **(Al-Jumaily, 1990, p. 11)**.

Soil is an essential natural resource that controls agricultural production in terms of quantity and quality, so human life is closely related. This was revealed by studying the geological structure of the study area. The spread of rock types, dry climate, and subsequent wind erosion led to the presence of rocky soils of low fertility as a result of the absence or lack of vegetation cover, which was reflected in the presence of two types of soil, namely dry soil and newly formed soils **(Sherif and Al-Shlash, 1985, p. 253).**

Natural vegetation development in any region of the world is related to climatic conditions and is negatively affected by factors such as lack of precipitation, high temperatures and high evaporation. There are low plateau areas with little vegetation in the Sidr, Al-Seih and Al-Behal regions **(Al-Jumaily, 1990, p. 22)**.

"Plateaus are defined as large areas of the earth's surface that rise above the surface of the earth, characterized the fact that their upper surfaces are semi-flat with steep sides, and sometimes appear wall-shaped" **(Abu Al-Enein, 1976, p. 491)**. ***"****The importance of the plateaus is shown through their impact on the hydrology of the region due to the nature of their area that provides natural traps for rainwater and that increase the ability of the basins to collect water"* **(Al-Bu Ali, 2016, p. 260).** The study area represents part of the Badia Al-Jazeera plateaus, which contains plateaus of varying heights due to the variation in the rock formation, as shown in **Figure 7**. The average height of the plateaus ranges between 200-300 m, and through the figure, it is possible to observe the surfaces of erosion, plains, plateaus, and valleys that cut off and intersect.

The plateaus are located within the Euphrates Formation has veins of hard coral limestone and basal limestone 2.5-9 m thick and a layer of scalloped limestone at the top 18 m high also topped by a layer of chalk and white limestone. The upper layer of this formation contains the protruding and coiled surfaces, which is the peculiar characteristic of the formation and its incompatible presence over the old formations with thin and lumpy layers as it is only resistant to external processes compared to other formations and sediments in the study area. Also, some plateaus extend for long distances outside the study area. The plateaus appear distinctly in the Al-Auqood Stream basin on the north and north-eastern side of the study area, as shown in **Photograph 19** and **Map 9**.

B. Erosion surfaces: Where stream erosion cuts formations of different lithologies and ages, nearly flat wavy plains are formed. **Photograph 20** shows the erosional surfaces in the northern part of the Al-Samtheai basin.

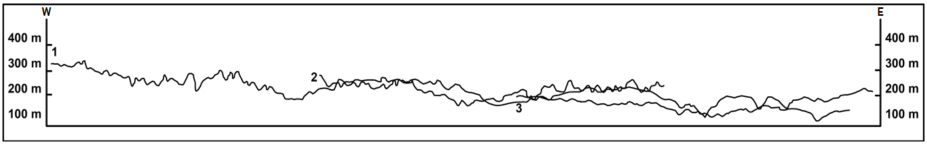
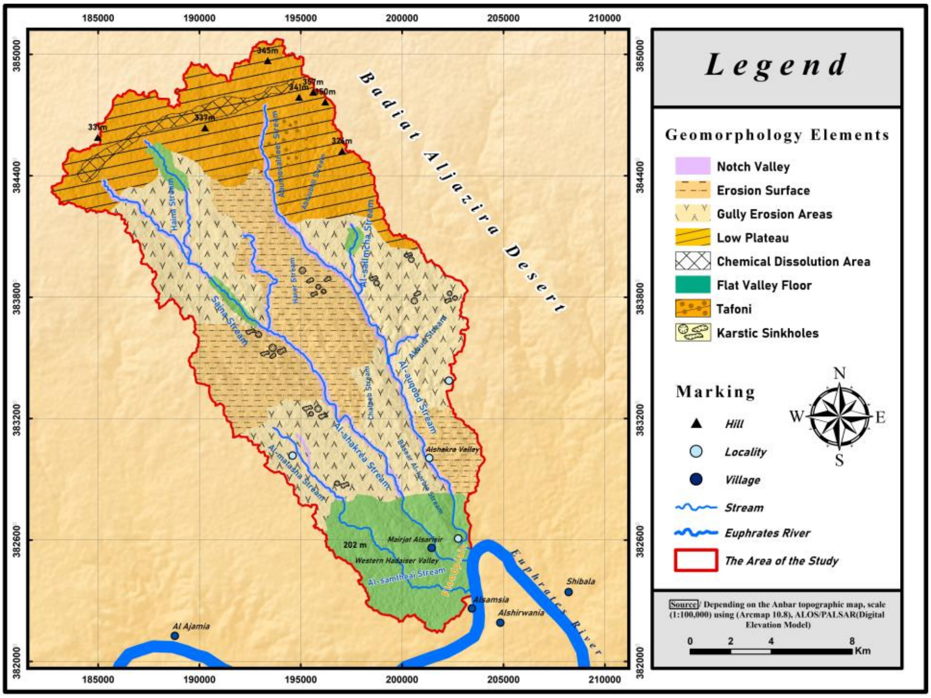


Figure 7. Profiles Showing Level Differences in the Study Area



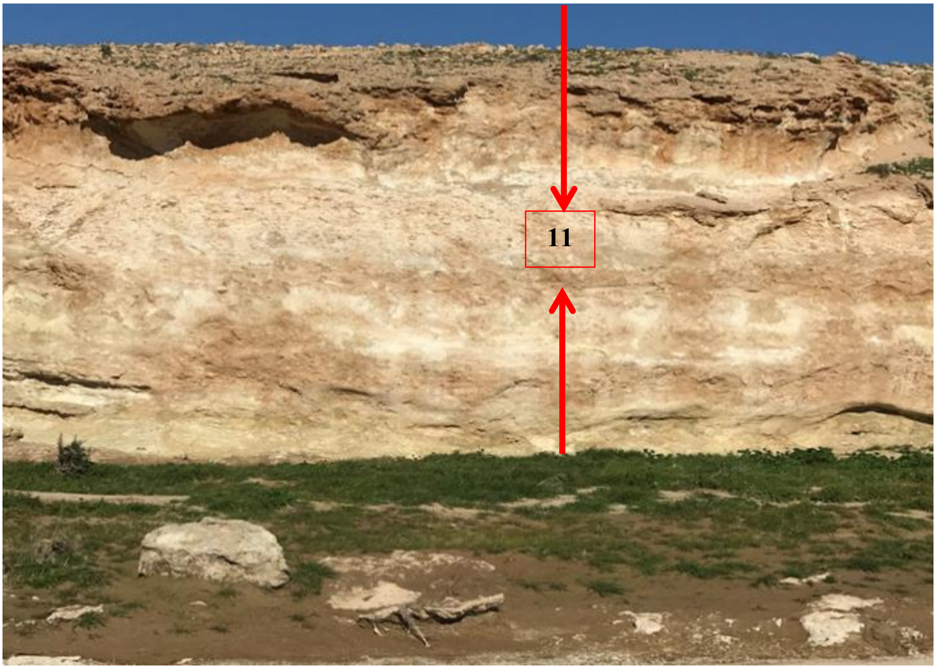
Map 9. Geomorphology Map of the Study Area

C. Hills: They are areas with a little and very little height from the neighboring lands that were formed as a result of exposing some buttes that have low hardness formations to severe erosional processes that led them to appear as a form of hills with different heights ranging from 2-13 m. They appear in the plain areas, north and northeast of the study area, and near some basins such as the Al-Shakreai and the Al-Auqood stream basins, as indicated on **Map 9**.

Photograph 19. Hills in the northern side of the Al-Auqood Stream basin

Photograph 20. Erosional surfaces in the northern part of the Al-Samtheai Stream basin

D. Rocky Ledges: There are many shapes of rocky ledges in the study area. There are ledges with Clastic rocks, as in the Al-Shakreai Stream basin, while solid rocky ledges with limestone appear within the Euphrates formation, such as the rocky ledge of the Al-Auqood Stream basin. The formation of these ledges is due to solid rock layers at the top and rocky clastic layers at the bottom. The rock layers resist weathering and erosion processes, so they become less responsive to external conditions **(Alhadithiu, 2020, p. 158)**. This difference resulted in a variation in the height of those ledges between 5-10 m for the ledge of a Clastic nature, while it rises to more than 10 m at the solid ledges of the Al-Auqood Stream basin **(Photograph 21)**.

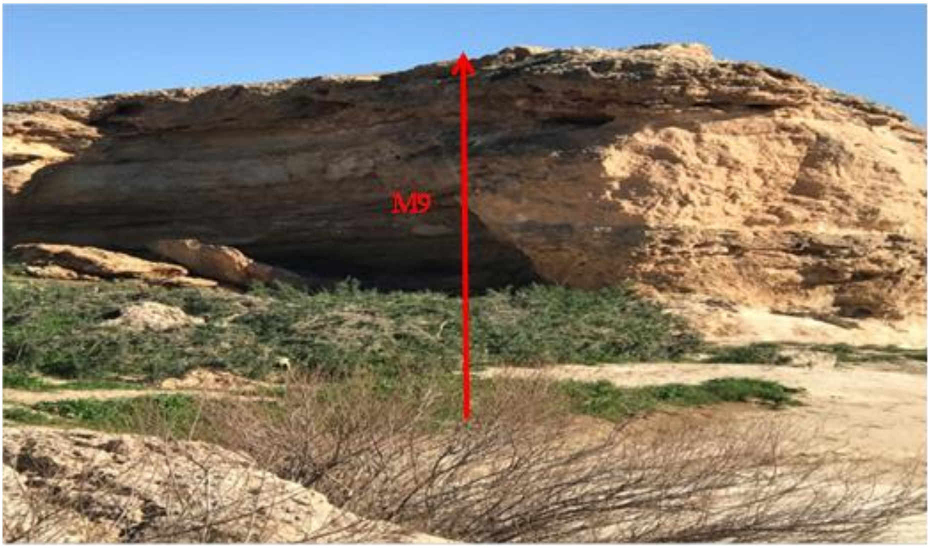


Photograph 21. Approximately 11 m high rock formation ledges of the Al-Auqood Stream basin

2. 4. 2. Chemical Dissolution Landforms

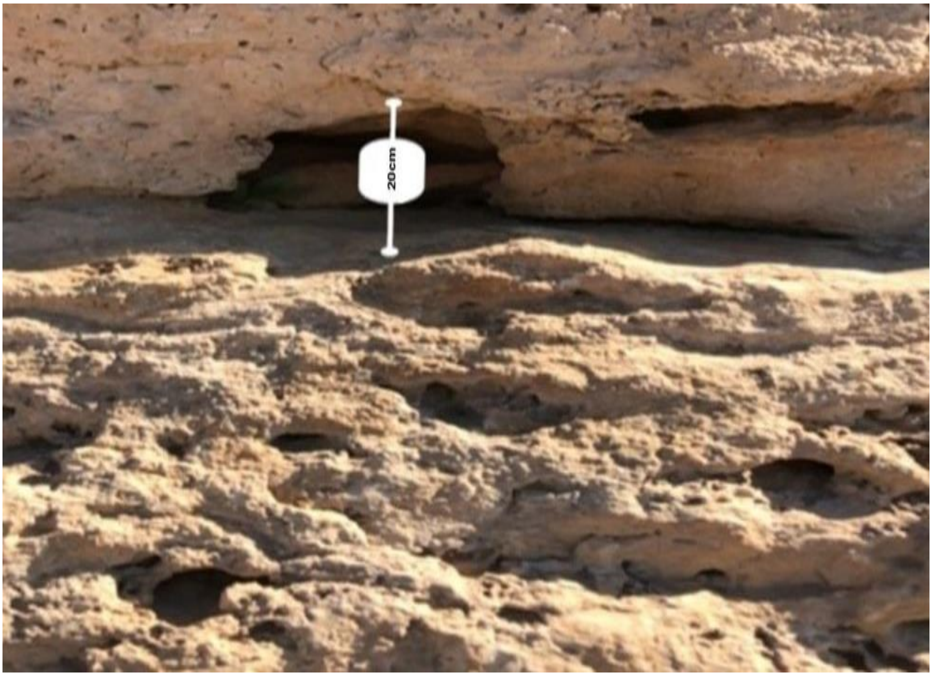
A. Karst depressions: limestone rocks are subjected to melting processes that contribute to lower rock layers than the adjacent lands and form distinctive forms known as karst depressions. Join things, and porosity help develop them and the existence of dense, fast-dissolving rocky layers such as gypsum and limestone. In the study area, most of these depressions are located within the upper and lower of Al-Fatha formation due to the high percentage of gypsum in it, which facilitates the process of dissolution and forming these depressions.

Photograph 22 shows the presence of limestone and gypsum rocks, which helped form the karst depression in the study area near the Al-Auqood Stream basin, at a depth of 8 m, as shown on **Map 9**.



Photograph 22. Karstic depressions in the east of the Al-Auqood Stream basin

B. Surface sinkholes: *"They appear widely on the surface of rocky ledges and in the regions of cracks and joints which occurred due to the chemical weathering by dissolution"* **(Murad, 2018, p. 110)**. In addition to that, the frost and dewdrop supply the rocks with humidity by converting carbon dioxide to dilute carbonic acid that reacts with water on the surface of the rocks and then under the dissolution process. These sinkholes vary by the height of their hole between 4-20 cm **(Photograph 23)**. Some of them were measured with 60 cm near the estuary region of the Al-Samtheai Stream basin.



Photograph 23. Dissolved karstic sinkhole at a depth of 20 cm between tafoni in the Al-Shakrea Stream basin

2. 4. 3. Other Eroded Landforms

These forms are divided in the study area into two types as follows:

2. 4. 3. 1. Landforms Eroded by Water

These shapes were formed in the regions that have heavy rain, which led to an increase in water erosion so that the following forms appeared:

Valleys: They are low regions formed due to tectonic processes such as cracks and faults. The rain has the most important and prominent role in developing the current shape. The valley descends towards the slope of the surface. The slope direction is in the north by the estuary and southeast of the estuary except for Al-Samtheai Stream basin where it descends from northwest to southeast **(Jafar, 2018, p. 157)**. The valleys have their shapes due to the three dimensions: depth, length, and width. In-depth, the water pressure is affected by the hydrological process. In width, the influence is by lateral erosion since it sweeps the materials of both sides of the valley, as shown in the photograph of the Al-Shakrea basin in its northern sections. While the length of the valley changes due to the regressive erosion, as shown in **Map 9** and **Photograph 24**. Physical disintegration events are also common in the study area due to daily and seasonal temperature differences **(Photograph 25)**.

Photograph 24. Physical and chemical dissolution environments acting together in the northern parts of the Al-Shakrea Stream basin

Photograph 25. Physical disintegration lands in the Al-Auqood Stream basin

2. 4. 3. 2. Landforms Eroded by Wind

These forms varied in the study area because the wind is the dominant and active factor in the region, and the dry and semi-arid climate which increases the wind factor. The forms include the following:

A. Desert pavements (Sarir-pebble desert): They are the flat surfaces in the desert covered by sand, gravel, and crumbs. These pavements are formed when the wind removes the crumbs, and fine materials and materials that cannot be carried remain on the surface. They are called (Al-Sarir) in the regions of the eastern part of the Sahara Desert in Africa **(Alzaqrati and Aleaziziu, 2007, p. 85).** The desert pavements of the study area can be seen in the southwestern parts since they appear in the plain regions near the estuary region of the Al-Samtheai Stream basin, which are free of natural vegetation and spread of gravel of different sizes and shapes **(Photograph 26).**

Photograph 26. Desert pavements in the southwest near the Al-Samtheai Stream basin

B. Wind holes (Tafoni): They are holes that appear in some areas facing the wind. These holes occur due to the difference in the structure of the rocky surfaces. The process of eroding these surfaces varies according to the strength of the wind, resulting in the formation of infinitesimal phenomena on these surfaces, the most prominent of them the phenomenon of drilling or tapping, which takes circular and semi-circular shapes **(Al-Awadi, 2017, p. 321)**. These shapes appear at some rocky edges of the basins of the Al-Auqood and the Al-Shakrea, as it is noted from **Photograph 27** and **Map 9** the variation and difference in sizes, shapes and heights holes and openings for some of the lower parts of those holes between 11 to 25 cm from the surface of the earth. They developed in the horizontal direction parallel to the wind direction.

Photograph 27. Tafoni holes formed by the wind in the Al-Auqood Stream basin

2. 4. 4. Accumulation Forms

These landforms are divided into sedimentary by water and sedimentary by the wind. As follows:

2. 4. 4. 1. Sedimental Landforms Caused by Water

A. Valley sediments: The basins of the study area contain deposits of different sizes and shapes. This variation results from the different drainage patterns of the basins and the density of the river ranks for each basin. The more the basin has heavy waterways, the more its efficiency in transferring water and load and the more effect on the depth and expansion of the basin, and the more variation in sediments that they carry **(Salloum and Siam, 2017-2018, p. 332)**. Sediments change over time. They are compressed under the weight of the accumulating materials. The water they contain is thrown out, their porosities reduce, and their volume becomes smaller **(Erinç, 2012, p. 40)**. The sediments appear in small pieces of stones, while the sediments for some basins are sand and gravel deposits **(Photograph 28)**.

B. The flood plain: One of the landforms resulting from water sedimentation. It represents areas with flat surfaces covered with different sediments on both sides of the river and expands around the course. Most of the flood plain sediments are silt and alluvial deposits and are in large quantities **(Al-Shammari and Arkan, 2017, p. 359)**. The flood plain occupies the southern part of the region. The existence of the flood plain is related to the presence of large rivers **(Karbel, 2011, p. 361)**. Therefore, it extended in the study area with the extension of the Euphrates River and was evaluated as agricultural areas and the concentration of the population in the Al-Samtheai Village. But the width of the plain does not differ in the study area, and any photograph could not be taken to clear it due to the security situation in the region and the army's exploitation of the plain areas for military headquarters.

Photograph 28. Sand and gravel deposits in the Al-Auqood Stream basin

2. 4. 4. 2. Sedimental Landforms Caused by Wind

Ripple Marks: They are ripples on the surface of sandy bodies, which are formed as a result of the effect of water or air currents, and they can be the same if the waves move in opposite directions **(Sawalha, 2005, p. 138)**. These waves occur as a result of the difference in the nature of the earth's surface, air density, wind speed, and sand size, as this leads to the transfer of sand grains mainly by jumping and by crawling for coarse grains from the surface that is facing the wind to the location of its shadow **(Salama, 2017, p. 283)**.

These signs are characterized as unstable. They may appear in the southwestern of the study areas in a particular season and may disappear in another season and perhaps in the same season due to changing wind speed and direction. The ripple marks disappear if the wind speed is more than 0.88 m/s **(Mahsub and Rady, 1996, p. 185)**. The ripple marks have been seen in the northern parts of the Al-Auqood Stream basin **(Photograph 29)**.

Photograph 29. Ripple marks in the northern parts of Al-Auqood Stream basin

2. 4. 5. Human-Made Landforms

They are the forms characterized by the rapidity of their occurrence and change whenever the person wants. A direct relationship with industrial progress characterizes these forms. The more advanced machines and equipment used by man to exploit the land, the more significant the change. In previous centuries, it was difficult to exploit high areas and mountains, but there was no obstacle for a man. The essential characteristic of man's relationship with nature is the close interconnection and correlation between nature, science, and technology. The more advanced technology, the more significant impact on the earth's surface **(Tamim, 2016, p. 383)**. Landforms were formed by human action through the following activities:

2. 4. 5. 1. Landforms Caused by Rock Quarries

The rocks constitute the primary material used by the residents in building houses. Due to the proximity of the rock quarries to the cities and villages in the study area, some residents have exploited these quarries located within the formation of the lower Euphrates near the Al-Auqood Stream basin and appear in the form of piles of varying height **(Photograph 30)**.

"The areas of rocks turn into depressions to collect rainwater after they were in the form of hills, which turned into basin areas lower than the surrounding land, interspersed with small piles of broken rocks" **(Al-Dulaimi, 2018, p. 476)**.

Photograph 30. Forms resulted from rock quarries near the Al-Auqood Stream basin

2. 4. 5. 2. Landforms Caused by Gravel and Sand Quarries

Gravel and sand quarries are among the most widespread quarries in the region, especially sand quarries. There are sand factories in the study area, most of which are located within the northern part of the study area. As a result of this exploitation, areas resembling lakes were formed to collect rainwater. What distinguishes these depressions from natural depressions is the presence of some remnants of factories near them. We apologize for the lack of photographs due to the security situation in the previously mentioned area.

These factories are used to prepare the district of Rawa and the neighboring villages with gravel and sand. The forms resulting from these quarries are among the landforms whose area increases unnaturally as they are affected by the size of their exploitation by the owners of the factories.

2. 5. Geomorphological Development in the Study Area

The geological structure reveals the nature of rocks in terms of their quality, composition, and movement. It has a significant role in the formation of valleys and the movement of water, and it has an impact on the spread of water springs and wells. And the study of the geological structure is part of it is essential to know the quality of the minerals that contributed to soil composition and its predominant physical and chemical properties, which can be determined by understanding the evolution of this structure, in light of which is determined by the nature of the terrain and soil. Therefore, the influencing factor is determining the characteristics of any area. The eras that the study area has passed through are undoubtedly part of it is one of the geological ages that Iraq went through and contributed to the formation of its surface features.

In general, the study area was the solid mass that lies to the west and southwest of Iraq and is represented in it the plateau of the Arabian Peninsula, which dominated the geological structure in Iraq and also part of the old continent Gondwanaland **(Aleany and Albarazi, 1979, p. 19)**. *"It was exposed by erosion, while it is noted that recent sediments covered some of the others which were affected by the repeated immersion of the Chi Sea to land in some continents and its retreat at other times as a result of the impact of tectonic movements on the region"* **(Alzaamili, 2007, p. 10)**.

"In these eras began with a decline in most regions of the world, and the continents expanded, but were soon followed by successive disturbances and declines during successive ages until the continents took their current form circa Late Pleistocene" **(Moustafa, 2003, p. 445)**. And the seawater flooded the land of Iraq again and implicitly Western Sahara from the Eocene

to the Miocene eras, erosion and sediment erosion factors moved erosion, which consists primarily of sand, to the seafloor. At the end of this era, there was a gradual rise of the sea to cover vast areas that were land areas, creating semi-enclosed basins. After the tidal process that occurred during the Miocene, severe offshore islands showed large areas completely submerged in water. Continued accumulation of sediments in the range of the stable pavement, and then it occurs in the Late Miocene cycle of the Alpine movements in the Tertiary period, and the attendant effect of inflection and sheathing in the area. The main natural geographic areas of Iraq and their boundaries were clearly appeared during the Pliocene accordingly, erosion areas and sedimentation basins were emerged sedimentation basins were concentrated in lowlands such as the Mesopotamian Basin, as well as broad concave folds, depressions, and major valleys **(Yacoub and Proay, 2002, p. 2)**.

Climate changes that occurred during the Quaternary, especially the Pleistocene, were effective in determining the dominant characteristics of the earth's surface. Because these climate changes are very recent **(Salama, 2017, p. 488)**. The spread of glaciers over large areas during glacial periods is one of the rare events in world history **(Al-Khafaji, 2008, p. 47)**.

Since the region, including the study area, is excluded from the effect of glaciation and also due to the low altitude, glaciation has not been observed here. But these regions are characterized by increased precipitation. Iraq and the Arabian Peninsula witnessed four wet ages as well as four ice ages. The northern regions of Europe, Asia and America were covered with glaciers. According to some studies, the amount of precipitation in Mesopotamia at that time was estimated as (1000-1500) mm **(Alhusni, 1964, p. 381)**. At the beginning of the Holocene, climatic conditions in the Northern Hemisphere were more humid than today; thus providing a suitable living environment for many human and animal communities. Over the last seven thousand years, these areas have become even more arid **(Altawash, 2013, p. 131)**. *"The Northern Badia is a plateau in the Arabian Peninsula with an undulating surface with some areas of high elevations and an elevation of about 360 meters above sea level. The surface is also characterized by its gradual slope from north to south towards the Euphrates River"* **(Al-Dulaimi, 2008, p. 56)**.

From the geological point of view, the study area is an extension of the geology of the Arabian Peninsula, which forms part of the northern section of the front terrestrial pavement of the Arabian Solid Block, which consists of the Arabian Shield and the Arabian Pavement, which is also divided into two parts, the stable pavement and the unstable pavement in which the area is located studying **(Fayyad, 2008, p. 6)**. The Miocene age is one of the most widespread formations of the third age in the study area, and its most important components are gypsum, silt, limestone, sand, and gravel **(Al-Jumaily, 1990, p. 11)**.

The study area has been divided into low plateaus and erosional surfaces since the Tertiary period due to the erosion of the lands that curl up and rise with the effect of rivers and winds. The lower parts are areas where sedimentation occurs, and karstic shapes are seen where rocks suitable for chemical dissolution are common.

CHAPTER THREE

3. MORPHOMETRIC ANALYSIS OF THE BASINS

Definition of Morphometry

"The study of water basins is of great importance to scholars and those interested in geomorphological field because of its direct impact on the hydrological features" **(Arthar, 1964, p. 239)**.

"As the water drainage system of valleys and the formation of sediment is related to those features that lead to a change in the surface features and produce sedimentary and eroded forms" **(Mkola, 1986, p. 28)**. The quantitative morphometric study is of great importance because it has become of modern trends that depend on the quantitative statistical and mathematical analysis in studying geomorphological shapes and features on the earth's surface. Quantitative studies are interested in both large and small river basins alike. Since the characteristics of river basins can be measured quantitatively, the investigation of drainage basins relies on quantitative morphometric models **(Al-Bibwati, 1995, p. 61)**. Analysis of morphometric parameters, terrain Before starting the surveys, the hydrological, about the topographic and geological condition It keeps us informed. With the help of GIS, morphometric, also called geomorphometry numerical measurement and analysis of features compared to the past can be done more easily and automatically **(Görgülü and Göl, 2021, p.107)**.

Geomorphologists are concerned with river basins formed by erosion and deposition by water and wind and the landforms they form. The valleys of the study area are among the basins that we will try to subject their landforms for morphometric quantitative analysis and study to prepare a developmental plan to construct the region, benefiting from its natural and human resources. Within the scope of morphometric analysis, a variety of numerical transactions were produced in which a basin compared to the other basin and the differences in which the basin is in which stage of the basin or the development of the stream network **(Öztekinci and Coşkun, 2021, p. 258)**. The study area consists of a group of basins, the most important of which are the Al-Shakrea Stream basin, Al-Auqood Stream basin, and Al-Samtheai

Stream basin. Map 9 shows the valleys in the study area. Each valley and its branches will be subjected to a quantitative study **(Jwda, 1991, p. 269)**. Studying the basins by the morphometric method is due to several reasons, the most important of which are:

- Rivers' basins have an area unit with characteristics that can be measured quantitatively and thus analyzed, classified, and compared.
- River basins include a group of streams arranged in a complete series.
- It can be treated river basins as a unit or a working system into which a quantity of power enters (sunlight, rainfall) and gets out like a river discharge and load.

Thus, **Horton (1945)** was able to combine form and process in one quantitative field. The morphometric characteristics are directly related to the natural features represented by the geological structure, the quantity of soil, rocks, vegetation, climate, and time. *"The morphometric study of the basins of the study area was carried out based on remote sensing technology and GIS software using"* **(Hamdan and Abu-Amra, 2010, p. 596)**. **ArcGIS P. 10.8 Program** and the digital elevation model (DEM) and satellite visuals with a discriminatory accuracy of 30×30 m and topographic maps at different scales and **Global Mapper Program**.

The morphometric analyzes in the research area were divided into three (3) groups as linear, areal, and relief parameters. The formulas applied to the basins in the field, and their references are shown in **Table 14**.

Table 14. Morphometric Parameters, Their Formulas and References Applied to the Study Area

Morphometric Parameter		Formula	Reference
Linear Parameters	Stream Length Ratio (Rl)	The mean length of a stream of a given order/Mean length of the next lower order stream in the same basin	Horton (1945)
	Bifurcation Ratio (Rb)	The stream numbers of any rank/The stream numbers of the following rank	Schumn (1956)
	Texture Ratio (Rt)	Total number of first stream orders/The basin perimeter	Smith (1950)
Areal Parameters	Circularity Ratio (Rc)	The basin area/The circle area with a circumference equal to the basin perimeter	Strahler (1964)
	Elongation Ratio (Re)	The length of circle's diameter with the area of the basin/The maximum length of the basin	Schumn (1956)
	Form Factor / Basin Shape (Rf)	Basin area/Square length of the basin	Horton (1945)
	Drainage Density (Dd)	The total length of waterways/Basin's area	Horton (1945)
	Stream Frequency (Fs)	Total number of valleys/Basin's area	Horton (1945)
	Infiltration Number (If)	Stream frequency x Drainage density	Faniran (1968)
Relief Parameters	Basin Relief (Bh)	Maximum height – Minimum height	Schumn (1956)
	Relief Ratio (Rr)	The difference between the highest and lowest points of the basin/The basin length	Schumn (1963)
	Hypsometric Curve (Hc)	Relative height/Relative area	Strahler (1952)
	Hypsometric Integral (Hi)	Mean height – Minimum height/ Maximum height −Minimum height	Strahler (1952)
	Gravelius Index (Compactness Coefficient) (Kg)	The basin perimeter / 2√ (The number pi * The basin area	Gravelius (1914)
	Ruggedness Number (Rn)	Basin relief × Longitudinal drainage density /1000	Strahler (1958)

3.1. Linear Morphometric Characteristics of the Basins

Determining the linear morphometry of the Al-Shakrea, Al-Auqood, and Al-Samtheai streams, which is the main factor in shaping the basin, is a priority compared to other parameters **(Table 15)**. Linear Morphometric Parameters applied in the basins, which are Basin Length (L), Maximum Basin Width (W), Stream Length Ratio (Rl), Bifurcation Stage, Bifurcation Ratio (Rb), and Texture Ratio (Rt).

Table 15. Linear Morphometric Characteristics of the Basins

Basin name	Basin length (L)	Maximum basin width (W)	Stream length ratio (Rl)	Bifurcation ratio (Rb)	Texture ratio (Rt)
Al-Auqood	33.12	6.72	1.82	4.78	1.18
Al-Shakrea	34.34	8.34	1.76	4.9	1.15
Al-Samtheai	17.88	3.67	1.58	5.25	0.47

3. 1. 1. Basin Length (L)

"According to the Walling and Gregory method, watershed length is one of the important basic dimensions in calculating some morphometric parameters and the distance measured from the lowest point in the basin to the farthest point around the basin" **(Gorliy, 1979, p. 61)**.

It is clear from **Table 15** that the total length of the basins of the study area is 85.34 km, while the main basins, such as Al-Shakrea Stream basin, is 34.34 km as the most extended basin in the study area. Al-Auqood Stream basin, which is the second-longest basin, is 33.12 km. In comparison, the shortest one is Al-Samtheai Stream basin, 17.88 km. The diversity of length of these basins is due to the severity of one of the dimensions from one basin to another. Accordingly, the greater the length and width, the greater the basin area. Also, the diversity in the length of the water basins reflects the diversity in the degree of the slope and relief. Therefore, they have a direct relationship since the highest slope is in Al-Shakrea and Al-Auqood streams. The lowest slope in Al-Samtheai Stream indicates their compatibility. It is also noted that basins of the study area, in general, are increasing in length and are classified as basins of large length due to the lack of topographical complications and their association with linear structures.

3. 1. 2. Maximum Basin Width (W)

"It means the straight distance between two farthest points on the perimeter of the basin, and it is one of the important morphometric parameters which helps to determine the form of the basin by the rate of width to length" **(Mahsub, 2001, p. 62)**. If the basin expands from its two sides, it has a round shape, and if it extends from one side, it is approaching the triangular shape. While if it develops on two opposite sides, it will be close to an oval **(Salloum, 2012, p. 376)**.

The basin length is proportional to width, as the more significant the width of the basin concerning its length, the faster the water reaches the mainstream almost at the same time because of the lack of its lost water, which leads to an increase in the capacity of the mainstream in a specified period and thus a high percentage of the risk of flooding **(Mahsub, 2001, p. 205)**. In contrast with this, the basins, which are very long concerning their width, are characterized by their continuous flow for a long time to reach the mainstream, which leads to an increase in the amount of lost water by evaporating or sedimentation, which leads to the low percentage of the risk of flooding **(Al-Saud, 2015, p. 12)**. The relations between maximum basin width and the basin length provide information about the fluvial characteristics of the basins. In basins where these two values are close to each other, circularity is high. On the other hand, as the difference between the maximum basin width and the basin length grows, the basin acquires a longitudinal appearance **(Arslantaş Dik, 2021)**.

It is clear from Table 15 and Map 10 that the maximum width in the basins of the study area is in the Shakrea basin with the highest width of 8.34 km, and the second is the maximum width of the basin in the Al-Auqood basin with an area of 6.72 km, and the lowest recorded is in the Al-Samtheai basin It reached 3.67 and showed clear differences from other currents. It means that there is a direct relationship between the maximum width of the basin and its area, which leads to a decrease in the risk of flooding in the basins of the study area.

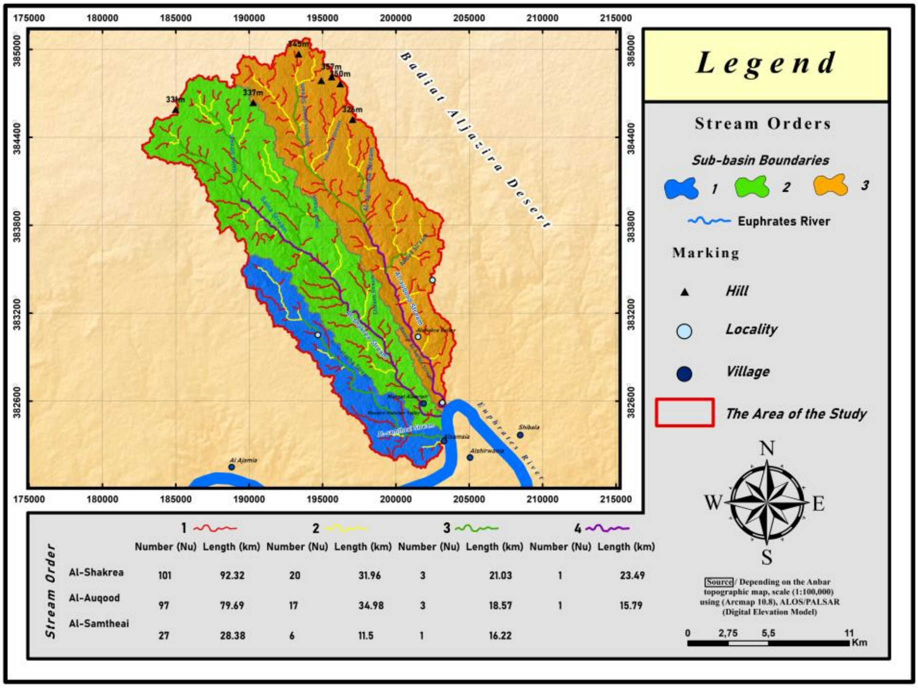
3. 1. 3. Stream Length Ratio (Rl)

The importance of studying the lengths of the waterways lies in determining the speed of water flow. The long valleys do not have high water flow velocity, unlike the short valleys, which decrease with the increase in length in the valley basins. The measurements of the waterways reflect the geological, topographic, and climatic nature of the study area, as shown in **Table 15** and **Table 16**. Stream length ratio is expressed by the following formula **(Horton, 1945; Jaganathan, Annaidasan, Surendran and Balakrishnan, 2015)**.

$$\text{Stream length ratio} = \frac{\text{The mean length of a stream of a given order /km}}{\text{Mean length of the next lower order stream in the same basin}}$$

Table 16. Lengths (km) and Ratios ($R\iota$) of the Stream Orders in Basins in the Study Area According to the Strahler Method

Stream Name	Length and Ratio	Length Ratio				Average
		1. Order	2. Order	3. Order	4. Order	
Al-Auqood	Length	79.69	34.98	18.57	15.79	37.25
	Ratio	2.41	1.88	1.17	-	1.82
Al- Shakrea	Length	92.32	31.96	21.03	23.49	42.2
	Ratio	2.88	1.52	0.89	-	1.76
Al-Samtheai	Length	28.38	11.5	16.22	-	18.7
	Ratio	2.46	0.71	-	-	1.58



Map 10. Bifurcation Stages, Numbers of Stream Order (Nu) and Lengths of Stream Order of the Basins in the Study Area According to Strahler Method

The stream length ratios of the three (3) basins in the study area were calculated **(Table 16)**. The longest stream, Al-Shakrea, has a length ratio of 1.76, Al-Auqood has a length ratio of 1.82, and the shortest, Al-Samtheai, has a length ratio of 1.58. Basins with high circularity also have a high river length ratio. Since the basins in the study area are far from circularity, the river length ratios are also low.

3. 1. 4. Bifurcation Stage and Bifurcation Ratio (Rb)

As a drainage network is established in a region, streams grow and develop by taking new branches. It is important to have information about the evolution of the streams, the age of the network, and the stage of its development. Various methods have been developed to take advantage of the number and lengths of stream tributaries for their detection. **Horton (1945)**, **Strahler (1952)**, and **Shreve (1967)** are some of them. In this study, stream orders were handled according to the Strahler method. *"The streams in the basin are ordered in a hierarchical rank according to their sizes"* **(Atalay, 2018, p. 157)**. According to Strahler method, this rank starts in the source part of the basin. Two 1st orders merge to form 2nd orders. Two second orders merge to form the 3rd orders. This progression continues until the mainstream branch. The mainstream, on the other hand, creates the last row and the largest numbered string **(Figure 8)**.

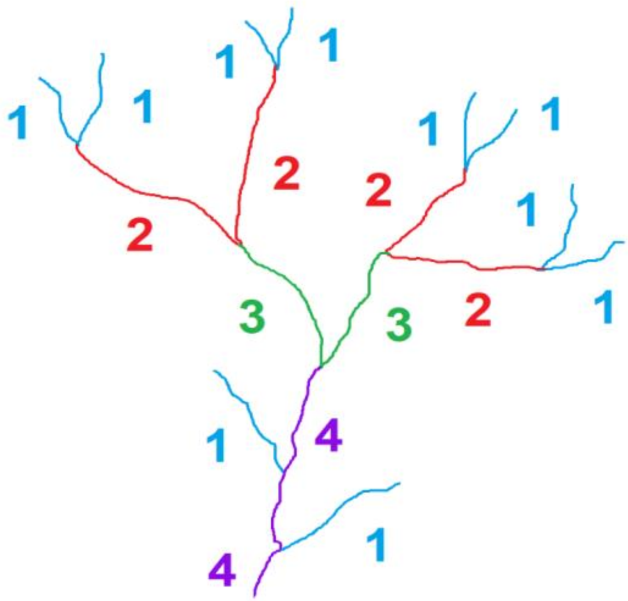


Figure 8. Stream Order Numbers According to Strahler (1952)

The valleys of the study area included four (4) bifurcation stages, where the first place is ranked on 225 valleys with a total length of 200.39 km. In contrast, the second place is ranked on 43 valleys with a total length of 78.44 km, while the third place is ranked on seven (7) valleys with a total length of 55.82 km. Fourth order contains two (2) valleys with a total length of 39.28 km. The total arrangement of the rivers in the study area was 277, and their length is 373.93 km, as shown in **Table 17**.

As for the basins of the study area, it reaches the first order of the Al-Shakrea basin, which is one of the largest basins in the study area. The number of stream courses in it reaches 101 valleys, with a total length of 92.32 km. Total 20 second-order number reaches 31.96 km for the Al-Shakrea basin. As for the third order of the basin itself, the number of valleys reaches three (3), with an estimated length of 21.03 km. As for the fourth and last order, the number of valleys is one (1), with an estimated length of about 23.49 km for the Al-Shakrea basin. The total number of stream orders is 125, and its length is 168.8 km.

Table 17. Numbers of Stream Order (Nu) and Lengths of Stream Order of the Basins in the Study Area According to Strahler Method

Stream name	Stream orders									
	1		2		3		4		Total	
	Number (Nu)	Length (km)	Number (Nu)	Length (km)	Number (Nu)	Length (km)	Number (Nu)	Length (km)	Number (Nu)	Length (km)
Al-Auqood	97	79.69	17	34.98	3	18.57	1	15.79	118	149.03
Al-Shakrea	101	92.32	20	31.96	3	21.03	1	23.49	125	168.8
Al-Samtheai	27	28.38	6	11.5	1	16.22	-	-	34	56.1
Total	225	200.39	43	78.44	7	55.82	2	39.28	277	373.93

As for the valleys, the Al-Auqood basin reaches the first order of the basin, and it is the second-largest basin in the study area. The number of stream courses in it reaches 97 valleys with a total length of 79.69 km. As for the second order of the same basin, the number of watercourses in it reaches 17 valleys with a length of 34.98 km for the Al-Auqood basin. As for the third order of the basin itself, the number of valleys got three (3) valleys with an estimated length of 18.57 km. As for the fourth and last place, the number of valleys is one (1), with an estimated length of about 15.79 kilometers for the Al-Auqood basin. The total number of stream orders is 118, and its length is 149.03 km.

As for the valleys Al-Samtheai basin, it reaches the first order of the basin, and it is the smallest basin in the study area. The number of stream courses in it reaches 27 valleys with a total length of 28.38 km. As for the second order of the same basin, the number of watercourses in it got six (6) valleys with a length of 11.5 km for the Al-Samtheai basin. As for the third order of the basin itself, the number of valleys has reached one (1) valley with an estimated length of 16.22 km. This basin only consists of three levels, unlike the other basins, all of which can be seen in **Table 17** and **Map 10**. The total number of stream orders is 34, and its length is 56.1 km.

Table 18. Bifurcation Ratios of the Stream Orders in the Study Area According to the Strahler Method

Stream Name	Stream Order Number and Length	Bifurcation Ratio				Total Stream Order and Average Bifurcation Ratio
		1. Order	2. Order	3. Order	4. Order	
Al-Auqood	Number	97	17	3	1	118
	Ratio	5.70	5.66	3	-	4.78
Al- Shakrea	Number	101	20	3	1	125
	Ratio	5.05	6.66	3	-	4.9
Al-Samtheai	Number	27	6	1	-	34
	Ratio	4.5	6	-	-	5.25

With the determination of the bifurcation ratio, it is an important index of which the site is half by the streams and at the same time to give significant tips on what the criteria affecting the fluvial process are **(Polat, 2019, p. 315)**.

These ratios may be similar in basins with similar climates and geological structures. Basins with a bifurcation ratio between 3.0 and 5.0

indicate homogeneous lithology with low topographic roughness. This result also demonstrates that tectonics does not significantly affect river valleys **(Schumn, 1956; Strahler, 1964; Turoğlu and Aykut, 2019).** The high bifurcation ratio indicates the cyclical flow characteristics in the river basins where infiltration is also high **(Strahler, 1964)**.

It is the ratio between the water channel numbers of one order to those of a higher order **(Al-Dulaimi, 2005, p. 157).** It relates the streams' numbers in two consecutive orders **(Al-Dulaimi, 2005, p. 272)**. It is one of the essential criteria used in geomorphological and hydrological studies where the discharge rate depends. And it is expressed by the following equation **(Abu Al-Enein, 1977, p. 272)**.

$$\text{Bifurcation ratio} = \frac{\text{The stream numbers of any rank}}{\text{The stream numbers of the following rank}}$$

General bifurcation ratio is derived by dividing the sum of the ratios by their numbers. By applying the equation to the stream Al-Shakrea basin, it was found that the bifurcation ratio is 5.05 for the first category and 6.66 for the second category of basins in the region. As for the basins of the third category in the basin, the bifurcation ratio is three (3), and the arrangement of the fourth category is one of the smallest 1 in the Al-Shakrea basin. The total bifurcation ratio of this stream is 4.9.

By applying the equation to the stream Al-Auqood basin, it was found that the bifurcation ratio is 5.70 for the first category and 5.66 for the second category of basins in the region. As for the stream beds of the third category in the basin, the bifurcation ratio is 3, in the Valley of Al-Auqood Basin. Stream beds increase in the study area whenever the climate is rainy, and the area of the basins increases. The total bifurcation ratio of this stream is 4.78. The bifurcation ratio is the primary controller of the discharge density and lack of run-off. By studying the water networks of the basins and streams of the study area, we deduce the correlation between the streams' numbers and length and between the area. Since the number and length of streams increase according to the increase of area, the thing is apparent in **Table 18**.

While the general bifurcation ratio is derived by dividing the sum of the ratios by their numbers, by applying the equation to the basins of the study area, it was found that the bifurcation ratio of the stream Al-Samtheai basin was 4.5 for the first order and 6 for the second order. The total bifurcation ratio of this stream is 5.25.

Considering these results, the basin with the lowest probability of flooding is the Al-Samtheai basin, with a bifurcation rate of 5.25, since infiltration is higher in the study area. The basin with the highest flood generation capacity in the field was the Al-Auqood basin with 4.78. Al-Shakrea basin is located in the middle of the other two basins with a value of 4.9.

The streams develop in the large basins and increase in length and number, unlike those of small basins taking the impact of climate into account **(Almumini, 1969, p. 122)**.

3. 1. 5. Texture Ratio (Rt)

It expresses the extent of the relief of the earth's surface and its cutoff by waterways if the basins are closer. In addition to their increasing numbers, this indicates the severity of the cut **(Mazara and Al-Barudi, 2005, p. 218)**.

The basin tissue is closely related to many features: tectonic region, rock nature, and how resistant to water erosion in the areas of solid rocks (granite, gneiss, quartzite), which are resistant to erosion. The topographic tissue of these rocks is coarse. Unlike the weakly resistant rocks (marl, clay, and alluvium), where the basin tissue is affected by the degree of permeability of rocks **(Eilaji, 2010, p. 82-84)**. The lower the permeability, the greater the chance of water erosion, which contributes to various channels, so the topographic softness prevails in the basin and vice versa. When the rocky cover has high permeability, this weakens the ability of surface runoff to erode, so the basin tissue becomes coarse, in addition to vegetation since plenty of vegetation reflects a rough tissue and vice versa. Since it has an essential role in regulating surface runoff, the regions with no vegetation are characterized by topographic soft tissue becoming the sudden and quick shower, which creates new water channels **(Abu Raya, 2007, p. 56)**.

Smith (1950) divided the basins according to the drainage distribution into three categories, less than four (4) stream /km^2 a coarse tissue, between 4-10 stream/km^2 medium tissue, and more than ten (10) stream /km^2 a soft tissue. The basin texture coefficient is extracted according to the following equation **(Al-Dulaimi, 2017, p. 82)**.

$$\text{Texture ratio (Rt)} = \frac{\text{Total number of first stream orders}}{\text{The basin perimeter/km}}$$

The basins of the study area are one of the basins with coarse tissue, according to **Smith (1950)**. The average of the basin tissues is 1.15 in the Al-Shakrea stream, as shown by the results, the basin is very steep, 1.18 in the Al-Auqood Stream Basin, as it is clear from the results, that the basin is very steep, and 0.47 in the Al-Samtheai stream. Basin as shown in the results, the basin has little incline, with the lowest rate, as shown in **Table 15**. All basins contain the coarse tissues mentioned above.

This situation indicates the permeability of rocks, the ability of the lithosphere to infiltrate the water underground, which reduces the surface run-off, and the power of water erosion, in addition to the lack of vegetation and mastery of linear phenomena which determined the waterways paths.

3. 2. Areal Morphometric Characteristics of the Basin

While linear parameters only provide the opportunity to comment on the drainage network, the areal parameters allow interpretation on both the drainage network and the entire basin surface **(Ritter, Kochel, and Miller, 1995)**. Spatial Morphometric Parameters applied in the Basin are Basin Area (A), Basin Perimeter (P), Circularity Ratio (Rc), Basin Length Ratio (Re) Form Factor/Basin Shape (Rf), Valley Density (Dd), Stream Frequency (Fs), Infiltration Number (If).

Table 19. Areal Morphometric Characteristics of the Basins

Basin name	Basin area (A)	Basin perimeter (P)	Circularity ratio (Rc)	Elongation ratio (Re)	Form factor/ Basin shape (Rf)	Drainage density (Dd)	Stream frequency (Fs)	Infiltration number (If)
Al-Auqood	124.13	81.64	0.21	0.37	0.11	1.20	0.95	1.14
Al-Shakrea	132.88	87.35	0.21	0.37	0.11	1.27	0.94	1.19
Al-Samtheai	46.37	56.42	0.28	0.42	0.14	1.20	0.73	0.87
Total	303.38	225.41	-	-	-	-	-	-

3. 2. 1. Basin Area (A)

"It is one of the important morphometric properties of the basin and their tributaries with water drainages. It can be determined according to the division of water and its sources" **(Salama, 2010. p. 138)**.

The study of the basin area is significant for morphometric and hydro morphometric analyses. There is a direct relation between the length of the valleys and the area of the basins. The watercourses of the basins get taller regarding the geological and climate conditions, unlike the basins of small areas (**Al-Sahaaf and Mohammed, 1988, p. 794)**. In addition to that, the basin area affects the amount of rain falling on the basin. The actual value of running water varies from one basin to another according to the geographical site, type of rocks, climatic conditions. Depending on the permeability and precipitation-temperature characteristics of these basins around the Euphrates River, there is a relationship between sediment deposition in the basin.

On the other hand, the area of the basin affects the amount of groundwater according to the volume of recharge. The larger the basin area, the greatest the opportunity for underground nutrition, especially the recharge area. It was noted that the basins of the study area are characterized by small regions of the source area, which indicates that the underground recharge is very weak compared to large valleys **(Abu Al-Enein, 1990, p. 68)**.

It is evident in Table 19 that the total area of the study area is 303.38 km^2. And it was divided into three main basins as shown in Map 10 varying in area from one basin to another. The largest one is the Al-Shakrea Stream basin, 132.88 km^2 of the total area with 43.79%. The second one is the Al-

Auqood Stream basin 124.13 km^2 with a rate of 40.91%, and the third one is the Al-Samtheai Stream basin which is the smallest one 46.37 km^2 with a rate of 15.28%.

The variety of the basins area is due to the environmental conditions and local and natural array of rocks since there is a relation between the nature of rocks and the area of the basin, which increases because of the deposits of the quaternary period and the sand, limestone, dolomitic and gypsum rocks which can. Interact with water and general activation of dissolving by chemical weathering, so it is noted that Al-Shakrea stream basin is the largest one of the total area and contains Rakta and Al-Ghar affleurements and deposits of quaternary period. The variety of affleurements contributed significantly to the expansion of the basin area. And the dissolving factor activates in the rock formations, such as the calcareous ones. The diversity of linear structure and the variety of capacity directions are apparent in Al-Shakrea and Al-Auqood streams, while Al-Samtheai Stream is the smallest basin. It can be noted the lack of diversity of rock formation except Al-Ghar Formation and the lack of linear structures.

But according to the current climate, its amount of rain doesn’t contribute to increasing the area of the basin, deepening its drainages, and activating the erosion, unlike the ancient climate of Pleistocene, which greatly contributes to developing the area of the basin and the formation of water basins and deepening their drainages. In contrast, the effect of the slope is small because of the gradual and straightforward gradient. However, the increase of the gradient rate is observed within Al-Shakrea and Al-Auqood stream basins that occupy the largest area of the entire basin in **Table 19**. According to the soil, it contributes to the expansion of the basin area as high as the permeability and porosity of the soil is due to its low resistance to water erosion when the soil with low permeability is more resistant to water erosion, the thing that leads to a small area of the basin and the multiplicity of terrain.

The soil of the study area is characterized by different restraint to erosion processes. According to natural vegetation, the study area is considered one of the vegetation of the poor area, which has its role on the expansion of basin area through its direct effect on the wind and water erosion. Therefore, the increase of natural vegetation contributes to obstructing surface run-off and reducing erosion and the obstruction of oblation. In the light of this, it appears that the water basins vary in their water output and the amount of water drainage and supply the mainstream with water.

3. 2. 2. Basin Perimeter (P)

It means the water dividing line that surrounds the basin from the highest point to separate one basin from the next. *"The perimeter is one of the basic morphometric parameters for its other morphometric properties (such as the area, the form, the circulatory, the elongation, the width, and the length) of the basin"* **(Al-Dulaimi, 2012, p. 155).** As shown in **Table 19** and **Map 10**, the study area's total perimeter is 225.41 km. According to the calculations, the perimeter of the Al-Shakrea Stream basin is 87.35 km, which is higher than the other basins. The perimeter of the Al-Auqood Stream basin is 81.64 km, and the perimeter of the Al-Samthei Stream basin is 56.42 km. The perimeter gives information about the basin. While the perimeter of young basins is longer, it is seen that this value decreases as time passes.

3. 2. 3. Circularity Ratio (Rc)

Knowing the circulation ratio leads to understanding the basin's form. The value is high as the basin form is close to circular shape and vice versa; the lower value indicates that the basin is far from the circular form. The circulation ratio of the basin is extracted according to the following equation **(Al-Dulaimi, 2005, p. 268)**:

$$\text{Circulation ratio} = \frac{\text{The basin area}}{\text{The circle area with a circumference equal to the basin perimeter}}$$

When this equation was applied to the study area, it concluded that the region's basins are far from the circular shape but close to being rectangular. As for the water dividing lines are extend irregularly and pass through a lot of meanders which leads to lengthening of drainages, especially in the least river orders which are located near the water dividing lines which contribute to river capture in the nearby areas that overlap with basins **(Al-Obaidi, 2005, p. 77)**.

The basins of the study area are far from the circular shape due to many factors, the most important of which is the geological factor represented by the slope of the ground layers, which takes south to north direction because the region is affected by the Alpic movement that occurred in the third geological era, which culminated in the Miocene. When the equation was applied on basins of the study area, it was clear that the circulation ratio was 0.21 in Al-Shakrea Stream, 0.21 in Al-Auqood Stream, and 0.28 in Al-Samtheai, which indicates that all the basins are far from the circular shape due to the reasons as mentioned above. These ratios are evident in **Table 19**.

$$\text{The circulation ratio} = \frac{\text{The area of the basin/km}^2}{\text{The area of its perimeter circle=the basin perimeter/ km}^2}$$

$$\text{Circumference ratio} = \frac{\sqrt{1}}{\text{Circulation rate}}$$

$$\text{The circulation ratio} = \frac{\text{The length of circle's diameter with the same area of the basin}}{\text{Maximum length of the basin}}$$

$$\text{Basin form parameter} = \frac{\text{The area of the basin km}^2}{\text{Basin length square km}^2}$$

3. 2. 4. Elongation Ratio (Re)

"This ratio determines how close the basin is to rectangular shape, unlike the circulation rate since when the number is close to zero, this means that the form is close to a rectangular shape" **(Al-Bibwati, 1995, p. 67)**. While the number one (1) means that the basin is circular, and zero (0) means that it is rectangular. This equation can extract this ratio:

Table 20. Basin Form Classification According to Strahler (1964)

Elongation Ratio (Re)	Basin Form
> 0.9	Circular
0.9 – 0.8	Oval
0.8 – 0.7	Less Long
0.7 – 0.5	Long
< 0.5	Too long

$$\text{Elongation ratio} = \frac{\text{The length of circle's diameter with the area of the basin}}{\text{The maximum length of the basin}}$$

By applying this equation to the study area, it was clear that the ratio was 0.37 in Al-Shakrea Stream, 0.37 in Al-Auqood Stream, and 0.42 in Al-Samtheai Stream, which means that these basins are far from a circular shape, as shown in **Table 19**. The thing which caused the water waves not to reach the stream simultaneously means that the risk of flooding in the rectangular basins is less intense than basins of circular shape. This affects the formation of the earth's forms in these basins. The geomorphological processes by running water are determined by the distance and the speed of run-off. The basins of the study area are all very long, as shown in **Table 19** and **Table 20**.

3. 2. 5. Form Factor / Basin Shape (Rf)

It is an index ranging from 0-1. The closer the result is to zero (0), the more elongated the basin shape it has. Basins, where the value is close to one (1) are close to circular shapes **(Alniqash and Al-Sahaaf, 1989, p. 522)**. The following equation calculates it:

$$\text{Basin form} = \frac{\text{Basin area /km}^2}{\text{Square length of the basin/km}^2}$$

Knowing how close the basin is to the triangle shape helps determine the speed of the water waves to reach the mainstream of the valley. This parameter is essential for knowing the hydrology and hydrography of the triangular shape of the basin. In this case, there are two possibilities. The first is that when the water flows from the base of the triangle towards the head (like most of the valleys of the region west of Euphrates River in the northern Iraqi desert), the danger of flooding is less, while the second case is that when the estuary is at the base of the triangle, the drainage culminates directly after rainfall **(Al-Bibwati, 1991, p. 99)**.

By applying the equation, the result was 0.11 in Al-Shakrea Stream, 0.11 in Al-Auqood Stream, and 0.14 in Al-Samtheai Stream, as shown in **Table 19**. This means that the basin is far from the triangular shape, affecting the sedimentary geomorphological processes and water erosion in the stream.

3. 2. 6. Drainage Density (Dd)

"It is calculated by the relative relationship between the length of the waterways (density) and the drainage area (reserve the quota of each one square kilometer of the basins area from the water drainage)" **(Al-Daghiri and Bourouba, 2017, p. 46)**. It is extracted from that according to **Horton (1932)** the following equation:

$$\text{Drainage density} = \frac{\text{The total length of waterways/km}}{\text{Basin's area /km}^2}$$

From **Table 19**, it was found that the rate of longitudinal drainage in all basins of the study area is low. It reached 1.27 in Al-Shakrea Stream basin, 1.20 in Al-Auqood Stream basin, and 1.20 in Al-Samtheai Stream basin, as it is shown that the ratios are similar for all regions. The drainage density of these regions is low and has coarse tissue due to the rocks of the formations of Euphrates, Al-Fatha, and Al-Nafiel, and the leakage of water inside the rocks, and the lack of running water.

3. 2. 7. Stream Frequency (Fs)

The density of the number of waterways is concluded according to the following equation **(Horton, 1932)**:

$$\text{Stream Frequency} = \frac{\text{Total number of valleys}}{\text{Basin's area /km}^2}$$

Both active and dry stream beds were taken into account in this assessment. From **Table 19**, it was found that Stream Frequency in the study area and its basins reached 0.94 in Al-Shakrea Stream basin, 0.95 in Al-Auqood Stream basin, and the lowest recorded in Al-Samtheai Stream basin amounted to 0.73. These numbers give the length per square kilometer.

All the basins of the region' valleys recorded similar values, with very few variations, due to several factors, including **(Turab, 1993, p. 273)**:

- The existence of local topography (plateaus, hills) of low altitude, resulting in heterogeneity of the surface of the area.

- The high permeability of limestone and gypsum rocks in the formations of Euphrates River, Al-Fatha, and Al-Nafail, leakage of large amounts of rainfall.
- Homogeneity in the rock layers in the formation of these valleys.
- Covering a large area of the surface with recent sediments.
- Lack of vegetation cover leads to water and wind erosion.
- Prevalence of soft-textured dendritic drainage pattern.

3. 2. 8. Infiltration Number (If)

The infiltration number of a basin is defined as the product of the drainage density and the stream frequency and gives an idea about the infiltration characteristics of the basin.

The infiltration number of a basin is defined as the product of the drainage density and the stream frequency and gives an idea about the infiltration characteristics of the basin **(Rai, Chaubey, Mohan and Singh, 2017; Rai, Mishra and Mohan, 2017; Rai, Chandel, Mishra and Singh, 2018)**.

Infiltration Number (If) = Stream Frequency (Fs) x Drainage Density (Dd)

The infiltration number (If) shows the relationship between drainage density and stream frequency. It indicates the presence of many ephemeral streams or long streams in the study area. If the percentage is low, this means a high rate of infiltration number in the study area, but if the value is high, it means a low infiltration number in an area. The study area and as shown in the table, the percentage of infiltration number in the basin of stream Al-Shakrea was 1.19 and in the basin of stream Al-Auqood 1.14 and the basin of stream Al-Samtheai 0.87. Infiltration numbers were low in all three basins in the study area. The excessive infiltration should be due to the prevalence of cracked limestones in the field **(Table 19)**.

Öztürk (2020) emphasized that the surface flow slows down relatively in areas where karst topography is typical. According to these results, it can be said that the surface flow is the slowest in the Al-Samtheai Stream basin, which has the lowest infiltration number. This is supported by the high bifurcation ratio (5.25), which indicates the excess seepage in the same basin.

3. 3. Relief Morphometric Characteristics of the Basins

The relief features of the basin express its three-dimensional structure. The indices used in determining the basin relief of the study area are Elevation (E), Slope (S1), Aspect (As), Basin Relief (Bh), Relief Ratio (Rr), Hypsometric Curve (Hc), Hypsometric Integral (Hi), Gravelius Coefficient (Kg) Ruggedness Number (Rn) **(Table 21)**.

3. 3. 1. Elevation (E)

The study area was divided into five categories, from 120 m height to 360 m above sea level **(Figure 9, Map 11, and Table 21)**. The following is an explanation of these categories:

Table 21. Relief Morphometric Characteristics of the Basins

Basin name	Basin relief (Bh)	Relief ratio (Rr)	Hypsometric integral (Hi)	Gravelius coefficient (Kg)	Ruggedness number (Rn)
Al-Auqood	218	0.0065	0.59	2.06	0.26
Al-Shakrea	204	0.0059	0.58	2.13	0.25
Al-Samtheai	143	0.0079	0.46	2.33	0.17

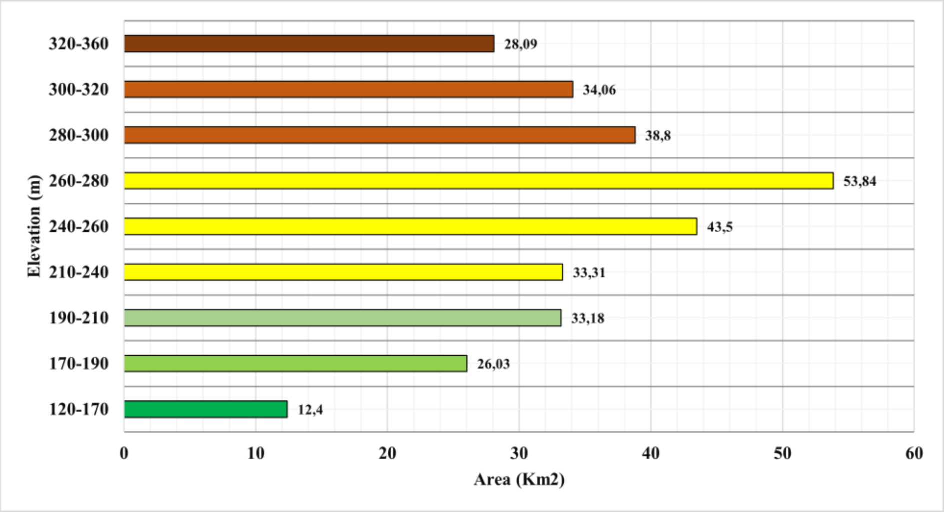


Figure 9. Altitude Categories in the Study Area

Table 22. Areas and Percentages of Elevation Categories in the Study Area

	Categories (m)	Area (km^2)	Percentage (%)
1	120-170	12.4	4.09
2	170-190	26.03	8.58
3	190-210	33.18	10.92
4	210-240	33.31	10.95
5	240-260	43.5	14.32
6	260-280	53.84	17.73
7	280-300	38.8	12.80
8	300-320	34.06	11.21
9	320-360	28.09	9.23
Total		303.21	99.83

3. 3. 1. 1. The First Category

It includes areas with height ranges between 120-170 m above sea level, with an area of 12.4 km^2 and a rate of 4.09%. It is represented in the south of the study area, specifically at the flood plain of the Euphrates River, and it is the smallest percentage recorded in the study area.

3. 3. 1. 2. The Second Category

It has an area of 26.03 km^2, including areas whose height ranges between 170-190 m above sea level with a rate of 8.58%. This category is larger than the first category in the study area and appears parallel in its distribution with the first category.

3. 3. 1. 3. The Third Category

It includes areas whose height ranges between 190-210 m above sea level, with an area of 33.18 km^2 and a rate of 10.92%. They are found in the southern and central regions of the study area.

3. 3. 1. 4. The Fourth Category

It includes areas whose height ranges between 210-240 m above sea level. Map 11 shows the location of this category with the middle of the valley and gradually takes place in the west and east of the study area, with an area of 33.31 km^2, while the rate was similar compared to the previous three categories, reaching 10.95%.

3. 3. 1. 5. The Fifth Category

It covered an area of 43. 5 km^2, including areas whose height ranges between 240-260 m above sea level, at the rate of 14.32%. This category is considered more extensive than the previous ones and is located within the study area’s middle, northern and eastern regions.

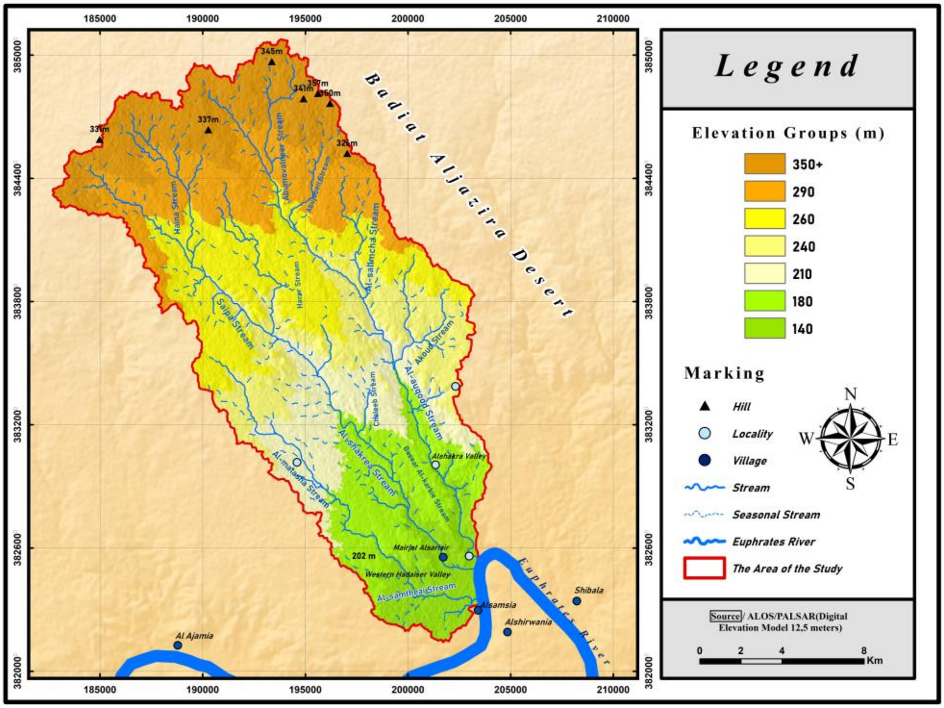
Photograph 31. The quarries within the sixth category in the northern section of the Al-Auqood Stream basin

3. 3. 1. 6. The Sixth Category

It includes areas whose height ranges between 260-280 m above sea level, with an area of 53.84 km^2 and a rate of 17.73% of the region's area. It is one of the largest categories recorded in the study area. It includes some of the central section, some northern regions, and the outskirts of the study area's basin from the western and eastern sides.

3. 3. 1. 7. The Seventh Category

It covered an area of 38.8 km^2, including areas whose height ranges between 280-300 m above sea level, at a rate of 12.80%. It is limited to some western and northwestern sections of the study area and some eastern parts.



Map 11. Digital Elevation Model Map (DEM) of the Study Area

3. 3. 1. 8. The Eighth Category

It includes areas which height ranges between 300-320 m above sea level, with an area of 34.06 km^2 and a rate of 11.21% of the research area. It is limited to the northern sections of the study area and the edges of the valley's basin from the northeastern and northwestern sides.

3. 3. 1. 9. The Ninth Category

It includes areas which height ranges between 320-360 m above sea level. It is considered one of the highest regions in the study area. It occupies an area of 28.09 km^2 and a rate of 9.23% of the area, which has the northeastern western edges of the basins, one of the basin's highest regions.

From what was previously mentioned, it is clear that the highest altitude was within the ninth category, which ranges between 320-360 m above sea level, located in the northeastern part of it, with an area of 28.09

km^2. There is a rate of 9.23%, and its percentage is almost low in the study area. While the lowest altitude was within the first category 120-170 m above sea level with 4.09%. This category includes Fatha Formation, one of the region's most plentiful formations, consisting of gravel and sand quarries **(Photograph 31)**. The most common elevation range in the study area is 260-280 meters, with an area of 53.84 km^2 and a rate of 17.73%.

3. 3. 2. Slope (Si)

The study of the slope is of great importance in practical studies of geography due to the relationship between slope and human activities such as agriculture and settling, as well as the critical role of the hydrology of the region due to its control over the movement of surface and subsurface water inside the village through the process of oozing and leaking. *"The projection areas of the places with a high slope are decreasing. Therefore, the elevation steps, where the projection area is relatively small, but the average slope is high, generally have slope character. On the contrary, the projection areas of flat fields are close to the real ones and are relatively higher"* **(Zorer and Tonbul, 2019, p. 29)**.

Slope levels were classified into six categories, as shown in **Map 12** and **Table 23**. With the increase in slope, the flow rate and load-carrying capacity of the streams increase, and accordingly, the erosion force increases **(Atalay, 2016).** When the study area is examined, it is seen that the slope values in the basins are quite low. The most common slope value is between 10-20°, which indicates the moderate flow of streams rate and load-carrying capacity.

3. 3. 2. 1. Semi-Flat Lands

This range includes the third-largest percentage in the study area, amounting to 3.17% with an area of 9.63 km^2 and a degree of gradient ranges between 0-2°.

Some geomorphological forms of a sedimentary nature appear in this range, such as the flood plain and estuary areas basins and valleys. Most agricultural areas are located near the Samsiya Village because the people need agriculture to cover their daily needs. The surplus is transferred to the neighboring cities, falls within this category **(Map 12 and Map 13)**.

3. 3. 2. 2. Very Gently Sloping Lands

They include lands with a broad and undulating surface due to tectonic movements in this land. This range occupies an area of 24.72 km^2 at a rate of 8.13%, and it is very less common percentage recorded in the study area, and its gradient ranges in this area 2-5°.

Table 23. Slope Values of the Study Area (°)

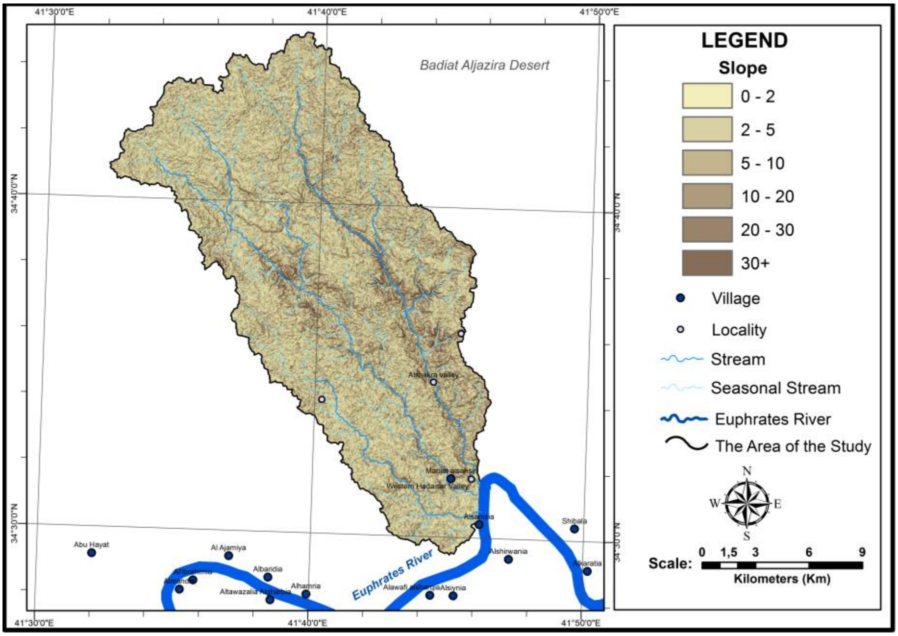
	Slope (°)	The type of land slope	Area (km^2)	Percentage (%)
1	0-2	Semi-flat lands	9.63	3.17
2	2-5	Very gently sloping lands	24.72	8.13
3	5-10	Light sloping lands	86.24	28.41
4	10-20	Moderate sloping lands	130.75	43.09
5	20-30	Steep lands	38.61	12.71
6	30+	Very steep lands	13.3	4.36
Total			303.25	99.87

3. 3. 2. 3. Light Sloping Lands

They occupy some hills that are characterized by lowness. The area covered in the study area is 86.24 km^2, with a ratio of 28.41%. This incline class ranked second with a gradient of 5-10°. They constitute the south of the study area **(Map 12 and Map 13)**.

3. 3. 2. 4. Moderate Sloping Lands

These areas with slope degrees between 10-20° are located near the flat areas, as shown in **Map 12**. They occupy is too much than others. The wind erosion they are exposed to and the weak resistance to this erosion. The area they occupy reached 130.75 km^2 with a rate of 43.09%. Some hills are used as military sites.



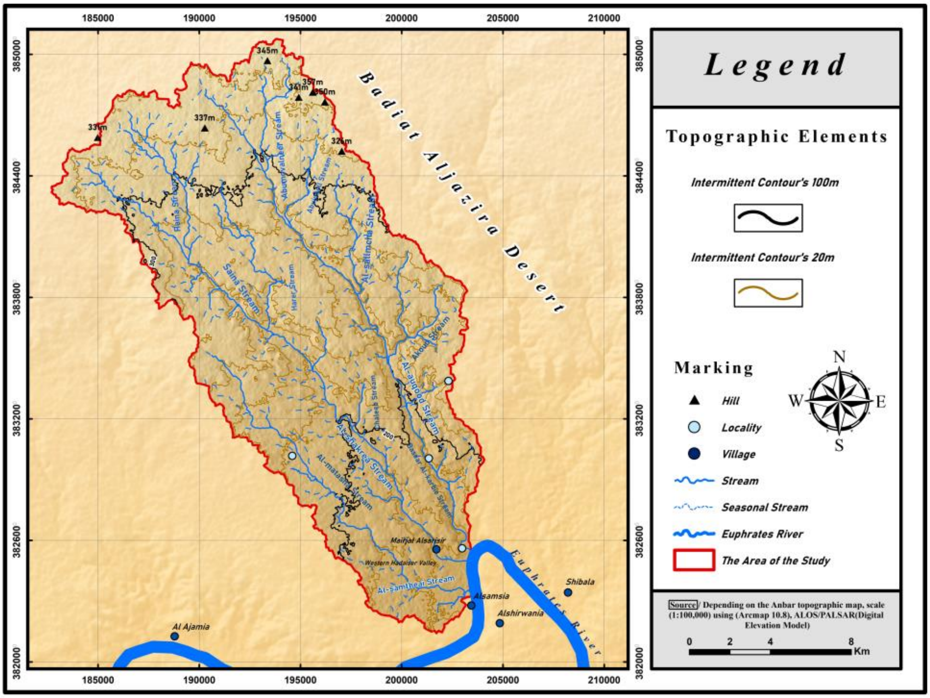
Map 12. Slope Map of the Study Area

3. 3. 2. 5. Steep Lands

Steep terrains represent a very small percentage of the study area. They represent the third place, reaching 38.61 km^2 with an estimated rate of 12.71% for the 20-30° category. It is common in the middle parts of Al-Auqood Stream and Al-Shakrea Stream.

3. 3. 2. 6. Very Steep Lands

Category 30 and higher grades, which are very steep terrain, reach 13.3 km^2 with a rate of 4.36%. As seen in **Table 23**, it forms the second-to-last least common slope in the study area.



Map 13. Topographical Characteristics of the Study Area

3. 3. 3. Aspect (As)

It is helpful to study the direction of the slope to find out which areas are subject to an increase in erosion activity, the temperature difference, amount of rain, and evaporation. The eastern slopes are more exposed to sunshine and high temperature than the other slope directions. The difference in the direction of the slope is the nature of the geological formation of the rocks, the internal movements that result in a change in direction, and the presence of fields and erosion processes.

Through **Map 14** and **Table 24**, it is clear that the southeast direction is the most dominant in the region, with an area of 64.71 km^2 and 21.32%. What distinguishes this direction from others is its spread in all directions of the study area. In the second place is the south direction with an area of 45.25 km^2 and 14.91%, and in the third place is the southwest direction with an area of 37.1 km^2 and a value of 12.22%. As it is mentioned above, these directions are exposed to high temperatures because they face the sun, are characterized by low humidity and are more exposed to erosion processes. In addition to that, most of the area of these two directions lies within the upper and lower Fatha Formation, characterized by its low resistance to erosion and weathering processes and the melting speed since most of its layers are gypsum.

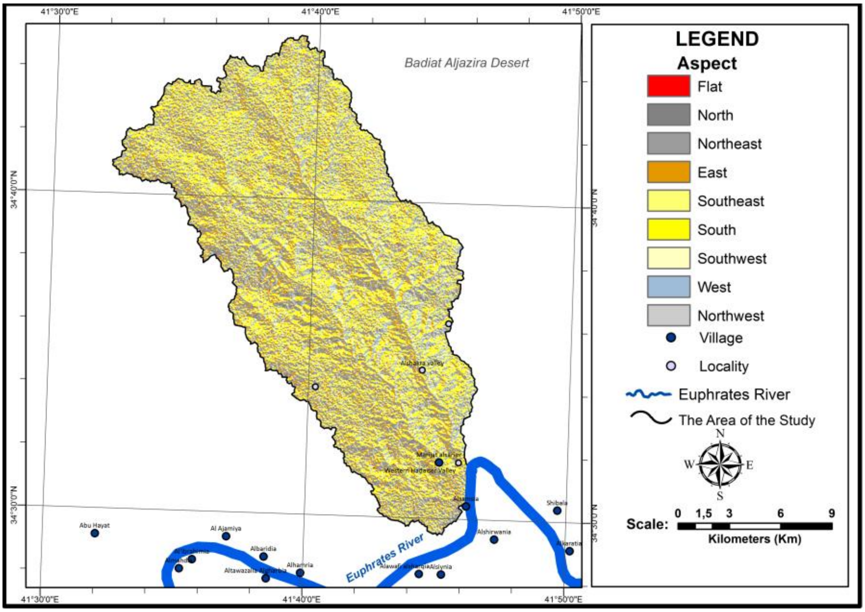
Next is the northeast direction, with an area of 36.62 km^2 and 12.07%. East direction covers an area of 35.58 km^2 with 11.7%.

Other than these the eastern direction is followed, which spreads in the area sources and estuaries basins and valleys, with an area of 32.91 km^2 and 10.8%. The northeast and the north aspect areas are located near to Al-Samtheai Stream basin, near the north edge, and within the Injata Formation.

The study area has the least flat aspect (2.95 km^2 and 0.9%), followed by the northwest (23.1 km^2 and 7.61%) and the west (25.04 km^2 and 8.25%) directions.

Table 24. Aspects (Slope Directions) in the Study Area

Slope direction	Area (km^2)	Percentage (%)
Flat	2.95	0.9
N	32.91	10.8
NE	36.62	12.07
E	35.58	11.7
SE	64.71	21.32
S	45.25	14.91
SW	37.1	12.22
W	25.04	8.25
NW	23.1	7.61
Total	303.26	99.78



Map 14. Aspect (Slope Direction) Map of the Study Area

3. 3. 4. North-South Direction Profiles in the Study Area

It is the gradual elevation in the basin from the source to the estuary. Therefore, the slope increases in solid rocks and reduces in soft ones. In addition to that, the form of the slope is affected by the climate and the geological environment. These two factors affect the geomorphological processes in the basin **(Al-Bibwati, 1991, p. 111)**.

The scholars of the geomorphological field are very interested in studying the longitudinal section for determining the stage of the stream basin and the changes in the stream base level over time like the erosion sedimentation and the changes that reflect the image of curvets part. The straight and flat sections represent a developed geomorphological stage. In contrast, the perfect piece of the basin is concave down. The degree of slope, rock nature, the prevailing climate, vegetation, density, and the basin's ability for erosion and sedimentation affect the formation of geomorphological features of the basin. Accordingly, each stage has unique features that form it **(Al-Bibwati, 1995, p. 76)**.

The longitudinal section of the Al-Shakrea Stream basin was drawn as shown in **Figure 10**, which begins from a high point 300 m above sea level where the stream begins and ends with the right bank of the Euphrates River in the southern parts of the stream at a high point 200 m above sea level. The simple gradual slope of the Al-Shakrea Stream basin is noted at the beginning of the stream continues to its end at the mouth of the Euphrates. The slope rate was 5.2 m/km, this valley is considered a light slope and is characterized by the length of its stream in the middle of the basin, and it is going through the youth stage. The rocks of this region are soluble. The evidence of that is the existence of some karstic features in the limestone rocks within the valley region.

As for the Al-Auqood Stream basin, the longitudinal section was drawn as shown in **Figure 11**, which begins from a high point 300 m above sea level, where the stream begins and ends on the right bank of Euphrates River in the southern part of the stream at a high point 200 m above sea level. The simple gradual slope of the minor basin of the Al-Auqood Stream is noted at the beginning of the stream and continues until at the end in the

Euphrates estuary. The rate of the slope was 5.6 m/km. This valley is of a slight slope and characterized by the length of its stream, and is going through the youth stage. The rocks of this region are soluble, and the evidence of that is the existence of some karstic features in the limestone rocks within the valley region.

While according to the minor basin of Al-Samtheai Stream, the longitudinal section was drawn as shown in **Figure 12**, which begins from a high point 250 m above sea level where the stream begins and ends in the right bank of Euphrates River in the southeast part in the study area at a high point 150 m above sea level, where the gradual, moderate slope of Al-Samtheai Stream basin in noted from the beginning of the stream and continues until at the end in Euphrates River. This type of slope is due to the short stream of the basin. The rate of the slope was 7.6 m. This valley is of a moderate slope compared to the basins mentioned above and is characterized by a short stream and is also going through a youth stage.

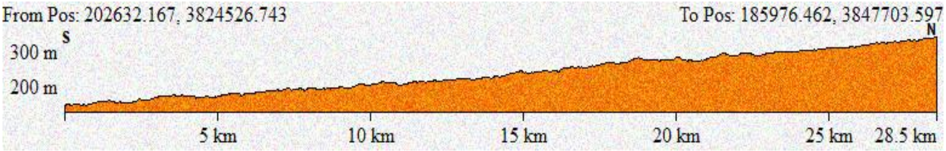


Figure 10. North-South Direction Profile of the Al-Shakrea Stream Basin

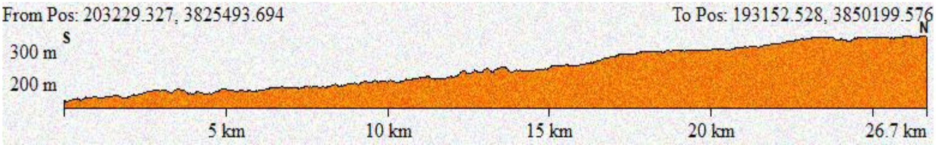


Figure 11. North-South Direction Profile of the Al-Auqood Stream Basin

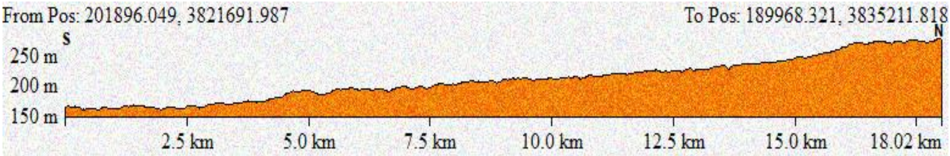


Figure 12. North-South Direction Profile of Al-Samtheai Stream Basin

3. 3. 5. West-East Direction Profiles in the Study Area

It is how can clear the development of valleys and basins within the geomorphological cycle and the terrain figures within chosen sections, the slope's rate and nature, and the rate of water erosion. We go over the cross-section of studied valleys from the source to the middle and ending with the estuary region. Figures from 13 to 21 show the west-east oriented profiles of the basins.

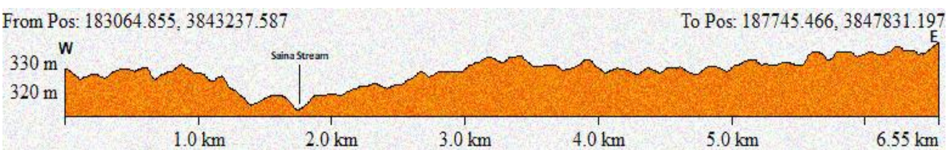


Figure 13. West-East Direction Profile of the Al-Shakrea Stream Basin in the Source Region

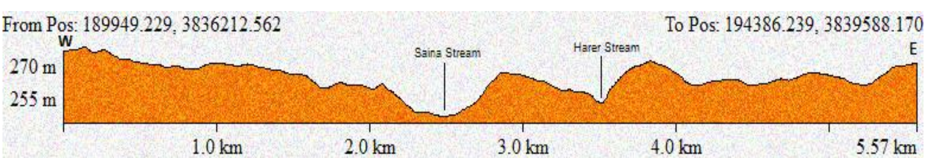


Figure 14. West-East Direction Profile of the Al-Shakrea Stream Basin in the Middle Region

The expanding basin is characterized by the asymmetry between the source, middle, and estuary, as it has more tributaries than other basins. The source region has a slope form on the west side and rises east. It is located between 320-330 m **(Figure 13)**, while the middle part is located between the height of 255-270 m **(Figure 14)**.

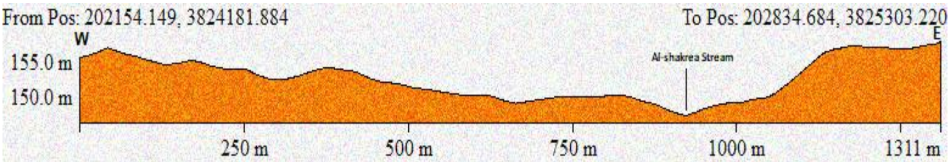


Figure 15. West-East Direction Profile of the Al-Shakrea Stream Basin in the Estuary Region

As shown, the slope stretches from the beginning to the middle, having the letter 'V' shape in the middle of the section. In **Figure 15**, it is clear that the estuary region is located between the altitude of 150-155 m and is high in the right and left sides and is sloping in the middle of the chosen section, and the valley has the shape of the letter 'V' as shown in the cross-section.

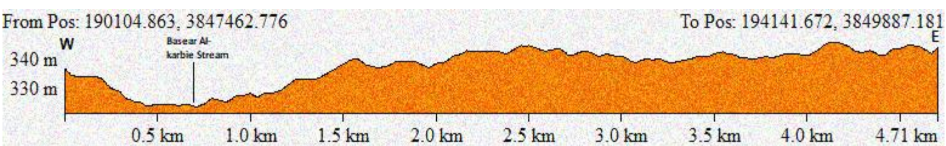


Figure 16. West-East Direction of the Al-Auqood Stream Basin in the Source Region

It is characterized by asymmetry between the parts of the source and estuary and the symmetry between the source and the middle. The source region is located between the altitude 330-340 m, where the valley has the shape of the letter 'V', as shown in **Figure 16**. In **Figure 17**, it is clear that the middle is located between 210-270 m while the estuary is between 155-165 m, as shown in **Figure 18**, and the estuary has the shape of the letter 'V' because both sides are rising and falling in the cross-section of the study area.

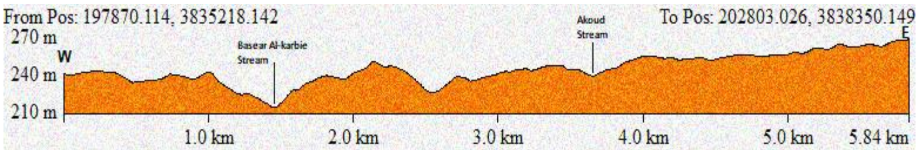


Figure 17. West-East Direction Profile of the Al-Auqood Stream Basin in the Middle Region

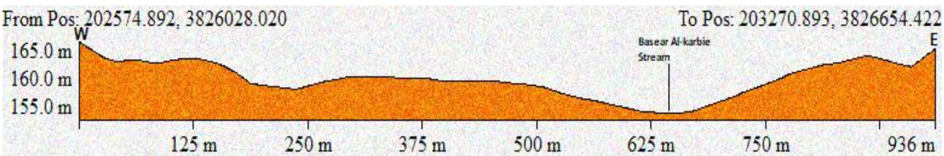


Figure 18. West-East Direction Profile of the Al-Auqood Stream Basin in the Estuary Region

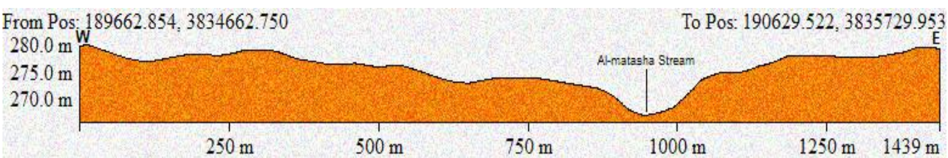


Figure 19. West-East Direction Profile of the Al-Samtheai Stream Basin in the Source Region

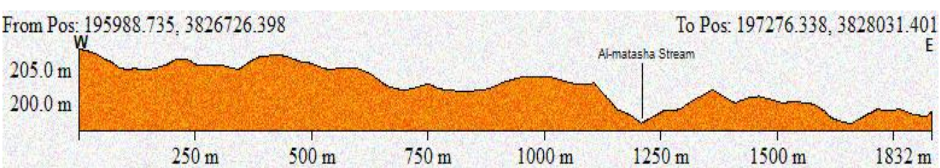


Figure 20. West-East Direction Profile of the Al-Samtheai Stream Basin in the Middle Region

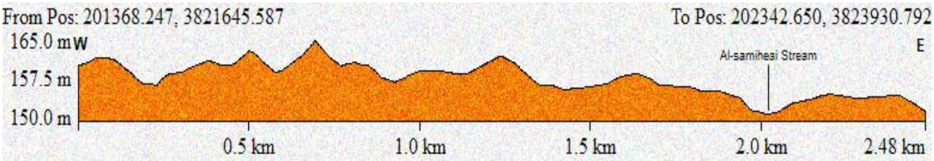


Figure 21. West-East Direction Profile of the Al-Samtheai Stream Basin in the Estuary Region

It is characterized by the asymmetry between the parts of the source and the middle and the symmetry between the head and the estuary. The estuary region is located between the altitude of 270-280 m, as shown in **Figure 19**. It has the shape of the letter 'V'. The middle region is located between 200-205 m. It is very high on the west side and low on the east. It is characterized by a significant slope and increased erosion due to the large area. It has the shape of the letter 'V' in the middle of the chosen section, as shown in **Figure 20**. It is located between 150-165 m according to sea level. The lower part is characterized by a gradual slope on the right, a large slope in the middle, and a letter-shaped rise on the right. The 'V' valley is located in the middle of the section, as shown in **Figure 21**.

3. 3. 6. Basin Relief (Bh)

"It means the relationship between the highest and lowest points of the basin divided by the basin perimeter multiplied by ten (10)" **(Abu Al-Enein, 1990, p. 73)** The formula is as follows:

$$\text{Basin Relief (Bh)} = Hmax - Hmin$$

$Hmax$: Maximum high point in the basin (m)
$Hmin$: It is the minimum high point in the basin (m)

By applying this equation to the study area, it is clear that the amplification rate is 204 in the Shakrea Stream basin, 218 in the Al-Aqood Stream basin, and 143 in the Samtheai Stream basin, as shown in **Table 21**. Basin relief values were low for all three basins in the study area. This is primarily due to the low elevations of the basins. These results also show that the slope values are very low in the study area. Intensely, there are rocks that have weak resistance to water and wind erosion. The low altitude is also reflected in the precipitation conditions.

3. 3. 7. Relief Ratio (Rr)

It is crucial for geomorphological studies since it is a guide and measure of the earth's topography. It can be extracted by calculating the difference between the highest and the lowest points of the basin divided by the length of the basin within the same unit of the measurement (m/km) **(Al-Dulaimi, 2005. p. 270)**.

It is expressed in mathematics with the following equation:

$$\text{Relief ratio} = \frac{\text{The difference between the highest and lowest points of the basin/m}}{\text{The basin length /km}}$$

As the number is large, this indicates the intensity of the relief. By applying this equation on basins of the study area, the relief ratio was 0.0059 in the Al-Shakrea Stream basin, 0.0065 in the Al-Auqood Stream basin, and 0.0079 in the Al-Samtheai Stream basin, as shown in **Table 21**. The lack of the slope is because the area wasn’t affected by any active tectonic movements and the geological nature and erosion features in the area since it occurs accessible land. Although the vegetation in the study area is weak, infiltration is high due to the widespread limestones.

3. 3. 8. Hypsometric Curve (Hc)

“It is used as a time scale of the erosion stage of basins. In addition, it indicates the number of rocks which is still waiting for erosion processes” **(Salama, 1980, p. 114)**.

“It is also one of the quantitative instruments to know the geomorphology of streams and rivers basins” **(Strahler, 1952, p. 1117-1142)**. Since it is the only instrument by which it can identify the stage of the basin, it can use it in classifying the landforms. The steep terrain areas are still

in the youth stage, while the flat areas are in progress of erosion to reach the aging stage. The hypsometric curve can be extracted according to the following steps **(Al-Eadhari, 2005, p. 147)**:

$$\text{Hypsometric curve} = \frac{\text{Relative height}}{\text{Relative area}}$$

$$\text{Relative height} = \frac{\text{Altitude of any choose contour line /mh}}{\text{The highest point in the basin /mh}}$$

$$\text{Relative area} = \frac{\text{The rate of the area between any contour line and basin perimeter /A}}{\text{The total area of the basin/A}}$$

- Excluding the total area of the basin.
- Excluding the area between each equal elevation line and another one to the end of the basin.
- Excluding the value (s) by dividing the area between any contour line and another one on the basin’s total area, as shown in the rule above.
- Defining the altitude value of each contour line.
- Defining the highest altitude in the basin.
- Excluding the value(s) by dividing the altitude value of each contour line on the highest altitude in the basin, as shown in the rule above.
- Drawing the hypsometric carve using the values (Relative space, Relative height). The stages are defined as follows:

1. Youth stage: It means imbalance since the stream is characterized by very powerful erosion activity and lack of sedimentation process.

2. Maturity stage: It is the stage where the river begins to balance so that 45% of the basin area is eroded and its deposition and erosion are balanced.

3. Aging stage: It is the last stage of the stream's life so that more than 55% of the basin area is eroded, and the deposition process is more considerable than the erosion process.

It is clear from, if the shape of the curve is curved towards up and very steep, this means that the basin is in the youth stage, and if the curve is near the middle, the basin is in the maturity stage, while if it is light slope flat at the bottom, it means that the basin reaches the aging stage.

As seen in **Figure 22** representing the Al-Shakrea Stream basin and **Figure 23** representing the Al-Auqood Stream basin, the youth stage has just been completed and the maturity stage has just begun. When the conditions of these two streams are compared, it is understood that Al-Auqood is the youngest basin in the study area.

The Al-Samtheai stream basin, on the other hand, is going through the full maturity stage as seen in **Figure 24**. Accordingly, the Al-Samtheai Stream basin is the oldest basin in the study area.

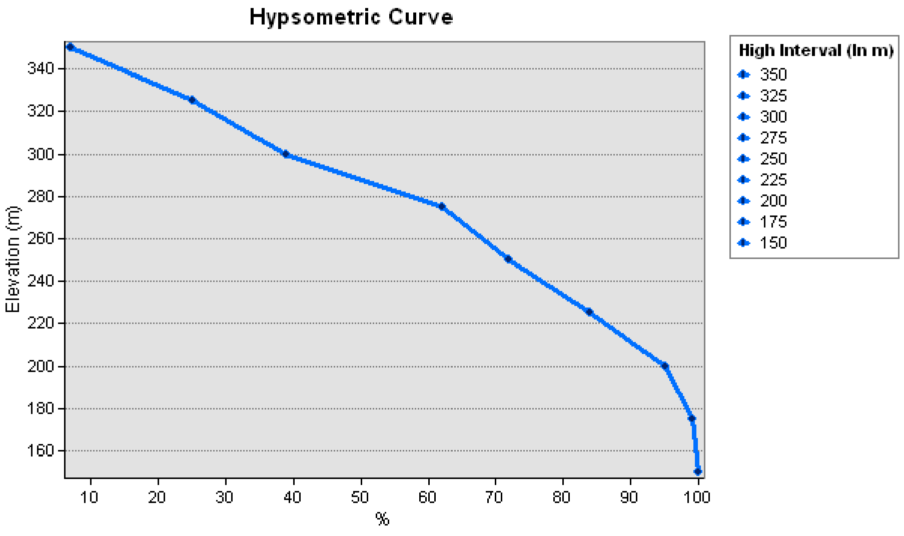


Figure 22. Hypsometric Curve of the Al-Shakrea Stream Basin

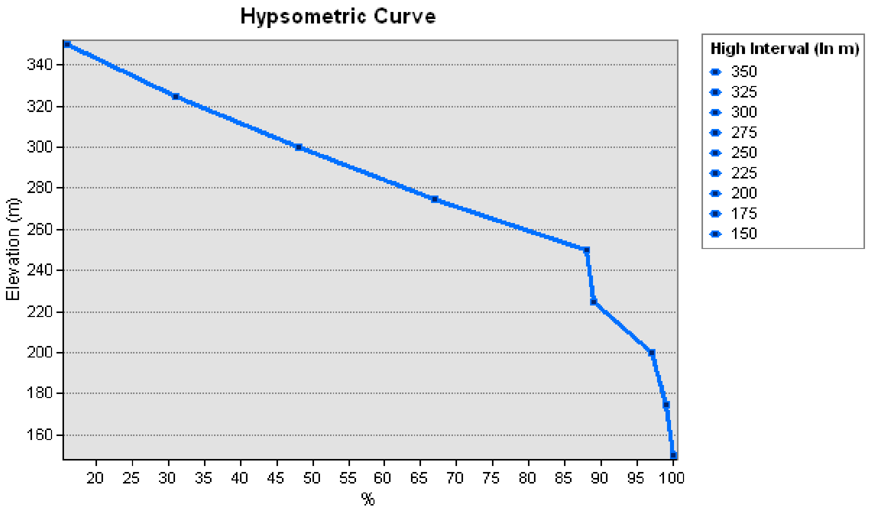


Figure 23. Hypsometric Curve of the Al-Auqood Stream Basin

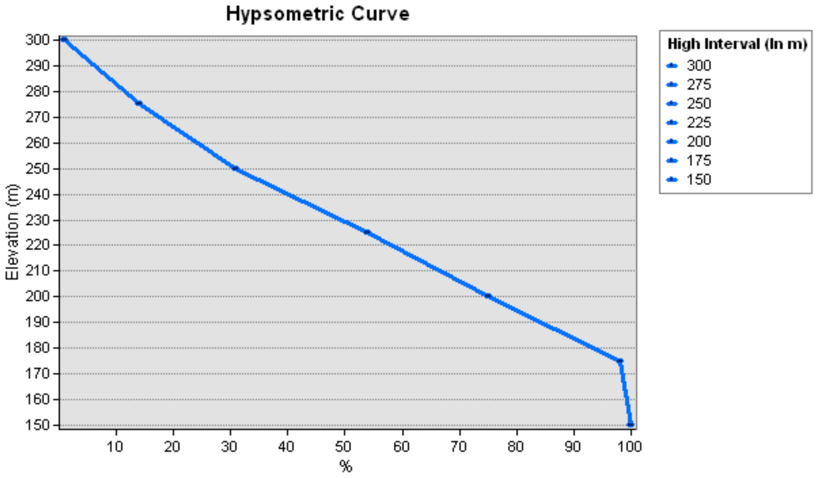


Figure 24. Hypsometric Curve of the Al-Samtheai Stream Basin

3. 3. 9. Hypsometric Integral (Hi)

It is one of the essential criteria by which the stage of basins' age can be defined depending on their area and terrains and defining the erosion cycle of any basin **(Al-Eadhari, 2005, p. 147)**. The increasing value of this index indicates the expanding area on the terrains. In other words, the considerable water erosion occupied a large area of the basin. Its numerical value ranges from 0 to 1. Hypsometric in the integral values of the specified range, mean the mean trough height difference obtained by dividing the maximum trough height and the minimum trough height difference. The integral values of the hypertrophy obtained as a result of the calculation are 0.60 and above. Values are youthful, values between 0.35-0.60 are maturity, and values less than 0.35 characterize terrain in the senescence line stage. The hypsometric integral is extracted by the following formula **(Abdel Aziz, 2001, p. 103)**.

$$Hi= H\ mean - Hmin/\ Hmax - Hmin$$

Hmean: medium elevation of the basin (m)
Hmax: Maximum high point of the basin (m)
Hmin: It is the minimum high point of the basin (m)

Table 25. Maximum, Minimum, and Average Height Values of the Basins in the Study Area

Basin name	Hmean (m)	Hmax (m)	Hmin (m)
Al-Auqood	269.4	357	139
Al-Shakrea	258.8	343	139
Al-Samtheai	205.8	282	139

The hypsometric integral values of the three basins in the study area are shown in **Table 21**. The integral value was calculated as 0.58 in the Al-Shakrea Stream basin, 0.59 in the Al-Auqood Stream basin, and 0.46 in the Al-Samtheai Stream basin. According to these results, as explained under the title of the hypsometric curve, all three basins pass through the maturity stage. Among these three basins, the youngest basin is Al-Auqood, the median Al-Shakrea and the oldest one is Al-Samtheai **(Table 21 and Table 25)**.

A mature basin has features such as inconspicuous slope and roughness, low flow velocity, poor erosion force, and increased sediment accumulation. It covers the area of the low plateau around the areas of the edges of the valleys and has the carrying capacity of the stream in these low areas. On the other hand, accumulation is high in the lands where the basins meet the Euphrates. Except for the regions where relatively narrow and deep valley formation is common, the erosion capacity of the streams is weak due to the lack of precipitation.

3. 3. 10. Gravelius (Compactness) Coefficient (Kg)

It shows the consistency and homogeny between the perimeter and the assembly space of the basin, the regularity of the meanders of the water dividing line. The number rate is more than the whole one (1). The low rates indicate the increase of the drainage surface area at the expense of the perimeter length, the lack of meanders, the regularity of water dividing lines, and the progression of the basin erosion. In contrast, the high rates indicate the increase of the length of the basin perimeter concerning its assembly space, irregularity and meandering the perimeter, and the novelty of its erosion cycle **(Almaghazi, 2015, p. 82-83)**. The compactness coefficient is extracted by this equation **(Moustafa, 1998, p. 263)**:

The basin perimeter / 2√ (The number pi * The basin area

P: Basin perimeter length (km)
A: The basin area (km²)

This coefficient uses the basin perimeter for measuring the shape instead of the area (unlike the circulatory ratio). It was evident in **Table 21** the high values of compactness coefficient. This value is 2.13 in the Al-Shakrea Stream basin, 2.06 in the Al-Auqood Stream basin, and 2.33 in the Al-Samtheai Stream basin. As this coefficient moves away from 1, the view of the basin gets longer. In addition, it is related to the relief effect on the waterline lines of the basins. All of the basins in the study area have an elongated appearance. Study area basins have high values of the coefficient that indicate the irregularity of water dividing lines and the novelty of basins in their geomorphological cycle. This corresponds with the result of the previous equations.

3. 3. 11. Ruggedness Number (Rn)

It indicates the rate of the basin relief and the slope of watercourses depending on the longitudinal drainage density of the basin. The highest values of the ruggedness indicate the density of relief and the dominance of water erosion which leads to the transfer of sediments from higher sewers in the stream basins to the bottom of slopes in the basins **(Al-Eadhari, 2005, p. 147)**. *"This value is one of the important criteria for morphologic measures and indicates the stage of development of the drainage basin with great accuracy. The ruggedness value is extracted by the following equation"* **(Abu Al-Enein, 1990, p. 73)**.

$$\text{Ruggedness value} = \frac{\text{Basin relief/m} \times \text{longitudinal drainage density km/km}^2}{1000}$$

From **Table 21**, it is clear that the basins of the study area are of low rugged value. It was 0.25 in the Al-Shakrea Stream basin, 0.26 in the Al-Auqood Stream basin, and 0.17 in the Al-Samtheai stream basin with a low value. This indicates the height in the basin is low, and the results are less. It can lengthen their waterways at the expense of the capacity of the basin area when it progresses in their erosion cycle. In small basins, the development of the drainage network is not fully completed. The ruggedness value is inversely proportional to the hypsometric integral.

3. 3. 12. Water Drainage Pattern

Dendritic pattern: It is one of the most common types, and it spreads in areas with few terrains, having rocks that are homogeneous in their resistance and not easily controlled **(Thornbray, 1975, p. 164)**. This pattern is widespread over sedimentary rocks and is characterized by tributaries branching out irregularly in all directions. The angle of the form is often not suitable, with branches forming a water pattern for stream basins of the region. This pattern appears widely in all the basins of the study area due to the homogeneity of the rocky layers, the nature of the hill land with a slight slope, and the dominance of dry climate. The study area has only this pattern, as shown in **Figure 25**. This pattern is characterized by collecting water rapidly from the minor orders to the mainstream, high water level and forming floods.

Figure 25. Dendritic (Tree) Drainage Model which is the Most Common Drainage Type in the Study Area

CHAPTER FOUR

4. RESULTS

4. 1. Discussion

Determination of morphometric properties in hydrographic basins is important for the production of objective and quantitative values in terms of earth shapes. This allows making evaluations that can be considered to establish the resulting, cause-result connection, as well as the possibility of explaining the characteristics of the basin in a more objective way **(Polat, 2019, p. 299)**.

In this study, morphometric analyzes were used to determine the geomorphological features of three neighboring stream basins in Iraq, namely Al-Shakrea, Al-Auqood, and Al-Samtheai. Geographic Information Systems has gained an important place in geoscience studies today and has become one of the most effective ways to achieve realistic results.

During the research, a literature review was done; various maps, profiles, tables, graphics were prepared; It was supported by fieldwork, and the writing phase was completed with office work. The geographical and geomorphological features of the selected area were revealed by numerical analysis.

The study area is located in the west part of Iraq, especially in the northwest of Al-Anbar, inside the Iraqi Desert. It is boarded by Ninawa from the north and Haditha Dam from the west. As mathematically, the region is located between latitudes of 34° 29' 42" N and 34° 45' 01" N, and also between longitudes of 41° 31' 18" E and 41° 46' 29" E. The research area covers an area of 303.38 km².

Geology also studies the composition of the area in the third age, which consists of two formations, the Eocene, and its rocks consist of dolomite and limestone, with a low porosity of 1-10%, in addition to being rich in calcium carbonate, which is characterized by its rapid dissolution in water. As for the Miocene age, it is one of the most widespread formations of the third age in the study area, and its most important components are gypsum, silt, limestone, sand, and gravel.

The prevailing climate in the study area is considered an arid climate, where it is dry in summer and cool and slightly rainy in winter. The highest temperature was recorded in July at a station with an average of 33.7°C, while it was recorded in Al-Qaim Station in June and was estimated at 33.5°C. As for the rainfall in Al-Qaim Station, the annual average of precipitation was 127.4 mm, and Al-Qaim Station recorded the yearly average of 153 mm as it became clear from the results mentioned that the area's climate is dry climate. The distances of reaching the mainstreams of tributaries in longitudinal basins are shorter than the circular basins, but the rainfall waters are drained without accumulation in the lower tributaries. In contrast to the circular basins, the flood and flood risk increases on the mainstream due to more accumulation of water to each other, due to the more accumulation of water to each other in severe rains in severe rainfalls **(Öztekinci and Coşkun, 2021, 354)**.

There are many formulas for determining the general characteristics of the climatic conditions of a place. The Thornthwaite method is the most widely used and accurate of these formulas. Display the annual indicators values for stations in the search area and in and around Al-Qaim and Anah stations. According to the Thornthwaite method, the prevalence of drought was observed in the study area.

The area chosen for this thesis is located in an arid region in terms of climatic conditions. **Abd Al-Hadi and Kareem (2015)**, who conducted similar research in Libya, also examined an arid region with deficient precipitation. According to Abd Al-Hadi and Kareem's findings, the basin in the study area tends to elongate, and when associated with climatic conditions, the risk of flooding is a very low possibility. In this respect, this thesis study and Abd Al-Hadi and Kareem's research are exactly similar.

Soil is an essential natural resource that controls agricultural production in terms of quantity and quality, so human life is closely related. This was revealed by studying the geological structure of the study area. The spread of rock types, dry climate, and successive wind erosion led to the presence of rocky soils of low fertility due to the absence or lack of vegetation cover, which is reflected in the presence of two types of soil, namely dry soil newly formed soils.

Natural plant growth in any region of the world is related to climatic conditions. Despite the lack of rainfall and high temperatures accompanied by a high amount of evaporation and the prevailing desert soil quality, vegetation cover exists and varies from one region to another, so we find the low plateau areas with little natural plants and different types, including Sidr, Al-Seih, and Al-Behal, which are characterized by their small size and low density, and they spread intermittently, during rainy seasons.

The study area mainly consists of low plateau areas as geomorphologically. The elevation and slope values in the land are low. Due to the prevalence of limestones, chemical dissolution draws attention in shaping the sections where precipitation occurs relatively. Apart from that, physical disintegration and mass movements (especially rockfalls) are among the other significant effective processes. There are erosion surfaces, flood plains, karst sinkholes, tafoni, V-shaped and flat valley formations, desert pavements, and ripple marks in the study area.

Many similar studies in which morphometric analysis studies are carried out using Geographic Information Systems. As an example of these; **Erginal and Cürebal (2007), Bahadır and Özdemir (2011), Topuz (2014), Altıparmak and Türkoğlu (2018)**. In these studies, linear, areal, and relief parameters for different selected basins were calculated and analyzed the results.

The study area consists of three stream basins which a total area is 303.38 km^2. One of them is the Al-Shakrea Stream basin, the largest with an area of 132.88 km^2. The median is the Al-Auqood Stream basin with an area of 124.13 km^2, and the smallest is the Al-Samtheai Stream basin with an area of 46.37 km^2. All three of the aforementioned streams flow into the Euphrates River.

Some comparisons were made between the results of the morphometry analyzes applied to this thesis and other morphometry studies given, and it was seen that there were some similarities with some of them. For example; **Altıparmak and Türkoğlu (2018)**, in their study on the morphometry of the Yakacık Stream basin, determined the hypsometric integral value as 0.49. Thus, the geomorphological development stage of the Yakacık Stream basin, which is seen to be in the maturity stage, was the same as in the creeks in this thesis study. In particular, it is almost the same as the hypsometric integral value of the Al-Samtheai Stream basin (0.46). All of the mentioned streams are in the maturity stage. In another study, **Fural (2016)**, who revealed the geomorphology of the Köprü Stream basin using morphometric analyzes, determined that the basin has a narrow and long extension.

Based on the analysis of morphometric parameters, this study focused on identifying some of the problems that may arise in the relevant basins, offering solutions, and how these basins can be a benefit in the future.

4. 2. Conclusions

This study is put forward to explain the appropriate steps for preparing geographical databases for the morphological characteristics of the Al-Auqood, Al-Shakrea, and Al-Samtheai basins, which are dry basins using GIS, which leads to the maximum accuracy in the outputs.

At the end of this thesis, the following conclusions were reached from the morphometric analysis:

- When the basin lengths in the study area were compared, it was determined that the longest basin was Al-Shakrea (34.34 km), the median was Al-Auqood (33.12 km), and the shortest one was Al-Samtheai (17.88 km).
- Data representing the maximum width of the study area basins were inferred through the GIS program, and it was seen that the maximum width in the study area basins was the Al-Shakrea Stream basin (8.34 km). The second is the Al-Auqood (6.72 km), and the third is the Al-Samtheai (3.67 km) stream basins. This indicates that among the three basins, the most river erosion constitutes the largest basin.
- Basins with low stream length ratio are long, while those with high stream length ratio are more circular. When the *Rl* value of the streams in the study area was examined, it was determined that the order from the more circular basins to the longer ones was as follows: Al-Samtheai, Al-Shakrea, and Al-Auqood. According to these results, it can be said that the drainage time of the waters is the

shortest in the Samtheai Stream basin, and the longest in the Al-Auqood Stream basin. These results support the results of the circularity ratio, basin shape (form factor), and elongation ratio.

- The number of bifurcation stages has been determined as four (4) in the basins. Al-Shakrea and Al-Auquood rivers reach four (4) stages, while the smallest basin, Al-Samtheai, has three (3) stages. The total number of bifurcation stages (for all numbers which are 1, 2, 3, and 4) in the study area is 277, and their length is 373.93 km.
- By adopting the Strahler method in calculating the ranks of the study area, it is calculated that the total number of the first order of the three basins is 225, and their length is 200.39 km. The number of the second order is 43 and 78.44 km in total. The number of the third order is 7, and the length is 55.82. the number of the fourth order is 2, and the length is 39.28 km.
- The total bifurcation ratio of Al-Shakrea, which forms the largest basin, is 4.9. Total bifurcation ratio for Al-Auqood is 4.78, and for the smallest basin, Al-Samtheai, is 5.25.
- Texture ratio can give clues about the infiltration properties of the basins and the permeability of the rocks. A higher rate indicates a higher slope and lower infiltration. Since the basins in the study area are longitudinal, the texture rates were low. The texture values were highest in Al-Auqood (1.18), followed by Al-Shakrea (1.15), and lowest in Al-Samtheai (0.47) in the three basins, respectively.
- The study area covers a total area of 303.38 km^2. Various researchers have made studies to classify the basins according to their size. For this thesis, the classification of the **European Parliament and Council of the EU (2000)** will be evaluated. According to this, those between 10–100 km^2 are called ‘Small’, those between 100–1000 km^2 are called ‘Medium’, those between 1000–10,000 km^2 are called ‘Large’, and those over 10,000 km^2 are called ‘Very Large’. Considering the areas of the river basins in the study area, among the 3 river basins, ‘Medium’ sized basins with both Al-Shakrea (132.88 km^2) and Al-Auqood (125.13 km^2) areas are formed. Since the area of the Al-Samtheai (46.37 km^2) river basin is less than 100 km^2, it can be said to be in the ‘Small’ basin

group. The basin area is important in terms of planning the investments to be made in the region.

- The basin perimeters in the study area are as follows: 87.35 km for Al-Shakrea, 81.64 km for Al-Auqood, and 56.42 km for Al-Samtheai. The total perimeter of the field is 225.41 km. This indicates that among the three basins, the most river erosion constitutes the largest basin.
- The circularity ratio values in the study area are 0.21 for the Al-Shakrea and Al-Auqood stream basins, and 0.28 for Al-Samtheai. These low values are proof that the basins are far from rounded. The Al-Samtheai Stream basin, which has a higher circularity ratio, is more circular than the other two basins. These results support the stream length ratio, basin shape (form factor), and elongation ratio results.
- Elongation ratio values were also quite low (0.37 for Al-Shakrea and Al-Auqood, 0.42 for Al-Samtheai basins). These numbers also support the long view of the basins. Low elongation ratio values indicate that the flood susceptibility of the basins is low. According to these results, the basin with the highest flood sensitivity is Al-Samtheai. These results support stream length ratio, circularity ratio, and basin shape (form factor) results.
- Basin shape values were calculated as 0.11 for Al-Shakrea and Al-Auqood basins, and 0.14 for Al-Samtheai. These low numbers indicate how far the basins are from roundness. This indicates that the Al-Samtheai Stream basin is closer to circular shape than the other two large basins. These results support the stream length ratio, circularity ratio, and elongation ratio results.
- In the basins of the study area, the stream frequency was highest in the Al-Auqood Stream basin (0.95), in secondary the Al-Shakrea Stream basin (0.94), and the lowest in the Al-Samtheai Stream basin (0.73). The scarcity of these values indicates the lack of flood potential in the basins.
- The drainage density in the research basins is low. Drainage density values of 1.27 for the Al-Shakrea basin, 1.20 for the Al-Auqood

basin, and 1.20 for the Al-Samtheai basin indicate high infiltration. Similarly, stream frequency values were also low (0.94 for Al-Shakrea, 0.96 for Al-Auqood, and 0.73 for Al-Samtheai). Also, the infiltration number is 1.19 for the Al-Shakrea basin, 1.14 for the Al-Auqood basin, and 0.87 for the Al-Samtheai basin. Both results (drainage density and infiltration number) show us that the infiltration rate in the basins is high. The basin, where cracked limestones are common, is quite suitable for infiltration due to its lithological structure.

- Basin relief values are 204 for the Al-Shakrea Stream basin, 218 for the Al-Auqood Stream basin, 143 for the Al-Samtheai Stream basin.
- The relief ratio value of the Al-Shakrea Stream basin is 0.0059, the Al-Auqood Stream basin is 0.0065, and the Al-Samtheai Stream basin is 0.0079 in the study area. These low relief ratio values indicate that the slopes of the basins in the study area are low. Erosion activities are low, surface flow is low due to the arid climate, and therefore, snow development is slow. Streams with low bed slope rates also have low erosion power. For this reason, the erosion ability of the rivers in the study area, especially in the middle and lower basins, has decreased and accumulation processes have come to the fore.
- Hypsometric integral numbers indicate that the basins in the study area are in the maturity stage. The value of this parameter is 0.58 in the Al-Shakrea basin, 0.59 in the Al-Auqood basin, and 0.46 in the Al-Samtheai basin. The basins of Al-Shakrea and the Al-Auqood have just completed their youth phase and have passed into maturity. Accordingly, the basin in the earliest stage is Al-Auqood, and the basin in the latest stage is Al-Samtheai. It also shows that the ability of rain to erosion in the study area is weak because of its scarcity, and most of the study area falls within the range of light and medium groove erosion. The results of the final classification of which parameters show this showed that the region's basins have low to moderate tectonic activity.
- Considering the age of the rocks in the study area, it is seen that they are Paleocene and later periods. These relatively young lands of the

Tertiary are composed of loose textured, infiltrate, chemical and clastic sedimentary rocks rather than crystalline or non-metamorphic very durable rocks. The fact that the geological units are very fractured and the tectonic processes they have undergone have significantly affected the development of the drainage system on them.

- The Gravelius coefficient parameter proves that the study area’s basins are far from the round shape because this value is greater than 1 for the basins. Al-Shakrea’s coefficient was calculated as 2.13, Al-Auqood’s coefficient was 2.06, and Al-Samtheai’s coefficient was 2.33.
- Ruggedness numbers were 0.25 in the Al-Shakrea Stream basin, 0.26 for Al-Auqood, and 0.17 for Al-Samtheai basin. These low values indicate that the basins are free from roughness. Besides, these results indicate that erosional activities are weak in all three basins.
- According to these results, the stream basin with the highest flood risk in the lower parts is Al-Samtheai, the second is Al-Auqood, and the least risky one is Al-Shakrea. Therefore, the priority of protection should also be in the Al-Samtheai basin. On the other hand, it can be said that the probability of flooding in the upper parts of the Al-Shakrea basin is higher than the others.
- There is a problem that arises from the natural environment characteristics of the basins in the study area and may cause difficulties in land use. The most important of these problems are; stony, alkalinity, erosion, salinity, barrenness and mass movements.
- Soil types in the study area have not yet completed their development, and fully mature soil horizons have not yet been formed. The limestones common in the area contain many cracks and voids. Soil cover has accumulated in these wide and deep spaces, and there are occasional xerophytic and semia-xerophytic plant communities on them.
- Obtaining morphometric data of river basins makes a great contribution to the planning of water use and utilization routes and

adequate protection from pollution. There are no potential water pollutants worth mentioning as there are no significant residential and industrial facilities in the basin.

- Land use in the region is not high and is mainly limited to agricultural use. Industrial services and human settlements follow, and their proportion is very small. In contrast, abandoned lands occupy the highest area, corresponding to 78.50% of the study area. Due to the inadequacy of climate, vegetation, and hydrographic conditions, the region cannot be evaluated as productive.
- As stated in the objectives, the population density in the region constituting the study area is very low, primarily due to the war problem. Villages were emptied and abandoned, and the population migrated from the region. The fact that the valleys in the basins are dry most of the year depending on the climate, the vegetation is very weak, the absence of wooded areas and forests make it difficult to do agriculture and animal husbandry in land use in this region since before the war. Since the precipitation is not sufficient, it is generally thought that the level of groundwater in the study area is also low. However, since the parts around the Euphrates River are wet, it may be possible to settle on these shores and carry out agricultural activities. In these areas, it is possible to talk about the possibility of flooding of the Euphrates, not the Al-Shakrea, Al-Auqood, and Al-Samtheai streams.

4. 3. Recommendations

In the light of the data and results obtained from this thesis research, the following suggestions were made:

- In order to obtain more accurate and detailed climate results, it is necessary to establish climate stations in the study area.
- Recording the monthly flow values of the rivers in the study area is important for the determination of sloping periods and possible flood periods.

- Morphometric and hydrogeomorphological studies should be encouraged for desert areas with promising investments and undiscovered natural resources.
- A factory or other industrial investments should be made for salt production and agricultural projects should be supported around the Al-Jazeera Desert in Iraq.
- Among the development projects that can be designed, it is thought that the most important ones are to reduce the waste and neglect of unattended land and to adopt the earth-fill dam method as it is a low-cost and easy-to-apply method.
- Incentive efforts should be made to clean the region from the remains of war, to repair the deficiencies, and to return the outgoing population to the region.
- With the establishment-dissemination of gravel, sand, or stone, the population can be attracted here, and the residents can be kept in stable conditions.
- Asphalt roads should be built to facilitate the movement of products in the region. Thanks to the solution of transportation problems, the ease of movement of the residents to the surrounding areas should be provided.
- By using GIS, databases and maps can be prepared in order to prevent the floods that may occur in the upper basins and the floods that may occur in the lower basins.
- It may be recommended to plant trees in suitable regions in the study area. Afforestation works in some parts of the basins will be beneficial in terms of water retention and erosion prevention.
- Considering the natural environment and human relations in the study area, besides the stream coastal conditions, biogeography, historical geography, archeology, and touristic features should be determined and developed. There is also a need for evaluations and development regarding transportation and accommodation.

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