

Ministry of Higher Education
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University of Babylon
College of Science
Department of Applied Geology



**Geotechnical and Hydrochemical Study for the Soil
and Water of AL-Musaiyab Great Water Project in
North Babylon Governorate - Iraq**

A Thesis

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By

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

(يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا

الْعِلْمَ دَرَجَاتٍ ۗ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ)

صدق الله العلي العظيم

سورة المجادلة: الآية (11)

Dedicate

To the one who led the hearts and minds of mankind... to the harbor of safety, the teacher of mankind, our Prophet Muhammad (peace and blessings of Allah be upon him and his family)

To my dear father, may Allah protect him

To my dear mother

To my brothers and sisters..to my dear colleagues

To everyone who supports me

Najlaa

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Summary

This study aimed to examine the physical, chemical, engineering and mineral properties of the slopes of the soil banks of the Great Musaiyab project and study the hydrochemistry of water as well as suggesting remedial measures to protect the banks of the river and its stability to ensure the optimal investment of the water resources of the river in quality and quantity.

Ten stations were identified along the Great Musayyib project within the study Area.

The results of the physical tests indicated that the grain size distribution showed that the proportion of silt is higher than that of clay and sand at a rate of (36.88%), and that of clay (31.9%) and average of sand (31.06%).

The average density values were the dry density ranges between (1.868-1.985) with an average of (1.9125) g/cm³,

The specific gravity ranges between (2.65-2.74) with an average of (2.69).

The results of the chemical tests showed that the carbonate(CaCO₃) concentration of soil ranges between (8-35)% with an average of (17.98)%, and the sulphate (SO₃) concentration ranges between (0.085-0.698) with average (0.3288)% and the gypsum concentration ranges between (0.184-1.5007) with average (0.7076)% and the organic matter ranges between (1.407-3.869)% with an average of (2.7435)%, while the total soluble salts(TSS) ranges between((0.295-3.9)% with an average of (1.7205)% .

The results of the engineering tests for the soil of the study area showed that the direct shear test where the cohesion(C)ranges between (0-50) kN/m² with an average of (14.8)KN/m² ,The angle of internal friction(ϕ)

ranges between (7-37) with an average of (22.75) and the compressive strength ranges between (3-48) KN/m² with average (19.6) KN/m² .

The mineral tests using X-ray diffraction indicated that the mineral content of the soil consisted mainly of Calcite, Quartz and Feldspar minerals in addition to Clay minerals .

The chemical and physical properties of water showed that the electrical conductivity ranged between (1196-1250) μ S/cm and the (pH) ranges between (6.44-7.46) with an average of (7.06) , The (TDS) percentage ranged between (720-914) ppm while the hardness values ranges between (420-576)ppm.

The results(cataions and anions) shows that the major the is calcium, sodium, bicarbonate and sulfate . As for the minor meatal, the nitrate ranges between (16.484-22.265)ppm with an average of (18.515) ppm and the phosphate ranges between (1.371-12.360)ppm with an average of (8.049) ppm.

The heavy elements, the lead(Pb) ranged between (3.3196-3.5644)ppm with an average of (3.469)ppm and the copper (Cu) ranges between (2.3760-2.5099)ppm with average (2.415) ppm, cadmium (Cd) ranges between(0.1087-0.2463)ppm with average (0,14) ppm, cobalt (Co) ranges between(2.0816-2.3192)ppm with average (2.195) ppm, zinc (Zn)ranges between (0.0116-0.2898)ppm with average (0.1249) ppm, while iron (Fe) ranges between (0.0-0.4780)ppm with average (0.1618) ppm.

The study showed methods for soil treatment and stabilization for each station within the study area.

List of Contents

Heading	Subject	Page
	Summary	I
	List of Contents	III
	List of Tables	VII
	List of Figures	VIII
	List of Abbreviation	X
1	CHAPTER ONE: Introduction	1-18
1 -1	Preface	1
1-2	Location of Study Area	1
1-3	Geology of Study Area	2
1-4	Aims of this Study	5
1-5	Previous Studies	5
1-6	Methodology	8
1-6-1	The Data Collection Stage	8
1-6-2	The Field Work Stage	8
1-6-3	Laboratory Work	10
1-7	Climatic Study	11
2	CHPTER TWO: Theoretical Background	19-37
2-1	Introduction	19
2-2	Physical Properties of the Soil	19
2-2-1	Grain Size Analysis	19
2-2-2	Soil Classification of for Engineering	20
2-2-3	Atterberg Limits	22
2-2-4	Maximum dry Density	23
2-2-5	Specific Gravity(S.G)	23

Heading	Subject	Page
2-3	Engineering properties of soil	24
2-3-1	Uniaxial Compressive Strength	24
2-3-2	Shear Strength	25
2-4	Soil chemical Tests	26
2-4-1	Carbonate (CaCO ₃ %)	26
2-4-2	Gypsum (Gyp%)	26
2-4-3	Sulfate (SO ₃ %)	27
2-4-4	Organic Matter	27
2-4-5	Total Soluble Salts (TSS)	27
2-5	Mineralogical Study of Soil	28
2-6	Hydrological Characteristics	28
2-7	physical properties	28
2-7-1	Electrical Conductivity (EC)	28
2-7-2	Hydrogen Ion Concentration (PH)	29
2-7-3	Total Dissolved Solids (TDS)	29
2-7-4	Total Hardness (TH)	30
2-8	Chemical Tests of Water	31
2-8-1	Major Cations	31
2-8-2	Major Anions	32
2-8-3	Minor Compounds	32
2-8-4	Heavy Elements	33
2-9	Water Suitability for Irrigation Purposes	35
2-9-1	Sodium Adsorption Ratio(SAR)	36
2-9-2	Soluble Sodium Percentage Na%	37

Heading	Subject	Page
3	CHAPTER Three: Soil Stabilization Method & Material	38-47
3-1	Introduction	38
3-1-1	Station No.1	38
3-1-2	Station No.2	39
3-1-3	Station No.3	39
3-1-4	Station No. 4	40
3-1-5	Station No.5	41
3-1-6	Station No. 6	42
3-1-7	Station No.7	42
3-1-8	Station No.8	43
3-1-9	Station No.9	44
3-1-10	Station No.10	44
3-2	Soil Stabilization	45
3-2-1	Stabilization by Cement	45
3-2-2	Stabilization with Calcium Hydroxide (Cao):	46
3-2-3	Using Rock Blocks	47
3-2-4	Soil Arming (Reinforcement)	47
3-2-5	Stabilization with Vegetation	47
4	CHAPTER Four: Results and Discussion	48-65
4-1	Introduction	48
4-2	Physical Properties of the Soil	48
4-2-1	Grain size Analysis	48
4-2-2	Soil Classification of for Engineering	51
4-2-3	Atterberge Limits	52

Heading	Subject	Page
4-2-4	Maximum dry Density	52
4-2-5	Specific Gravity	52
4-3	Engineering properties of Soil	52
4-4	Chemical Tests of soil	53
4-5	Mineral Tests of Soil	54
4-6	Hydrological Characteristics	56
4-7	Physical Properties	56
4-8	Chemical tests of water	58
4-8-1	Major Cations	58
4-8-2	Major Anions	59
4-8-3	Minor Compound	60
4-8-4	Heavy Metals(Trace Elements)	61
4-9	Water suitability for irrigation purposes	63
4-9-1	Sodium Adsorption Ratio(SAR)	64
4-9-2	Soluble Sodium Percentage(Na%)	64
4-10	Soil Stabilization	64
5	Chapter Five:Conclusions and Recommendations	66-69
5-1	Conclusions	66
5-2	Recommendations	69
	References	70-80

List of Tables

Heading	Table	Page
Table(1-1)	Geologic Sequence of the Study Area, Jassim and Goff (2006)	3
Table(1-2)	The Coordinates of the Water and Soil Sampling Sites	9
Table(1-3)	Method of Chemical Analysis and Parameter are used in the laboratory	10
Table (1-4)	The Monthly Averages of Climate Elements in the city of Al-Hilla for the period (1990-2019) from the Iraqi Meteorological organization	12
Table (2-1)	Classification of soil Cataloguing System to Define the Texture and Grain size of a Soil	20
Table (2-2)	Reference to the coarse soil grains	21
Table (2-3)	Describes the Liquidity Limit values for	22
Table (2-4)	Descriptive Terminology of Clayey Soil Consistency vs. Numerical Value of Compression strength in the unit of KN/m ²	25
Table (2-5)	Relationship between Electrical Conductivity and Mineralization	29
Table (2-6)	Classification of Water According to TDS in (ppm)	30
Table (2-7)	Classifications of Water According to the Total Hardness	30
Table(2-8)	Classification for the tolerance of Crops by Relative Salt Concentration for Agriculture(Todd,2007)	35
Table (2-9)	The value of SAR , Na% in the Water Samples	37
Table (2-10)	Classification of Irrigation Water based on Na%	37
Table (4-1)	The results of some physical Test of Soil in the Al-	49

	Musaiyab Water Project	
Table (4-2)	Acompression and Shear Strength values and Soil type	53
Table (4-3)	The results of soil Chemical Tests	54
Table (4-4)	Annul Discharge Rate of Great Ai-Musaiyab Project for the period(2019-2021)	56
Table (4-5)	Physical Parameters for Water Sample	57
Table(4-6)	The Concentration and Contast of Major Cations in ppm for the water sample (IQS,2009)and (WHO,2011)limits	59
Table(4-7)	The Concentration and Contast of Major Anions in ppm for the water sample (IQS,2009)and (WHO,2011)limits	60
Table (4-8)	The Concentration and Contast of Minor Compounds in ppm for the water sample (IQS,2009)and (WHO,2011)limits	61
Table(4-9)	The Concentration and Contast of Trace Elements in ppm for the water sample (IQS,2009)and (WHO,2011) and(EPA,2011)limits	63
Table (4-10)	The value of SAR,Na% in the water sample	64
Table (4-11)	The Stabilization Technique of Soil Slope	65

List of Figure

Heading	Figure	Page
Fig(1.1)	Location map of the Study Area	2
Fig (1-2)	The Fieldwork of the Study Area	9
Fig(1-3)	The Monthly Average Values of Tamparature	13
Fig(1-4)	The Monthly Average Values of Rainfall	14

Fig(1-5)	The Monthly Average Values of Wind	15
Fig(1-6)	The Monthly Average Values of Evaporation	16
Fig (1-7)	The Monthly Average Values of Relative Humidity	17
Fig(1-8)	The Monthly Average Values of Sunshine	18
Fig(2-1)	Physical Tests of Soil	24
Fig(2-2)	Engineering Tests of Soil	26
Fig(3-1)	Station No.(1) in Al-Musaiyab water project	38
Fig(3-2)	Station No.(2) in Al-Musaiyab water project	39
Fig(3-3)	Station No.(3) in Al-Musaiyab water project	40
Fig(3-4)	Station No.(4) in Al-Musaiyab water project	41
Fig(3-5)	Station No.(5) in Al-Musaiyab water project	41
Fig(3-6)	Station No.(6) in Al-Musaiyab water project	42
Fig(3-7)	Station No.(7) in Al-Musaiyab water project	43
Fig(3-8)	Station No.(8) in Al-Musaiyab water project	43
Fig(3-9)	Station No.(9) in Al-Musaiyab water project	44
Fig(3-10)	Station No.(10) in Al-Musaiyab water project	45
Fig(3-11)	Stabilization with Vegetation	47
Fig(4-1)	The results of Grain size Analysis (Sieves analysis&Hydrometer analysis)	50
Fig(4-2)	Plasticity Chart and the Soil Classification Along the Along the Great Ai-Musaiyab Project	51
Fig(4-3)	XRD Chart for the AL-Musaiyab Water Project Station(1,5,9)	55

List of Symbols

Symbol	The meaning in English
ASTM	American Society for Testiny and Materials
BSI	British Standard Institution
EPA	Environemental Protection Agency
G.S	Specific Gravity
IQS	Iraqi Quality Standard
L.L	Liquid Limit
MOWR	Ministry of water Resoures
OMC	Optimum moisture content
P.I	Plasticity Index
P.L	Plasticity Limit
SAR	Sodium Adsorption Ratio
TDS	Total Dissolved Solids
T.H	Total Hardnees
T.S.S	Total Soluble Salts
USCS	Unified Soil Classification System
WHO	World Health Organization

Chapter one

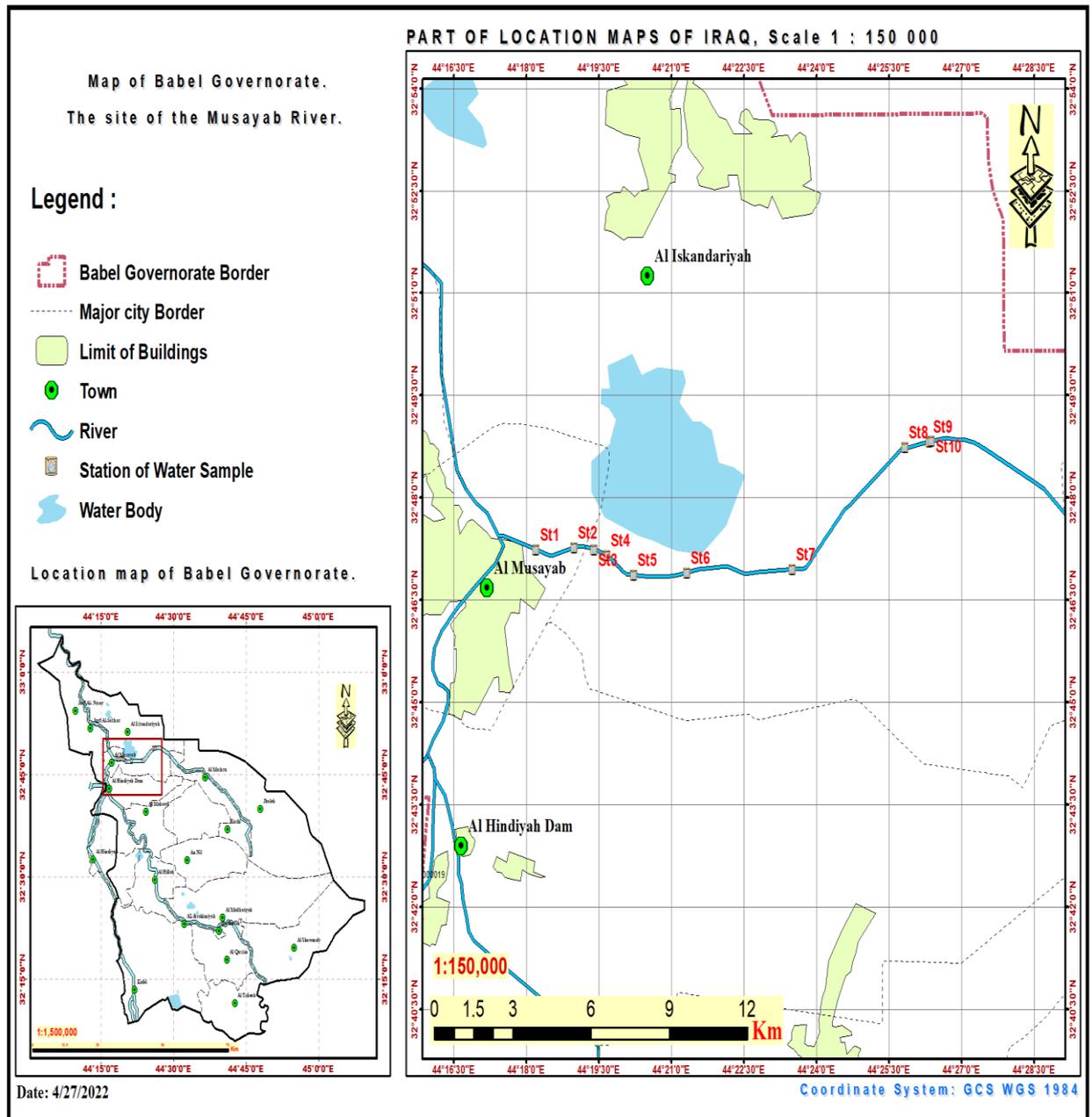
Introduction

1 -1 Preface

Water resources constitute an important element in the conduct of all economic and social activities. It is a necessity for human life. If interest in its resources is a basic requirement, the Great Musaiyab project is one of the major strategic agricultural projects in Iraq due to its clear economic and social effects on society since 1957, the year in which the project was officially opened(Al-Zaidi,2012) until the present time, the project has gained great importance and is still at various levels, As it provided water through the (Al-Musaiyab project channel) and its branches that feed the entire project area and suitable soil for agriculture, so it contributed to the elimination of desertification and salinity and contributed to stopping the migration of farmers to the city (MOWR,2014).

1-2 Location of Study Area

The Great Al-Musaiyab project is located in the north of Babylon Governorate, between the Tigris and Euphrates rivers, 65 km south of the city of Baghdad. The study area is at the longitude($44^{\circ} 18' 12'' - 44^{\circ} 26' 23''$)and latitude($32^{\circ} 47' 14'' - 32^{\circ} 48' 50''$), As showin fig. (1.1). the total area coveres 334,780dunums (Al-Moussawi,1997)and the design dischare reached $40\text{m}^3/\text{sec}$.



Fig(1.1) Location map of the study area and Sampling Sites(of the Researcher work).

1-3 Geology of study area

The sediments of the Mesopotamian plain covers the central portion of a synclinal depression . The geologic sequence of the study area according to Jassim and Goff (2006) in Table (1-1) .

Table(1-1):Geologic sequence of the study area(Jassim and Goff, 2006)

Lithology	Formation	Thicknees	Age
Clayey silt,SAND Pebbles	Alluvial	0-1000m	Recent to Pleistocene
UNCONFORMITY			
Silty sand,Pebbles, marl.	Mukdadia(Bakhtiari) Injana(upper Faris)	700-1000m	Pliocene- Middle to Upper Miocene
Marl,Gypsum, limestone	Fatha(Lower Fars)	100-400m	
Limestone	Euphrates-Asmari	70-200m	LowerMiocene

Geologically , the study area includes mainly Quaternary sediment of Pliocene to Miocene age . Babylon Govemorote within the study area is characterized by plain surface with gentle gradient around 22 cm / km . General direction of the slope in the study area is from North and West toward East and South East parts of Iraqi (Al - Jubori , 2002) . The sediments of the study area mainly consist of the deposits of Tigris and Euphrates Rivers and their branches in addition to the aeolian deposits . The rives carry high rates of suspended sediment ; 95 % of these sediments are deposit in the southern flood plain , while 5 % reaches to the Arabian Gulf (Buringh , 1960) . The most important formations in the study area are :

- Euphrates Formation (Lower Miocene) : This formation is composed at the type locality of shelly , chalky , well bedded recrystallized limestone (Bellen *et al.*, 1959) . The environment of formation is shallow marine with coral reef (Al - Sayyab *et al .*, 1982) . The thickness in the type locality is 8 m only . The thickness in the surrounding areas,as well as in the boreholes is usually many times more, reaching to amaximum of 100m.Avarage thicknees around 60m-70m(Buday,1980).

- Fatha Formation (Middle Miocene) : This formation distributes widely in Iraq , it is characterized by Evaporates that contain ; anhydrates , gypsum , and salts , overlying with limestone and marl . The thickness of the formation is widely different ; it reaches to 900m in the middle parts of the flood plain , (Buday, 1980)
- Injana Formation (Upper Miocene) Lithologically , this formation is divided into two main units (Hassan , & Al - Khateeb , 2005) .
 - a. Lower Clastic Unit : It consists of alternation of different clastic rocks (claystone , sandstone and siltstone) or a mixture of these rocks of different ratios . The thickness of this unit reaches up to 25 m. The succession of this unit shows some lateral and vertical variations .
 - b. Upper Cave - Forming claystone unit : It is informally named the Cave forming clay stone unit It consists of claystone ; it may change laterally or vertically to silty claystone. The thickness of this unit reaches 6.0 m or more in some places . The environment of deposition is initially lagoon and fluvial lacustrine (Buday, 1980)
- Dibdibba Formation (Pliocene Pleistocene) This formation is exposed widely in central and south of Iraq . Dibdibba Formation is composed of pebbly sandstone and sandstone with some claystone , siltstone , and marl associated with secondary gypsum . It is 350 m thick (Buday & Jassim , 1987).
- Quaternary Deposits: This region belongs to the typical Quaternary area with no exposures of the older bedrock. The sediments of quaternary deposits cover most of the flood plain including the study area, it consists of younger alluvial deposits that belong to Holocene, and the older alluvial deposits belong to Pleistocene. It consists of the flood plain of Tigris and Euphrates Rivers and their branches in addition to the deposit of irrigation canals that distributed on both sides of rivers. Most of Quaternary sediments

consist of clay , silt , and sand in addition to the chemical deposit such as gypsum, carbonate and salts from the evaporation of the groundwater . The second deposits represent older alluvium deposit such as Terraces that distributed along northwest the flood plain (Falloja Mahmoodia). These sediments graded from gravel , sand to the silt and clay toward flood plain (Domas , 1983). Study area lays within depressed flood plain on the natural levees (Al- Ani , 1986) .

1-4 Aims of this Study

1. Studing the physical, Engineering, chemical and mineralogical properties of the soil slopes of river banks.
2. Studing the hydrochemistry of water for Al - Musaiyab water project.
3. suggesting remedial measures to protect the channel banks and their stability to ensure optimum investment of the water resources of the river qualitatively and quantitatively .

1-5 Previous Studies

The Previous studies on Al- Al-Musaiyab water project focused on different aspects, including topography ,geomorphology of the region and the economic significance of the river. Most of the previous studies did not pay attention to the nature of the soil slopes of the canal banks .

The following are the most important of these studies:

1. Buringh(1960) studied the soil of all Iraq including the study area and described the sediment of the river banks as silty loam.

2. Al-Ebadi (1981) studied the agricultural fashions in Babylon Governorate and provided some notice for treatment the salinity problem.
3. Al-Ubaidy(1983) studied the hydrogeochemistry of the Euphrates River and studied the potential contamination and assessment water quality of Euphrates River for different uses.
4. Al-Ani(1986)studied the Hydrogeochemistry and the sedimentology of Al-Sebakh area central and southern of Iraq included sebakh AlMusaiyab, Al-Eskandarya, Al-Dywanya, Al-Kifil, Al-Semawa, Al-Hilla, Al-Hashimya, and Al- Mahmoodya. This study explained that the water was alkali and has low to extreme salinity. It has chloride solutions in most sebakh, while it was sulfates in Al-Eskandaria and Al-Dywania sebakh.
5. Al-Mossawi (1989) studied the geography and irrigation activities within Babylon Governorate, and studied soil samples taken from the banks of the irrigation canals. He found that the soil type is mainly silty loams, and there were differences in the nature and the characteristics of the soil from place to place as well as in depth.
6. Al-Sam *et al.*, (1990) studied the drainage and the soil salinity in the Mesopotamian, and explained the increase in salinity of the soil and shallow ground water and pointed out the necessity to carry out the systematic drainage network to control the increase of this phenomenon.
7. Issa, (1995) studied the Hydrochemistry of the Euphrates River and its polluted sediments south of Al-Hindiyah. The study determined the impact of human activities on the change of the Euphrates river water quality and its hydrogeological characteristics. The study

- show that Euphrates River sediments is polluted with elements of Cr, Pb, Ni, Zn and Cd from several sources.
8. Manni (2003) studied the Hydrochemical properties of the ground water and the mineralogy of soil sediments in the open reservoirs within some selected areas within Babylon governorate and concluded that the water was hard with high concentrations of sulfate due to the high existing of gypsum in the soil.
 9. Al-Ammar(2004) studied the hydro-chemistry of shallow groundwater, streams water and some of the water drains within Babylon Governorate, concluded that the water was hard with high concentrations of sulphat due to the high presence of gypsum in the soil.
 10. Al-Bassam, and Al-Mukhtar (2007) studied heavy minerals in the sediments of the Euphrates River in Iraq. This study show that there are several sources for Heavy Minerals in the Euphrates River sediments, including igneous and sedimentary complexes in Turkey and Syria, Injana and Dibdibba formations inside Iraq, as well as the clastic derived from NE Iraq by the Tigris River and its tributaries, which show their influence in the Mesopotamian part of the river basin.
 11. Al-Robaiee(2008)studied the Stabilization of Silt and Clay Soils for sites in Hilla city by(Cement, Hydrated lime). He explained that the Clayey Silt soils prevail in most of the lands of the city of Hilla, and showed from the study that the stabilizers with the soil give the desired resistance to the foundation of the roads.
 12. AL-Shihmani, (2015) studied the effect of leaching the saline soil (AlSebakh) by using different qualities of water and show their impact on some physical and chemical properties of the soil.

13. Al-Ali, (2016) studied the Hydrogeochemistry of surface and ground water and their effects on the soil of the Greater Musaiyab Project - central Iraq.

1-6 Methodology

Stages of research involved:

1-6-1 The Data Collection Stage

1. Collecting data, research papers, reports and theses related to the subject of the study
2. Collecting hydrological information about the area from the Department of Water Resources, Al-Musayyib branch.
3. Preparing climatic data for the period from (1990-2019) from the Iraqi Meteorological Authority, Al-Hilla branch
4. Preparing a site map of the study area at a scale of 1:50000 Fig(1-1)

1-6-2 The Field Work Stage

1-6-2 (A) Water Sampling

The field work started on 4/12/2021, which included a field trips to the study area in order to select the stations. The number of slope assessment sites reached 10 stations. Nine samples of water were selected for chemical and physical analysis, which included the physical properties (Electrical conductivity EC, degree of acidity pH and Total Dissolved Salts (TDS) measured directly in the field using Multimeter Hana (Hi,9821) and samples were taken using 1 liter plastic containers to analyze heavy metals, Major element (Anion and Cations) and minor element (Nitrates and Phosphates), and the GPS was used to determine the sampling stations as in Table (1-2) and Figure (1-1)

Table(1-2) The Coordinates of the Water and Soil Sampling Stations.

Number of station	Longitude E	Latitude N
St1	44° 18` 12``	32° 47` 14``
St2	44° 18` 59``	32° 47` 16``
St3	44° 19` 24``	32° 47` 14``
St4	44° 19` 40``	32° 47` 09``
St5	44° 20` 13``	32° 46` 52``
St6	44° 21` 19``	32° 46` 54``
St7	44° 23` 30``	32° 46` 57``
St8	44° 25` 50``	32° 48` 44``
St9	44° 26` 20``	32° 48` 49``
St10	44° 26` 23``	32° 48` 50``

**Fig (1-2) The Fieldwork of the Study Area**

1-6-2 (B) Soil sampling

Collected 10 samples from the river banks soil along the study area and put it in storage bags to test the physical, chemical, engineering and mineral properties, the station samples shown in Table (1-2)

1-6-3 Laboratory Work:

After the field work was completed, the water samples were carried to the Chemistry laboratories in the College of Science, University of Babylon to conduct chemical tests as shown in the Table (1-3), as well as the soil samples were carried to the National Center for Laboratories and Construction Research (Babylon Branch) and to the laboratories of the Earth Science Department in the College of Science, University of Babylon to conduct the following tests:

1. The physical tests include grain size analysis, density, Atterberg limits, specific gravity.
2. The engineering tests include uniaxial compressive strength, direct shear test.
3. The chemical tests of the soil samples at sites include sulphates (SO_3), gypsum, carbonates (CaCO_3), Organic matters and Total Soluble Salts (TSS).
4. Mineralogical test to identify the mineral components of soils.

Table(1-3): Method Chemical of Analysis and Parameter are Used in the Laboratory

Parameter	Methods of analysis
Na^+ , K^+	Flame photometer-APHA, 1998
Ca^{2+} , Mg^{2+} , T.H	Titration with EDTA (Ethylene Diamine Tetracetic acid)

Cl ⁻	Argentometric method (silver nitrate method)
(SO ₄) ⁻²	Turbid metric method and colorimetric method
(HCO ₃) ⁻	Titration method using indicator titrated with HCl
PH	Conductivity meter and PH meter
TDS	Gravimetric TDS meter , cyber scan 10
EC	Conductivity meter
Trace elements	Atomic absorption spectrometer/GBC 933 plus

1-7 Climatic Factors

Climate has a great influence on the hydrological cycle in terms of the quantity and quality of runoff in any region of the world, whether in terms of increasing or decreasing water losses, and it has a great impact on other elements such as vegetation cover, geomorphology and soil (Shaker, 1985). The climate of the study area is characterized as continental, dry and relatively hot in summer and cold and little rain in winter, influenced by the Mediterranean climate (Al-Khatib, 1988). Monthly averages of climatic parameters of Hilla meteorological station for the period (1990-2019) taken from the Iraqi meteorological organization (Table 1-4).

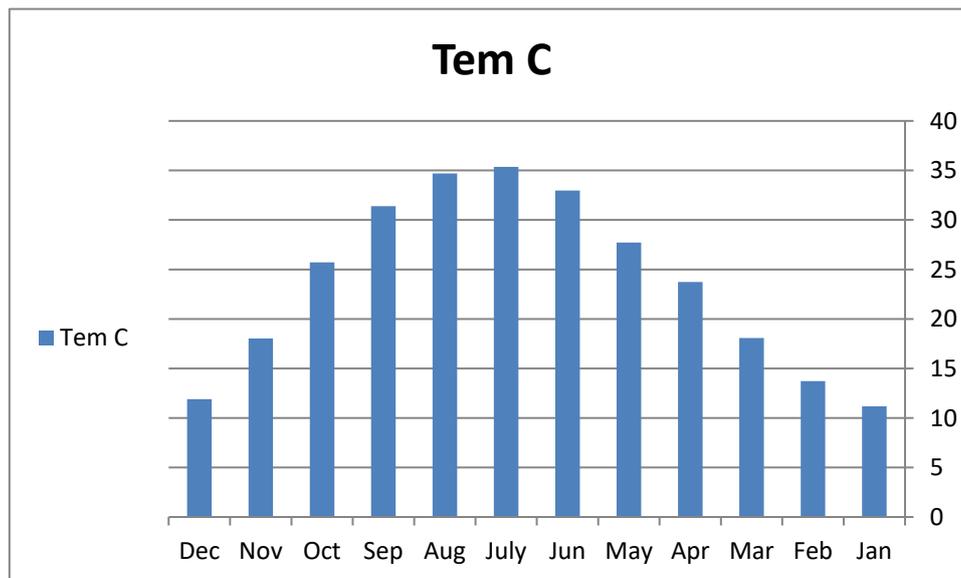
Table (1-4) The Monthly Averages of Climate Elements in the City of Al-Hilla for the period (1990-2019) from the Iraqi Meteorological organization

Month	Tem. (C°)	Rainfall (mm)	Relative Humidity %	Wind Speed (m/s)	Evap. (mm)	Sunshine (h/day)
Jan	11.17	23.97	71.447	1.486	53.542	6.17
Feb	13.72	11.87	64.080	1.805	80.665	7.31
Mar	18.08	11.60	52.536	2.157	140.38	7.66
Apr	23.74	10.29	43.818	2.026	189.78	8.462
May	27.71	3.2	35.391	1.947	264.21	9.075
Jun	32.98	0.008	29.621	2.531	333.83	11.18
July	35.36	0.000	29.4	2.65	353.80	11.773
Aug	34.69	0.000	31.86	1.943	306.25	11.425
Sep	31.39	0.213	36.269	1.485	243.32	10.15
Oct	25.72	3.49	46.191	1.305	163.52	8.45
Nov	18.02	28.52	62.13	1.210	81.40	7.045
Dec	11.9	19.10	66.55	1.406	57.751	6.280
Average	23.750	94.752		1.829		

1-7-1 Temperature

Temperature is one of the most important climate factors and the most direct and indirect influence on water resources through its impact on other climate factors such as atmospheric pressure, wind movement, cloud formation, rainfall and evaporation rates (Al-Dahi, 1989) It is evident from the Table (1-4) and figure (1-3) that there is a discrepancy in the average temperature for the period (1990-2019), as the highest

average temperature was in July (35.36°C), while December recorded the lowest average temperature (11.9°C). The effect of higher temperatures and less rainfall leads to the weakening of the vegetation cover, thus reducing its stability. The high temperature for a long period of the year dries up the muddy soil, disintegrates particles, and facilitates the gusts of wind that sweeps it.

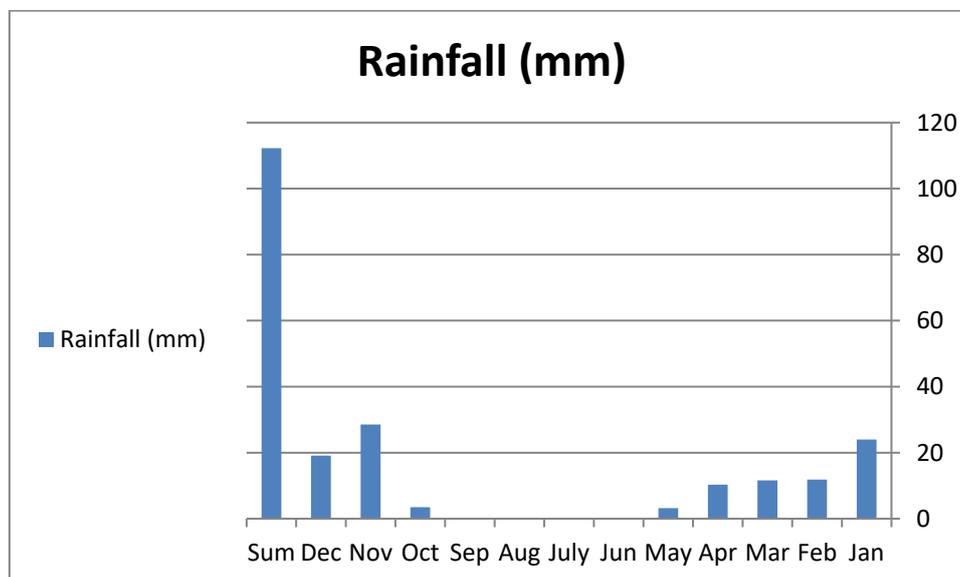


Fig(1-3) The monthly average values of Temperature

1-7-2-Rainfall

One of the most climatic factors that have an impact on the hydrological cycle, especially in dry and semi-arid areas, the increase in rainfall leads to an increase in river drainage, which is reflected in the river's ability to water erosion of the banks, which leads to the emergence of many bends and zigzags, while the lack of rain that coincides with high rates of evaporation reduce its impact on the formation of river sides (Al-Badran, 1987). The location of the study area is characterized as being located within the climatic regions. It is hot and dry and thus is characterized by low rainfall and low relative humidity. The highest rate of rain was recorded during the month of November, at a rate of (28,52)

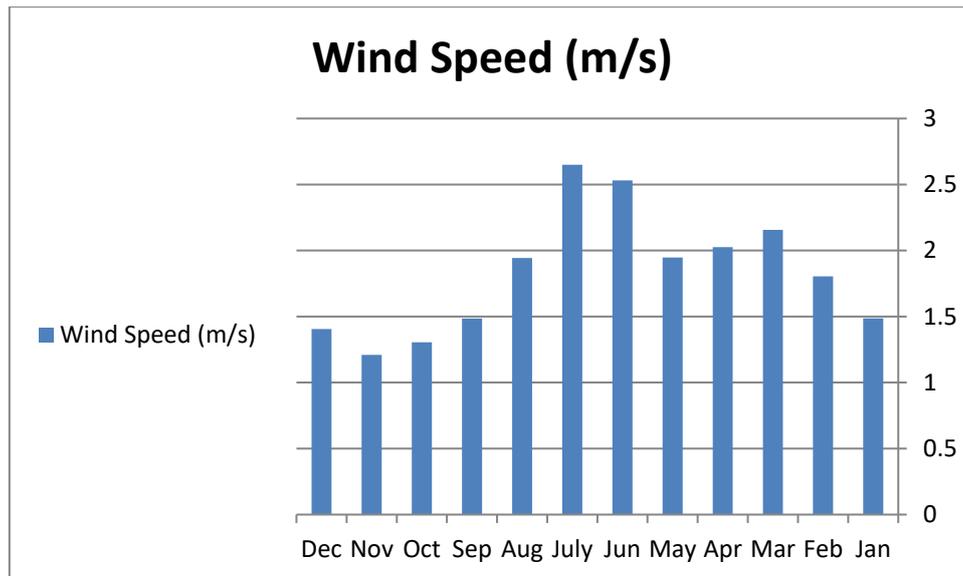
mm, and the lowest rate during the months (June, July, August, and September), where it reached zero.



Fig(1-4) The monthly average values of Rainfall

1-7-3- Wind

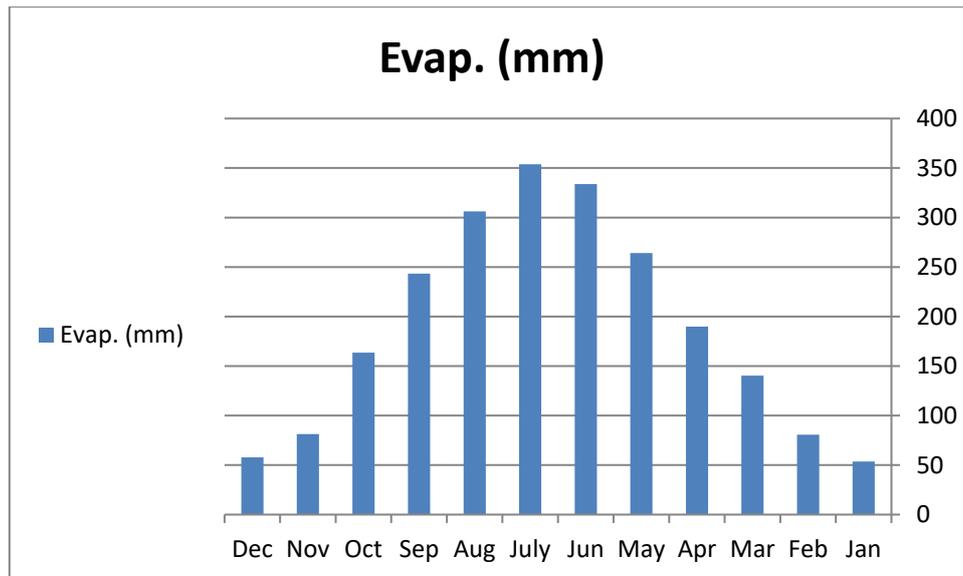
Wind is one of the important factors in the climate, which is considered one of the permanent factors affecting the formation of the general geomorphological appearance of dry and semi-arid regions as a factor of disintegration, Transport and sedimentation (Naqash, 1989). Wind affects the hydrological cycle through the characteristics that it has of speed, direction, temperature and humidity, meaning the more dry, high speed and high temperature it leads to an increase in evaporation and thus an increase in water losses and vice versa. It is evident from the Table (1-4) and Figure (1-5) that the lowest rate of wind gusts was during November at a rate of (1.210) m/s, and the highest rate recorded during the month of July was (2.65)m/s



Fig(1-5) The monthly average values of Wind

1-7-4-Evaporation

It is one of the climatic factors that characterizes the dry and semi-arid areas, and it is an important element in the water cycle in nature (Al-Hadid, 1984), as the high rates of temperature, the lack of rainfall and relative humidity affect the increase in evaporation rates and consequently the increase in water losses, which negatively affects the drainage watery. It is clear from Table (1-4) and Figure (1-6) that evaporation rates increases in July if it reaches (353,80) mm, coinciding with the rise in temperature, wind speed and dryness, in addition to the lack of rainfall and low relative humidity, while the lowest rate of evaporation is recorded in January, where it reached (53,542) mm



Fig(1-6) The monthly average values of Evaporation

1-7-5-Relative humidity:

It is the percentage of what is actually present of water vapor in the air to the largest amount of moisture that the air can carry under the same temperature and atmospheric pressure (Al Sarraf, 1980). The relative humidity in the air is very important because it reduces the drying out of the soil and thus increases its cohesion and protects it from erosion (Jaber, 2008). It is clear from Table (1-4) and Figure (1-7) that the highest rate of relative humidity is in January, reaching (71.447%), while the lowest rate is (29,4%) during July.

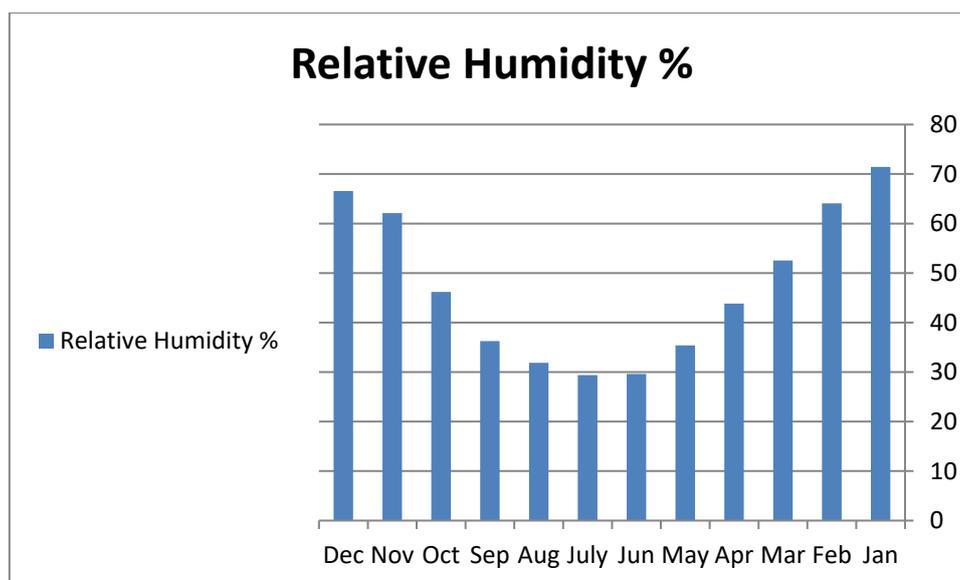


Fig (1-7) The monthly average values of Relative Humidity

1-7-6- Sunshine

A number of hours during one - day are known as solar sunshine (Chow , 1964). It is one of the most important climate elements that have great control on the amount of the evaporated water . The number of brightness hours are considered as solar influence on the temperature and relative humidity and then it has effects on the real evapotranspiration. The monthly averages of sunshine for the period (1990- 2019) are shown in Table (1-4) . Highest average of sunshine is recorded in July (11.77 hour/day) while the lowest is recorded in January (6.1 hour / day). see Figure (1-8) .

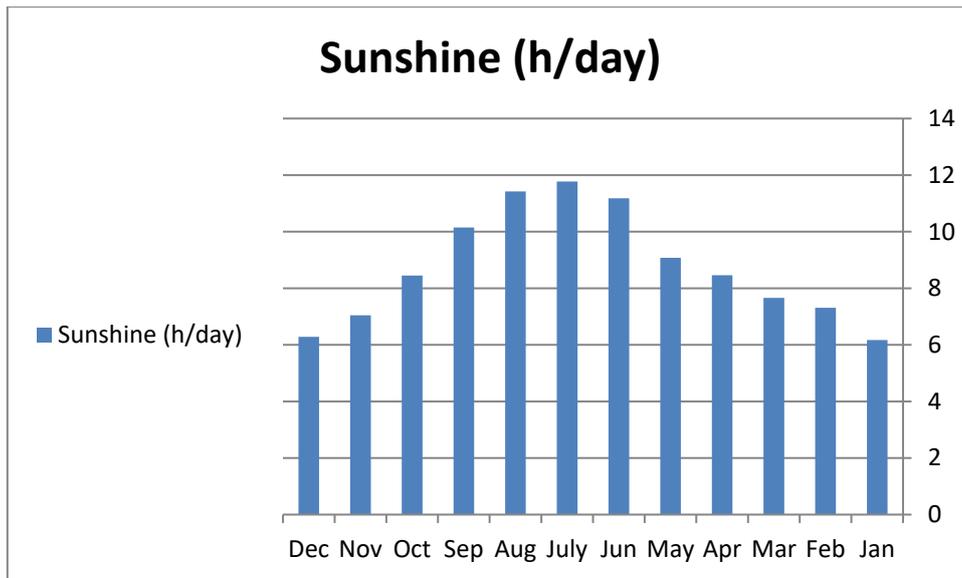


Fig (1-8) The monthly average values of Sunshine

Chapter Two

Theoretical Background

2-1 Introduction

This chapter deals with the physical, chemical and engineering properties of the Musaiyab project soil and the problems it is exposed to and the impact of water on it have been studied, and it includes the study of Hydrological and Hydrochemical characteristics of Al-Musaiyab Water Project. Checked out Major elements cations and anions are (Ca^{+2} , Mg^{+2} , Na^+ , K^+ , SO_4^{-2} , Cl^- , CO_3^{-2} , HCO_3^-), minor elements (NO_3^- , PO_4^{-3}), trace elements (Copper (Cu) , Zinc (Zn) , Lead (Pb) , Cadmium (Cd) , Cobalt (Co), and Iron (Fe) and physical properties (Electrical Conductivity (EC) , degree of acidity (PH), Total Hardnees (TH), and Total Dissolved Solids (TDS)

2-2 Physical Properties of the Soil**2-2-1 Grain size Analysis**

Soil consists of granules of different sizes. The percentages of these sizes can be found through (mechanical analysis). The classification of soil depends mainly on the particle size of the soil grains, where the soil is in the form of a mixture of gravel, sand and fine granules in different proportions (Krynine & Judd, 1957). The soil is separated into different size- groups after passing through two stages:

1-Sieve Analysis

In this test, soil particles with diameters greater than 0.075 mm are separated by means of a set of standard sieves bearing numbers between No. (4) and No. (200) according to the American specifications, where the soil was separated into groups of different sizes and used to classify the soil for engineering purposes . As well as the ability to predict the movement of water in the soil (Bowels, 1984).

2-Wet Analysis (Hydrometer) :

It is used to separate granules with a diameter of less than 0.075 mm passing through a sieve number 200, where the hydrometer measures the density of the water and soil solution, which indicates the percentage of soil granules suspended to that solution.

2-2-2 Soil Classification of for Engineering**2-2-2-1 Unified Soil Classification System(USCS):**

It is a soil classification system used to describe the texture and size of soil particles. This soil system can be applied to most loose materials (non-cohesive) and is represented by a two-letter symbol as in Tables (2-1)and (2-2)

Table (2-1) Classification of soil cataloguing system to define the texture and grain size of a soil

First and/or second letters		Second letter	
Letter	Description	Letter	Description
G	Gravel	P	Poorly Classified(Unvarying Particle Dimensions)
S	Sand	W	Well-Classified(Varied Particle Dimensions)
M	Silt	H	High Plasticity
C	Clay	L	Low Plsticity
O	Organic		

Table (2-2):Reference to the Coarse Soil Grains (Evet,2007)

Major Division		Group Symbol	Group Name
Gravel-	Fine <5% clean gravel	GW	Well-graded gravel , fine to coarse gravel
		GP	Poorly graded gravel
	Fines 5-12% Dual system	GW-GM ,GW-GC	Well-graded Gravel silty or Clay
		GP -GM , GP-GC	Poorly- graded Gravel silty or Clay
	Fine >12%	GM	Silty gravel
		GC	Clayey gravel
Sand	Fine<5% clean sand	SW	Well-graded Sand,fine to coarse Sand
		SP	Poorly graded Sand
	Fines 5-12% Dual system	SW-SM ,SW-SC	Well-graded Sand silty or Clay
		SP-SM ,SP-SC	Poorly-graded Sand silty or Clay
	Fine >12%	SM	Silty sand
		SC	Clayey sand

2-2-3 Atterberg Limits

The Atterberg limits is a basic measure of the moisture contents in which the soil change from one state to another, i.e. the percentage of soil moisture. When the moisture contents increase in the clay soil, there are noticeable changes to its texture and behavior (Thabit & Al-Asho, 1993), These include:

2-2-3-1 Liquid Limit(L.L):

It is defined as the water content that transforms the performance of the soil from the plastic phase to the liquid phase (Tsytovich, 1986). This transformation does not happen suddenly, but rather gradually on several differences in the water contents. Table (2-3) shows description of the liquidity limit values for (kerbs& walker,1971).

Table (2-3): Describes the Liquidity Limit Values (Kerbs& Walker,1971).

Liquid Limit %	Description
<20	Very low liquid limit
20-25	Low liquid limit
25-50	Intermediate liquid limit
50-70	High liquid limit
70-90	Very high liquid limit
>90	Extra high liquid limit

2-2-3-2 Plasticity Limit(P.L):

It is the water content of the sample at which the soil disintegrates when wrapped into fine threads with a diameter of 3.25 mm (Lambe, 1951), and the sample is re-formed and the experiment is repeated repeatedly to obtain the most accurate results.

2-2-3-3 Plasticity Index (P.I):

The plasticity index defines the extent of the moisture contented in which the soil remnants in the plastic state, which is the numerical difference between the liquidity limit and the plasticity limit of the soil and it can be written as follows $(PI = L.L - P.L) \dots (2-1)$.

2-2-4 Maximum dry Density:

This test aims to determine the maximum dry density and the optimum moisture content(OMC) of the soil (Al-Zubaidi, 2006)., and this test is done by preparing four or five samples of the concerned soil so that each sample contains a water content more than the previous by about 2% and compacting each sample in a mold. It has fixed dimensions. The test was done according to(ASTM D 698-2012).

2-2-5 Specific Gravity(G.S):

The specific gravity of soil refers to the ratio of the weight of a specific volume of the material to the weight of an equal volume of distilled water (Bowels, 1984). Determining the specific weight of soil is important in deriving many soil parameters such as porosity, void ratio, dry and saturated density and degree of saturation. The test was carried out standard (BS 1377-2).



A-Liquid limit(LL) of Soil



B-Grin size analysis (Sive analysis)



C-Grin size analysis by (Hydrometer)

D-Maximum dry density by
(procter test)

Fig(2-1):Physical tests of Soil

2-3 Engineering properties of Soil

2-3-1 Uniaxial Compressive Strength

The uniaxial compressive test (unconfined) is a special case of triaxial test when the cell pressure is equal to zero (Al-Adili, 1998) and this experiment is conducted in the case of saturated cohesive soil (Al-Asho, 1991). The Uniaxial compressive Strength of soil models was measured according to the American Standard (ASTM D 2166-00,2003). Table (2-4) shows descriptive terms of consistency vs. numerical value of

unconfined compressive strength of clayey soil in the unit of KN/m^2 (Peck *et al*, 1967).

Table (2-4) Descriptive Terminology of clayey Soil consistency vs. Numerical Value of Compression strength in the unit of KN/m^2 (Peck *et al*, 1967).

Unconfined compressive strength KN/m^2	Consistency
Less than 25	Very soft
25-50	Soft
50-100	Medium
100-200	Stiffness
200-400	Very stiffness
Over 400	Hard

2-3-2 Shear Strength

The shear box test is sometimes called the direct shear test because the vertical stresses and shear stresses at the breaking level are measured directly (Al-Asho, 1991). It is most suitable for tests in the case of draining water specifically on granular soils such as sand or heavy clay. The shear strength of soil sample is measured according to the American specification (ASTM D 3080-98, 2000).



A-Shear Strength of Soil Test



B-Un confind Compressive Strength Test

Fig(2-2): Engineering Tests of Soil

2-4 Soil Chemical Tests

The chemical analyses were carried out for soil samples taken from the study area to know the chemical properties of the soil according to British Standard (BS1377-2).

2-4-1 Carbonate ($\text{CaCO}_3\%$)

Calcium carbonate is the most among the types of carbonates in the soil because lime is similar in dimensions to clay particles of less than 0.002 mm. An increase in calcium carbonate by 30% or more causes a decrease in the water capacity of the soil and leads to serious engineering problems such as soil weakness (Al-Adili, 1998).

2-4-2 Gypsum (Gyp%)

Gypsum is hydrated calcium sulfate ($\text{CaSo}_4.2\text{H}_2\text{O}$). It is a medium soluble salt whose dissolving is 1.9 g / liter. It is a white substance in the form of crystals of different sizes and shapes. It spreads in dry areas due to the lack of rain that washes the soil from gypsum. (Gorshkov & Yakoshov, 1967). The presence of gypsum reduces the

optimum dry density and increase the proportion of moisture content , and reduces the resistance of the soil.

2.4.3 Sulfate (SO₃%)

Sulfates are usually found in the soil in the form of sodium and magnesium sulfate, and calcium sulfate is found in the form of gypsum that is slow to dissolve in water. The sources of these sulfates are human activities such as the creation and use of fertilizers and pesticides in agricultural activities (AL-Qaraghuli, 2005).

2-4-4 Organic Matter

Organic materials vary due to the diversity of their sources, which are either plant or animal. Plants are considered the main source of organic matter, as they result from the decomposition and disintegration of plants, charcoal and cutting shells (Terzaghi & Peck, 1974), and their negative impact is summarized in:

- a. Decrease in the value of the bearing capacity of the soil.
- b. Increasing the compressibility of the soil (Sheikhel et al, 1999).
- c. Increasing swelling and shrinkage due to the change in moisture content, as it absorbs large amounts of water up to 5 times or more than the weight it occupies (Scott, 1974).
- d. The presence of gas in the voids of organic soil leads to an immediate subsidence.

2-4-5 Total Soluble Salts (TSS)

The weight percentage of all water-soluble soil salts, where the degree of solubility of the salts varies according to their nature. The chloride salts are easier to melt than carbonates and sulfates, and the degree of solubility is affected by temperature, pH value, and the amount of dissolved CO₂ gas, as well as the process of evaporation and humidity.

The percentage is high if it reaches (0.5%).) because it increases the strain in the clay soil layers (Lambe & Whitman,1969).

2-5 Mineralogical Study of Soil :

Mineral analysis of soil samples was carried out for three samples (station 1, station 5 and station 9). X-ray diffraction (XRD) analysis was performed on the samples after sieving them in sieve No. 200 with an amount of 2g for each sample. This XRD examination was conducted at Babylon University, College of Materials Engineering.

2-6 Hydrological Characteristics

1- Annual Water Discharge:

By water drainage, it means the average of what passes of water in cubic meters during one second. The importance of studying the annual water drainage and for certain periods is that it determines the general drainage of the stream and compares it with the average annual expenditures, in addition to knowing the characteristics of the water years, whether they are wet, dry or average (Al-Jaghifi & Al-Madhidi, 2011).

2-7 Physical Properties :

2-7-1 Electrical conductivity (EC)

Electrical conductivity is the ability of 1cm^3 of water to conduct electrical current, at temperature of 25C° measured by micromohs/cm ($\mu\text{hs/cm}$) or (Mhs/cm). The EC depends on water temperature, where an increase in water temperature of one degree (C°) causes an increase in electrical conductivity by (2%) (Hem, 1985). Also the EC increases with the increase of the total dissolved salts (Detay,1997).

Table (2-5): Relationship between Electrical Conductivity and Mineralization (Detay , 1997).

EC ($\mu\text{hs/cm}$)	Mineralization
<100	Very Weakly mineralized water
100-200	Weakly mineralized water
200-400	Slightly mineralized water
400-600	Moderately mineralized water
600-1000	Highly mineralized water
>1000	Excessively mineralized water

2-7-2 Hydrogen Ion Concentration (pH)

The pH of a solution represents the negative logarithm of the hydrogen ion activity (Boyd, 2000). $\text{pH} = -\log [\text{H}^+]$(2-2) , pH parameter used as indicator of the acidity or alkalinity of a solution, depends respectively on whether its value is less or greater than 7. pH of the natural waters is an important factor that determines the suitability of water for various purposes ,including toxicity to animals and plants (Ahipathy & Puttaiah, 2008).

2-7-3 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) is the residue of material left in a container after evaporation of a water sample and subsequent drying of the residue (Glenn, 2005) . The concentration of dissolved ions in natural

water depends on the type of soil and rock with which it is in contact and the period and climate of the tangency process (Hem,1989).

Table (2-6): Classification of Water According to TDS in (ppm).

Water Class	Altoviski,1962	Drever,1997	Todd,2007
Fresh water	0-1000	<1000	10-1000
Slightly-brackish water	1000-3000	1000-2000	----
Brackish water	3000-10000	2000-20000	1000-10000
Salty (Saline) water	10000-50000	35000	10000-100000
Brine water	>50000	>35000	>100000

2-7-4 Total Hardness (TH)

Total hardness mainly reflects water contents of calcium and magnesium ions and it is expressed by its equivalent from calcium carbonate (Todd , 2007) according to the following equation : $TH = 2.497 Ca + 4.115 Mg$(2-3) , Where: TH , Ca , Mg are all measured in ppm. Hardness is an important criterion for determining the usability of water for domestic, drinking and many industrial uses (Karanth, 2008).

Table (2-7): Classifications of Water According to the Total Hardness.

Type of water	Total Hardness (ppm)		
	Altoviski (1962)	Boyd (2000)	Todd (2007)
Soft	0-<75	0-50	0-60
Moderate hard	75-<175	50-150	60-120
Hard	175-<300	150-300	120-180
Very hard	>300	>300	>180

2-8 Chemical tests of water

2-8-1 Major Cations

2-8-1-1 Calcium Ca^{+2}

It is the most abundant mineral in alkaline-earth minerals as it is present in all types of soil (White, 2005) and it is a major component of many igneous rocks such as pyroxene, plagioclase and amphibole (Holand, 2003). It is found in water naturally because of its abundance in the earth's crust, where it dissolves from all types of soil and rocks, especially limestone deposits, dolomite and gypsum (Weight & Sandergg, 2001).

2-8-1-2 Magnesium Mg^{+2}

It is one of the alkaline-earth minerals. Its sources in water are dolomite, clay minerals, fertilizers and livestock feed (Greenwood and Earnshaw, 2002). The geochemical behavior shows that the magnesium ion is smaller than calcium and sodium, so its ability to combine with water is greater (Hem, 1989).

2-8-1-3 Sodium Na^{+}

It is the most abundant element in the alkali metal group in nature. It is produced from alkali feldspar and evaporation minerals such as halite and rock salt (Appelo, 1999). In igneous rocks, sodium is more abundant than potassium, but in sediments it is much less abundant (Faure, 1998).

2-8-1-4 Potassium K^{+}

It is the most common in sedimentary rocks. It is found in silicate rocks and their minerals, clay minerals, evaporation rocks and organic residues (Hem, 1985) in addition to fertilizers from potassium concentration in water (Daly, 1994).

2-8-2 Major Anions**2-8-2-1 Chloride Ion Cl^-**

The most abundant element of the halogens is found largely in sedimentary rocks and evaporites such as halite. It is also found in igneous rocks such as Apatite (Davis & Dewist, 1966) and it also arises from human sources such as sewage and industrial waste (Drever, 1997).

2-8-2-2 Sulfate Ion SO_4^{2-}

The natural source of the sulfide ion in water is the dissolution of sulfate minerals present in sedimentary rocks such as gypsum and anhydrite (Todd, 2007) as well as resulting from human activities such as sewage leakage, chemical fertilizers, detergents and pesticides (WHO, 2006).

2-8-2-3 Bicarbonate and Carbonate HCO_3^{-1} , CO_3

The bicarbonate ion is considered as a product of the alkalinity of water, which is the ability of water to interact with the hydrogen ion (Faure, 1998). The main source of bicarbonate ions and carbonate is carbon dioxide in the atmosphere or in the soil dissolved in water or in the unsaturated zone lying between the surface of the land and water table (Ljungberg, 2004). It is produced from the dissolution of calcium and magnesium carbonate (lime rock) (Davis & Dewist, 1966).

2-8-3 Minor Compounds**2-8-3-1 Nitrates NO_3^-**

Most of the nitrates are from organic, industrial or agricultural sources due to the use of fertilizers. Animal waste, plants, industry and wastewater disposal are other sources of nitrates (Hudak, 2000 and Al Badri & Al Ameri, 2004). Nitrates have a significant effect on plant

growth and a danger to drinking water if nitrate levels are (10ppm) or more (Landschoot, 2007).

2-8-3-2 Phosphates PO_4^{-3}

They are chemicals that contain phosphorous that are abundant in sediments (Hem, 1991). Its negative effects help the growth of algae and aphids, and reduce the concentration of dissolved oxygen in water. The sources of these phosphates are chemical fertilizers if the nitrogen oxide value is high (Ali & Al Manmi, 2005).

2-8-4 Heavy Metals (Trace Elements):

They are those elements that have an atomic number greater than 20 and a density greater than 5 g/cm³, which are natural substances and spread in nature in a very wide way and move between the parts of the environment and its components continuously from one place to another and from one form to another (Al omar, 2000) The sources of these elements are either naturally emitted during geological processes such as erosion and transferred from sediments to the aquatic environment in the form of dissolved and suspended in rain water or by wind (Papagiannis *et al*, 2004). Or from human sources through industrial activity, as many industries are sources of metal pollution, such as the manufacture of cement, pesticides and others (Papagiannis *et.al*, 2000). Six elements were analyzed and compared with the specifications of the health standards standards for the elements:

1- Zinc (Zn)

one of the transitional metallic elements, its density is 7.1, its concentration is low, and it has a low solubility in the pH range of most natural waters (Boyd, 2000) representing about 75% or 0.075 ppm of the

earth's crust. As for sea water, it contains 30 ppm of zinc and 20 ppm in limestone (Alloway & Ayers, 1997).

2- Lead (Pb)

The amount of lead ions is low in the water due to the low solubility of lead compounds in groundwater (Drever, 1997). Industrial activities such as mining, solid waste disposal, fertilizers, paint work, etc. lead to an increase in lead concentration (Hem, 1985). It is considered one of the toxic elements for living organisms, and increasing its concentration may cause serious diseases (World Health Organization, 2007).

3- Cadmium (Cd)

Cadmium is considered a toxic and polluting element to the environment and is not necessary for humans and animals (Manahan, 2001). The sources of this element are phosphate fertilizers, dirty and heavy domestic water, burning of waste and products of industrial activities (Hem, 1985).

4- Copper (Cu)

It is one of the common natural elements where it is present in the form of sulfides or oxides and its concentration rises with the increase in temperature and the increase in the acidity of the water PH It has good solubility in an acidic oxidizing environment (Drever, 1997) and it is considered toxic if its concentration exceeds the permissible limit in drinking water (WHO, 2007).

5- Cobalt (Co)

Cobalt is found in nature, mostly in the earth's crust, in association with other chemical elements, and its concentration in the earth's crust

reaches 20 ppm, and its concentration is high in suprabasal rocks and little in limestone (Allaway & Ayers, 1997). Sources of this element through weathering of minerals and rocks that contain cobalt, as well as fertilizers, industrial activities and waste disposal (Hem, 1985).

6- Iron (Fe)

Iron is one of the abundant mineral elements in the earth’s crust and it is essential in human, animal and plant life (Fetter, 1980), but it becomes toxic when its concentration increases (WHO, 2007). Sources of this element in water through corrosion of pipes in groundwater wells (Dradka,1987) and the oxidation of pyrite, organic materials, sedimentary rocks and coal (Boyd, 2000).

2-9 Water suitability for irrigation purposes

Suitability of water for agricultural and irrigation purposes’ depends on the kind and amount of salts that present in the water and their effects on crop growth and development (Todd, 2007). The plants acceptance for total dissolved solids and electrical conductivity in water which uses for irrigation are different and it is depends on the quality of plants (Todd, 2007).

Table (2-8): Classification for the tolerance of crops by relative salt concentration for agriculture (Todd,2007)

Crop Division	Low Salt Tolerance crops EC(μhs/ cm)	Medium Salt Tolerance crops EC(μhs/ cm)	High Salt Tolerance crops EC(μhs/ cm)
Fruit Crops	(0-3000) Limon,Peach,Pear Apricot,Orange, Apple.	(3000-4000) Cantaloupe,Olive,Figs,Pomegranate.	(40000-10000)Date palm
Vegetable	(3000-4000) Green	(4000-10000)Cucumber, Peas,	(10000-

Crops	beans,Celery,Radish.	Onion, Carrot, Potatoes,Lettuce, Cauliflower, Tomato	120000)Spinach,beets
Field Crops	(4000-6000) Field beans	(6000-10000) Sunflower ,Corn,Rice,FlaxmSorghum.	(10000-16000) Cotton,Sugar beet,Barley(grains)

An evaluation of water for irrigation depends upon many principles such as Sodium Adsorption Ratio (SAR), Electrical Conductivity (EC) and Sodium concentration percentage (Na %) (Ayers and Westcot 1989) (Don, 1995), Table (2-8). These classifications are suggested to classify water for irrigation purposes by using above parameters as well as pH and TDS, Sodium Adsorption Ratio (SAR), and soluble sodium percentage (Na%). In addition to the major and minor ions as follows:

2-9-1 Sodium Adsorption Ratio(SAR):

The sodium adsorption ratio (SAR) indicates sodium concentration in water . (SAR) is considered an important parameter for the evaluation of water suitability for irrigation where the sodium accumulation in the soil will affect the rate of water infiltration through the soil. (SAR) values used for estimation of infiltration problems for soil that as a result of sodium increase with relative to the sum of calcium and magnesium in a ratio of (1:3) , this will lead to soil crumble and shrinking of the porosity (Ayres and Westcot, 1989). The sodium adsorption ratio (SAR) values are calculated according to the following equation(Todd,2007):

$$SAR= Na^+/\sqrt{(Ca^{+2}+Mg^{+2})/2} \dots\dots\dots(2-4)$$

Where:

SAR:Sodium Adsorption Ratio

Na⁺ ,Ca⁺ ,Mg⁺ :Concentration of ions by (epm) units.

Table(2-9) Classification of irrigation water based on SAR values(Todd,1980).

SAR	Water Class
<10	Excellent
10-18	Good
18-26	Fair
>26	Poor

2-9-2 Soluble Sodium Percentage(Na%)

Increasing of sodium ion ratio in irrigation water will affect the soil efficiently where it leads to decrease its porosity and permeability, thus will affect on the plant growth or stunted growth. (Na %) value was calculated according to the following equation, (Todd, 2007) :

$$\text{Na\%} = \frac{\text{Na}^+ + \text{K}^+}{\text{Ca}^{+2} + \text{Mg}^{+2} + \text{Na}^+ + \text{k}^+} \times 100 \dots\dots\dots(2-5)$$

Where all ionic concentrations are expressed in (epm) , Classification of irrigation water according to the percent sodium, as shown in table (2-10).

Table(2-10) Classification of irrigation water based on Na%(Todd,1980).

Water class	Na%
Excellent	<20
Good	20-40
Permissible	40-60
Doubtful	60-80
Unsuitable	>80

Chapter Three

Soil stabilization

Method & Material

3-1 Introduction:

Field Description of Soil: After selecting the stations, the orientations (inclination) of the bank slopes (as well as the soil thickness) have been measured. The slope orientation(inclination) are represented by two number, the first one is the direction (azimuth) of slope inclination (to the left), the second one is the slope angle (to the right), like (190/30). Then field description of soil and failures was conducted , and the studied stations number has reached (10) stations .

3-1-1 Station No.1 :

This station lies , on the left side bank at latitude ($32^{\circ} 47' 14''$) N and longitude ($44^{\circ} 18' 12''$) E . The bank slope inclination is ($190/30^{\circ}$) and the slope height is (3.0) m . The soil at this site is composed of sandy Silty clay, (MH) ,Low - plastic and moisture content of (11.11%). This station is one of the unstable sites , where the observed failures of soil masses include soil fall as in figure (3-1).



Fig(3-1): Station No.(1) in Al-Musaiyab Water Project

3-1-2 Station No.2 :

This station lies , on the left side of bank at latitude ($32^{\circ} 47' 16''$) N and longitude ($44^{\circ} 18' 59''$) E . The bank slope inclination is ($160^{\circ} / 34^{\circ}$) and the slope height is (4.0) m . Fig (3- 2) . The soil at this site is composed of clayey silty sand , (SM) , Low - plastic and moisture content of (11.23%) . This station is one of the unstable sites, where the observed failures of soil masses include soil fall as in Figure (3-2).



Fig(3-2): Station No.(2) in Al-Musaiyab Water Project

3-1-3 Station No.3 :

This station lies , on the left side bank at latitude ($32^{\circ} 47' 14''$) N and longitude ($44^{\circ} 19' 24''$) E . The bank slope inclination is ($200/ 50^{\circ}$) and the slope height is (3.5) m . The soil at this site is composed of sandy silty clay, (MH), The soil low plastic and moisture content of (12.4%). This station is one of the unstable sites, where the observed failures of soil masses include soil fall (3-3).



Fig(3-3): Station No.(3) in Al-Musaiyab Water Project

3-1-4 Station No. 4 :

This station lies, on the left side bank at latitude ($32^{\circ} 47' 09''$) N and longitude ($44^{\circ} 19' 40''$) E . The bank slope inclination is ($210/ 60^{\circ}$) and the slope height is (3.0) m. The soil at this site is composed of sandy clayey Silt, (CL-ML) , The soil has low plastic and moisture content of (11.7 %) . This station is one of the unstable sites, where the observed failures of soil masses include soil fall.



Fig(3-4): Station No.(4) in Al-Musaiyab Water Project

3-1-5 Station No.5 :

This station lies, on the left side bank at latitude ($32^{\circ} 46' 52''$) N and longitude ($44^{\circ} 20' 13''$) E . The bank slope inclination is ($190^{\circ}/25^{\circ}$) and the slope height is (3.2) m . see Fig (3-5) The soil at this site is composed of sandy silty clay , (ML), The soil low plastic and moisture content of (12.3%) . This station is one of the unstable sites , where the observed failures of soil masses include soil fall .



Fig(3-5): Station No.(5) in Al-Musaiyab Water Project

3-1-6 Station No. 6 :

This station lies, on the left side bank at latitude ($32^{\circ} 46' 54''$) N and longitude ($44^{\circ} 21' 19''$) E . The bank slope inclination is ($170 / 30^{\circ}$) and the slope height is (3.0) m. see Fig (3-6) The soil at this site is composed of sandy clayey silt , (ML) , The soil has low plastic and moisture content of (12.9 %). This station is one of the unstable sites where the observed failures of soil masses include soil fall .



Fig(3-6): Station No.(6) in Al-Musaiyab Water Project

3-1-7 Station No.7 :

This station lies, on the left side bank at latitude ($32^{\circ} 46' 57''$) N and longitude ($44^{\circ} 23' 30''$) E . see Fig(3-7) . The bank slope inclination is ($180 / 60^{\circ}$) and the slope height is (3.0) m . The soil at this site is composed of Silty sandy clay , (MH) , The soil low plasticity and moisture content of (12.6%). The station is one of the unstable sites, where the observed failures of soil masses include soil fall .



Fig(3-7): Station No.(7) in Al-Musaiyab Water Project

3-1-8 Station No.8 :

This station lies , on the left side bank at latitude (32 ° 48' 44 ") N and longitude (44 ° 25' 50 ") E . see Fig(4 -8). The bank slope inclination is (160/ 30°) and the slope height is (3.2) m .The soil at this site is composed of clay silty sand, (SM), The soil low plasticity and moisture content of (11.11%) . The station is one of the unstable sites, where the observed failures of soil masses include soil fall .



Fig(3-8): Station No.(8) in Al-Musaiyab Water Project

3-1-9 Station No.9 :

This station lies , on the left side bank at latitude ($32^{\circ} 48' 49''$) N and longitude ($44^{\circ} 26' 20''$) E . Fig(3-8) . The bank slope inclination is ($180/ 20^{\circ}$) and the slope height is (3.2) m .The soil at this site is composed of sandy silty clay, (MH), The soil low plasticity and moisture content of (13.6%) . The station is one of the unstable sites, where the observed failures of soil masses include soil fall as in Figure (3-9).



Fig(3-9): Station No.(9) in Al-Musaiyab Water Project

3-1-10 Station No.10 :

This station lies , on the left side bank at latitude ($32^{\circ} 48' 50''$) N and longitude ($44^{\circ} 26' 23''$) E . Fig(3-10) . The bank slope inclination is ($170/ 50^{\circ}$) and the slope height is (3.0) m .The soil at this site is composed of clay silty sand, (SM), The soil low plasticity and moisture content of (12.3%) . The station is one of the unstable sites, where the observed failures of soil masses include soil fall as in Figure (3-10).



Fig(3-10): Station No.(10) in Al-Musaiyab Water Project

3-2 Soil Stabilization

Is the process of improving mechanical or chemical properties or both to meet certain engineering requirements. The stable mode mainly depends on the quality of the soil and the desired properties. The soil stabilization process includes several methods aimed at increasing soil stability and improving its engineering properties by increasing shear strength and reducing compressibility, among others. Soil stabilization includes:

3-2-1 Stabilization by Cement:

The traditional method is to mix crushed soil with a specific amount of Portland cement and water. The choice of cement depends on the type of soil to be treated and the desired final strength. There are many types of cement on the market such as portland cement, blast furnace cement, sulfate resistant cement and high alumina cement. The activity of the cement begins when it is mixed with water and soil. This is an initial process. These compounds dissolve in porous water and interact with clay compounds in the soil. All processes can be called secondary

processes(Herzog,1963) . During secondary processing, cement reacts with water to form hydrated silica , hydrated alumina, and hydrated lime. At the same time, gypsum (CaSO_4) reacts with C_3A (Flaharty,1983) to form crystals. The clay particles adjacent to the cement particles are affected, causing the silica and alumina in the mud particles to melt, resulting in an increase in pH in the soil's porous water. Calcium hydroxide is produced by hydrolysis of cement. Silica and alumina combine with calcium ions to form additional cementitious materials that bind the clay particles together. The primary process imparts resistance stiffness, while the secondary process improving the resistance and stability of soil-cement with additional cement products that increase internal adhesion(Herzog,1963and Croft,1967)

3-2-2 Stabilization with Calcium Hydroxide $\text{Ca}(\text{OH})_2$:

When $\text{Ca}(\text{OH})_2$ is added to soil, soil properties are improved because calcium hydroxide is hydrolyzed and thermally reacted causes a certain amount of water to be released in the soil through evaporation. This results in a reduction in moisture content. The second effect of adding CaO is ion exchange, which leads to a decrease in the plasticity of clay particles(Berry et al.,1966). $\text{Ca}(\text{OH})_2$ interacts with the clay particles for a long time, creating a binding material that binds the soil particles together. The most important additions of calcium hydroxide to soil include(Kiki,2006):

1. Decrease the fluidity limit and increase the plastic limit, thereby reducing the plasticity index very significantly.
2. The ion-exchange capacity value decreased, which also led to an increase in soil pH.
3. Decrease the optimum dry density of the soil and increase the optimum moisture content.
4. Reduce the expansion rate in the soil.

5. Increase soil strength by increasing the unconfined compressive strength and effective shear strength of the soil.

3-2-3 Using Rock Blocks:

This method is used to stabilize soil by covering river bank slopes with rock masses in areas with severe erosion characteristics. This method is not used on both sides of all slopes, as it may store water and prevent river discharge from nearby farmland.

3-2-4 Soil Arming (Reinforcement):

One of the methods used to stabilize soil, an important application for arming soil, is the use of flat armature rods, iron rods, or any material that withstands resistance the ability of tensile strength to improve the stability of soil and increase its bearing capacity. The principle of soil reinforcement depends on the interaction between reinforcement elements and soil particles to achieve the purpose of reinforcement(Al-Asho,1991).

3-2-5 Stabilization with Vegetation:

This method is one of the best and easiest ways to stabilize the soil and is done by using trees, shrubs and herbs, and it can be used in all areas, as it is considered the least expensive of the procedures for protecting the banks of rivers and provides good and stable vegetative coverage of the soil in addition to increasing the aesthetics .



Fig(3-11): Stabilization with Vegetation

Chapter Four

Results and

Discussion

4-1 Introduction

This chapter includes all the results related to the study of the Geotechnical and Haydrochemical properties of Soil and Water in the Al-Musaiyab great water project, Babylon Governorate. The result Show the following:

4-2 Physical Properties of the Soil

4-2-1 Grain size Analysis

Through sive analysis and hydrometer analysis, It was found The maximum value of the percentage of Clay is (45.2%) in Station No. (1) and the minimum is (13.7%) in Station No. (8), and the average percentage of clay is (31.9%), while the maximum percentage of silt is (54%) in Station No. (4)The minimum percentage is (24.7%) in Station No. (7), and the average percentage of silt is (36.88%). The maximum percentage of sand is (51.6%) in Station No. (2), and the minimum is (16.4%) in Station No. (9) and the average percentage of sand is (31.06%) . The results are shown in the Table(4-1)and Figure(4-1).

Table (4-1): The results of some physical test of soil in the Al-Musaiyab water project.

St.No	Paricles size distribution sive Analysis & Hydrometr analysis			Index Properties			Sym USCS	G.S	Max.d. Density g/cm ³	O.M.C %
	Clay %	Silt%	Sand %	LL%	PL%	PI%				
1	45.2	35.1	19.7	31.0	19.0	12.0	MH	2.74	1.920	11.11
2	17.1	31.3	51.6	25.5	18.2	7.3	SM	2.66	1.896	11.23
3	43.3	38.4	18.3	30.1	19.5	10.6	MH	2.73	1.890	12.4
4	28.1	54	18.1	23.4	18.4	5.0	CL-ML	2.69	1.873	11.7
5	38.2	35.7	26.1	25.4	19.1	6.3	ML	2.71	1.985	12.3
6	28.1	46.1	25.8	25.5	19.5	6.0	ML	2.69	1.974	12.9
7	41.1	24.7	34.2	29.2	18.4	10.8	MH	2.74	1.868	12.6
8	13.7	36.3	49.7	23.4	18.0	5.4	SM	2.65	1.912	11.11
9	42.2	39.9	16.4	30.0	19.0	11.0	MH	2.73	1.888	13.6
10	22	27.3	50.7	26.6	19.7	6.9	SM	2.65	1.919	12.3
Average	31.9	36.88	31.06	27.01	18.88	8.13		2.69	1.9125	12.125

4-2-2 Soil Classification of for Engineering

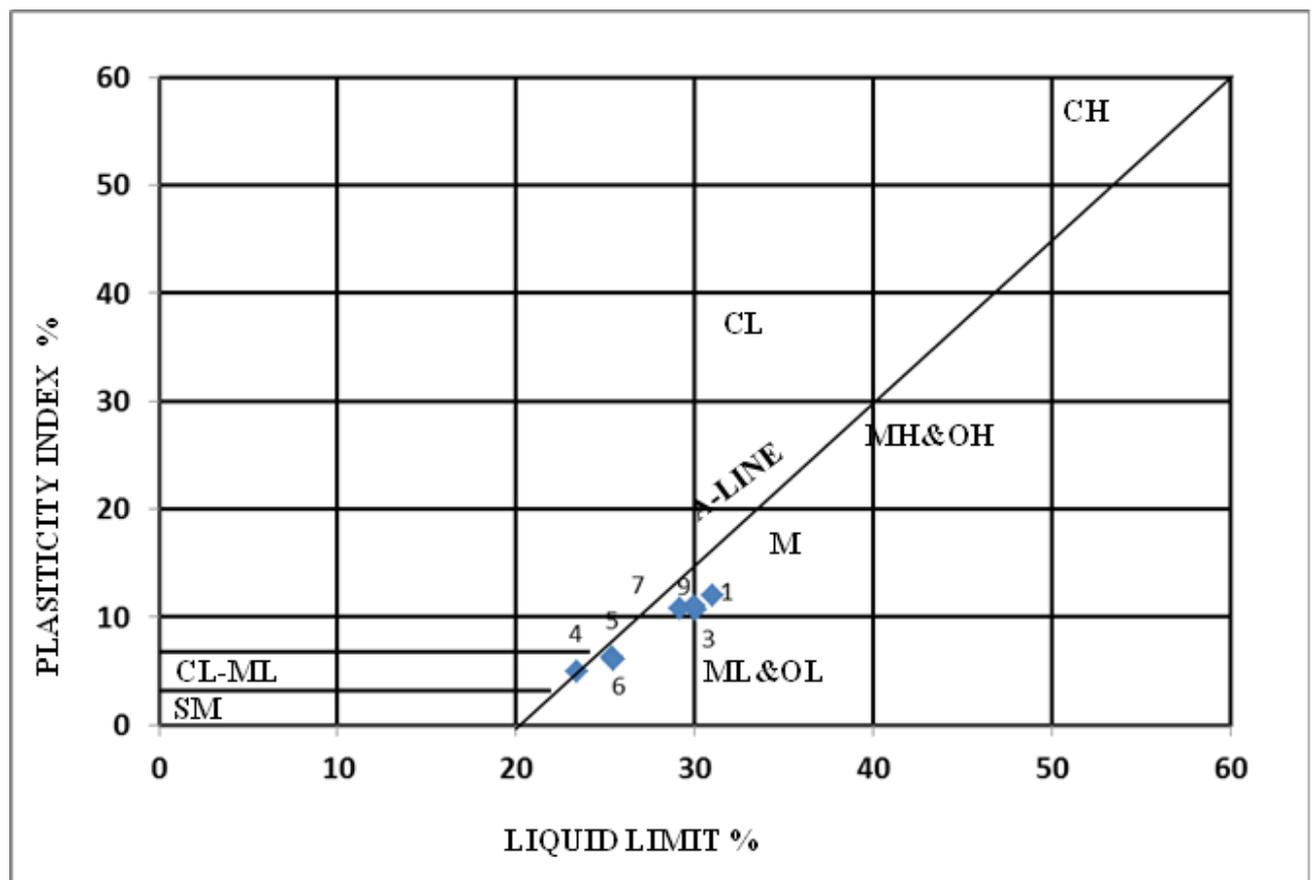
4-2-2-1 Unified Soil Classification System (USCS):

Soils are classified according to the Unified Soil Classification System (USCS) as having low plasticity if they are ($LL < 50$) or high plasticity if they are ($LL > 50$). From figure (4-2) the soils in all stations along the Great AL-Musaiyab Project as following :

A- High plasticity (MH) including the following (1,3,7,9).

B- Low plasticity (ML) including the following stations (5, 6).

C- Low plasticity (CL-ML) including the following station (4).



Fig(4-2); Plasticity Chart and the Soil Classification Along the Great Al-Musaiyab Project.

4-2-3 Atterberge Limits

- 1- The maximum value of the liquid limit(L.L) is (31.0)in St 1 and the manimum value is (23.4) in St 4& St 8.
- 2- The maximum value of the plasticity limit (P.L) is (19.7) in St 10 and the manimum value is (18.0) in St 8.
- 3- The maximum value of the plasticity index (P.I) is (12.0) in St 1 and the manimum value (5.0) in St 4.

4-2-4 Maximum dry Density:

The maximum Value is (1.852)g/cm³ in station No.5 and the manimumvalue is (1.868)g/cm³ in station No.7 and average(1.9125)g/cm³

4-2-5 Specific Gravity

The maximum value (2.74) in station No.1&No.7and the manimum value (2.65) in station No.8&No.10.

4-3 Engineering properties of Soil

- 1- The maximum value of the uniaxial compressive strenght is (48) in station No.9 and the minimum value is (3) in station No.3, When classifity the Uniaxial Compressive Strength with Peck et al.1967 the Uniaxial Compressive Strength of Soil bank river is very soft& Soft.
- 2- From shear strength test the maximum value of (C) is (50) KN/m² in station No.9 and the minimum value is (0.0) in station No.8,While the maximum value of (ϕ) is (37) in station No.8 and the manimum value (7) in station No.9.The results are shown in Table (4-2).

Table (4-2) Acompression and shear strength values and soil type.

ST.NO	Type of sample	Type of Soil	Uniaxial compressive strength (kn/m ²)	Shear strength parameters	
				Ø	C(kn/m ²)
1	Disturbed(Remoulded)	MH	27	8	25
2	Disturbed(Remoulded)	SM	6	27.5	5
3	Disturbed(Remoulded)	MH	3	27.5	5
4	Disturbed(Remoulded)	CL-ML	30	30	20
5	Disturbed(Remoulded)	ML	11	26	3
6	Disturbed(Remoulded)	ML	27	17	30
7	Disturbed(Remoulded)	MH	9	27.5	5
8	Disturbed(Remoulded)	SM	16	37	0
9	Disturbed(Remoulded)	MH	48	7	50
10	Disturbed(Remoulded)	SM	19	20	5
Average			19.6	22.75	14.8

4-4 Chemical Tests of Soil

According to the results shown in the Table(4-3) show the following:

1-The percentage of sulfate SO₃ ranges between (0.085_0.698) %, with average (0.3288) % .

2-The CaCo₃ carbonate ratio ranged between (8-35) % , with a rate of (17.98) % .

3-The percentages of gypsum ranged between (0.184-1.5007)% and an average of (0.7076) % .

4-The percentages of organic substances ranged between (1.407 - 3.869), with an average of (2.7435).

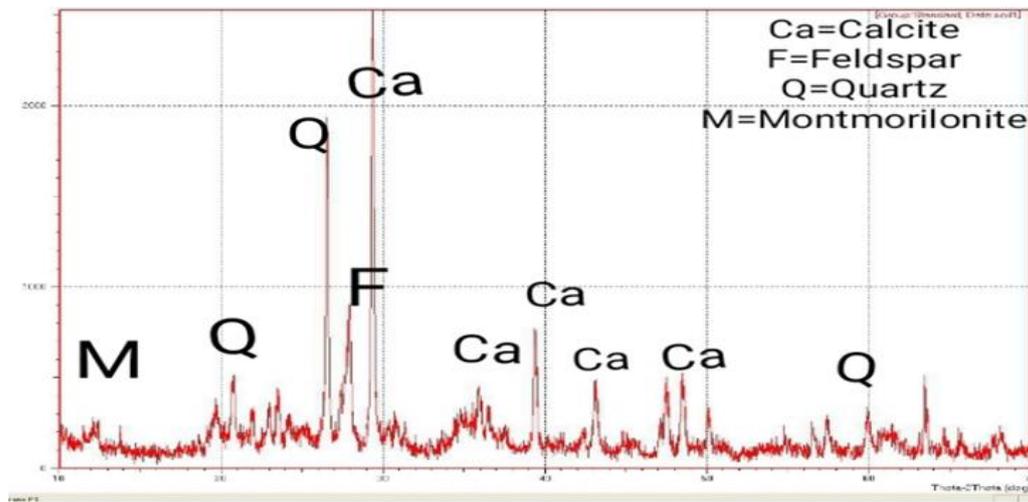
5-The percentages of Total Soluble Salts (TSS) ranged between (0.295- 3.9)% with an average of (1.7205)%.

Table (4-3): The results of Soil chemical Tests.

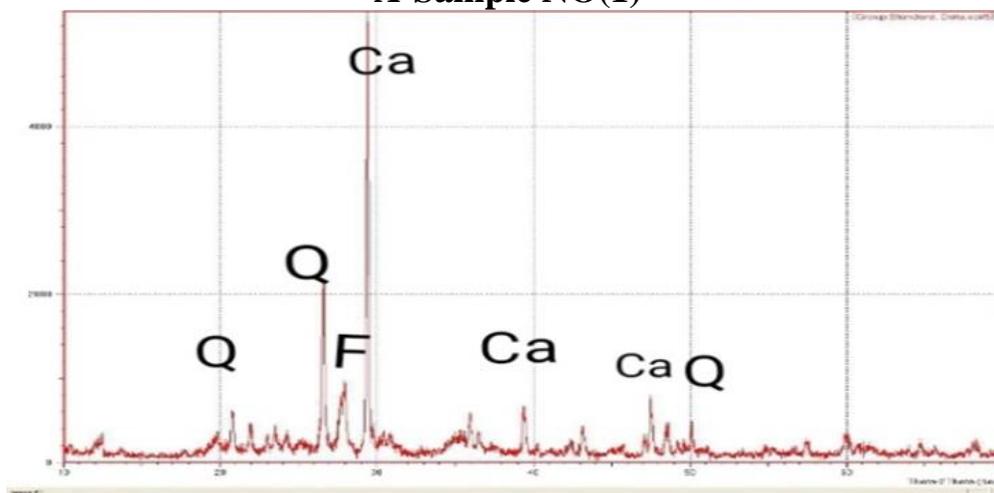
S.T	CaCO ₃ %	GYP%	SO ₃ %	Org.m%	T.S.S%
1	8	1.345	0.625	1.407	2.475
2	19	0.789	0.367	3.869	1.865
3	10.8	1.5007	0.698	2.814	3.243
4	16.6	0.321	0.149	2.462	0.672
5	19.4	0.523	0.243	3.5175	0.936
6	9.4	0.8554	0.397	2.462	2.132
7	12.2	0.305	0.142	3.5175	0.873
8	26.4	0.538	0.250	2.814	0.814
9	23	0.715	0.332	2.814	3.9
10	35	0.184	0.085	1.758	0.295
Average	17.98	0.70761	0.3288	2.7435	1.7205

4-5 Mineral Tests of Soil

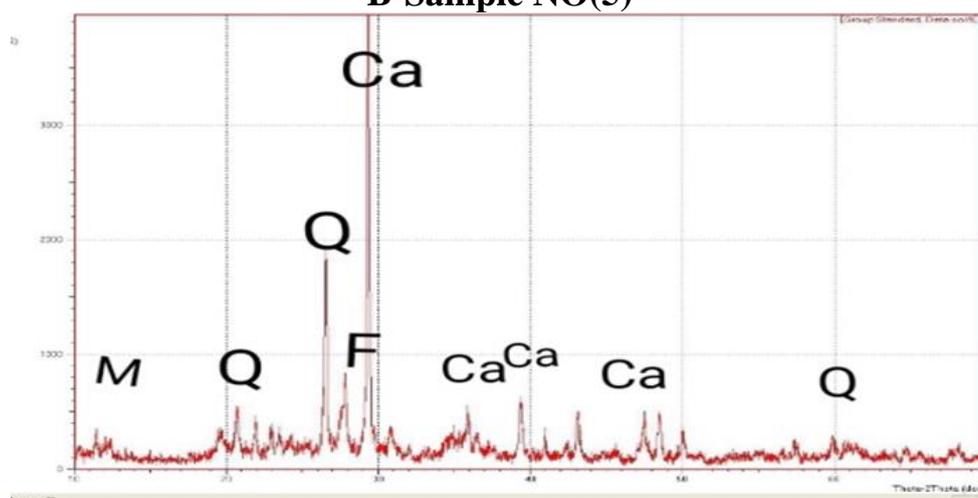
The X-ray diffraction results showed that the mineral content of the samples mainly consists of calcite, quartz, feldspar, and clay minerals. The results are shown in the Figure(4-3).



A-Sample NO(1)



B-Sample NO(5)



C-Sample NO(9)

Fig(4-3): XRD Chart for the AL-Musaiyab Water Project Station(1,5,9).

4-6 Hydrological Characteristics

In The average general discharge of the Great Musaiyab Project schedule was 36.66 m³/sec in July . As for the discrepancy between the years, 2019 recorded the highest discharge rate of 34.74 m³/sec , while the lowest rate was recorded 2021 with a water discharge rate of 24.72 m³/sec. As shown in Table (4-4).

Table(4-4) Annual Discharge Rate of Great Al-Musaiyab Project for the period(2019-2021).

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Anul
Years													M ³ /s
2019	17.41	17.85	29.19	31.33	33.06	40.33	45.00	45	46.83	42.74	46.83	21.32	34.74
2020	24.03	25.68	39.19	37.00	26.74	34.73	35.00	34.32	27.66	19.03	24.66	10.64	28.64
2021	18.87	18.75	25.00	23.53	25.00	26.6	30.00	30	30	25	20.8	23.35	24.72
Average	20.10	20.7	31.12	30.62	28.26	33.88	36.66	36.44	34.83	28.92	30.76	20.10	29.36

4-7 Physical Properties:

1-The maximum value of the Electrical Conductivity(EC) is (1250) $\mu\text{hs}/\text{cm}$ in station (3) and the manimum value is (1196) $\mu\text{hs}/\text{cm}$ in station (7) with average(1230) $\mu\text{hs}/\text{cm}$.The EC values and the degree of water mineralzation according to (Detay , 1997) show that the type of all water samples in the study area are excessively mineralized water . see Table (2-5) and Table (4-5).

2-The maximum value of the Total Hardnees(TH) is (576)ppm in station(1) and the minimum value is (420) ppm in station (8) with average (512.888) ppm .The TH values were compared with the classification of

water hardness (Al toviski, 1962; Boyed,2000, and Todd ,2007), It is clear that the water of studt area is classified as water (Very hard), as shown in Table (2-7)and Table(4-5).

Table(4-5):Physical Parameters for Water Samples.

St.No	EC(μ hs/ cm	pH	TH(ppm)	TDS(ppm)
1	1202	6.96	576	878
2	1247	6.46	544	896
3	1250	6.44	536	876
4	1243	7.15	512	854
5	1240	7.2	448	914
6	1241	7.3	504	720
7	1196	7.46	552	836
8	1232	7.3	420	890
9	1220	7.32	524	824
Average	1230	7.06	512.888	854.222

3-The maximum value of the Total Dissolved Solids(TDS) is (914) ppm in station (5) and the manimum value is (720) ppm in station (6) with average (854.222)ppm . TDS values were comared with three water ratings Altoviski(1962), Drever(1997) and Todd(2007), It is clear that the water of study area is classified as water (Fresh water) as in Table (2-6)

.4-The maximum value of the Hydrogen Ion Concentration(PH) is (7.46) in station(7) and the manimum value is (6.44) in station(3) with an average of (7.06).The PH results are shown in Table(4-5).

4-8 Chemical tests of water

4-8-1 Major Cations

1-The maximum of calcium value is (161.923) ppm in station (4) and the minimum value is (115.430) ppm in station (8) with an average of (130.393)ppm.As shown in Table (4-6).

2- The maximum of magnesium value is (59.136) ppm in station (1) and the minimum value is (19.712) ppm in station(5)with average (42.012) ppm.

3- The maximum of sodium value is (121)ppm in station (2) and the minimum value (94.3) ppm in station (9) with an average of (105.022) ppm.

4-The maximum of potassium value is (5.8) ppm in station (2) and the manimum value is (3.7) ppm in station (8) with an average of (4.9)ppm.

Table(4-6) The Concentration and Contast of Major Cations in ppm for the water sample (IQS,2009) and (WHO,2011)limits.

St.No	Ca ⁺	Mg ⁺	Na ⁺	K ⁺
1	125.049	59.136	118.8	5.6
2	121.843	53.76	121	5.8
3	136.272	43.904	104.2	5.1
4	161.923	24.192	106.7	5.1
5	144.288	19.712	101.4	3.8
6	118.636	46.592	99	5
7	121.843	55.552	103.8	5.2
8	115.430	29.568	96	3.7
9	128.256	45.696	94.3	4.8
Average	130.393	42.012	105.022	4.9
IQS,2009	150	100	200
WHO,2011	100	125	200	12

4-8-2 Major Anions

1- The maximum value of the Chloride Ion is (39.987)ppm in station (6) and the minimum value is (11.996) ppm in station (9) with an average of (24.436)ppm.As shown in Table (4-7).

2- The maximum value of the Sulfate Ion is (416.438)ppm in station (1) and the manimum value (313.563)ppm in station (6) with average (373.642)ppm.

3-The maximum of Bicarbonate value is (1732.878) ppm in station (1) and the minimum value is(97.626)ppm in station (7) with an average of (357.964) ppm. While the maximum of Carbonate value (96.0) ppm in

station (7) and the minimum value (0.0) ppm in station (1) with an average of (48.0) ppm.

Table(4-7) The Concentration and Contast of Major Anions in ppm for the water sample(IQS,2009)and (WHO,2011).

St.No	Cl ⁻	SO ₄ ⁻²	HCO ₃ ⁻	CO ₃ ⁻
1	27.991	416.438	732.878	0.0
2	21.993	357.182	244.067	24.0
3	21.993	390.102	219.660	24.0
4	15.995	371.996	146.440	72.0
5	27.993	362.943	195.253	72.0
6	39.987	313.563	195.253	48.0
7	31.990	399.978	97.626	96.0
8	19.993	349.775	195.253	48.0
9	11.996	400.801	195.253	48.0
Average	24.436	373.642	357.964	48.0
IQS,2009	350	400
WHO,2011	250	250	200	...

4-8-3 Minor Compounds

1- The maximum of Nitrates value (22.265) ppm in station (9) and the minimum value is (16.484) ppm in station (6) with an average of (18.515) ppm. As shown in Table (4-8).

2-The maximum of Phosphates value is (12.360) ppm in station (1) and minimum value (1.371) ppm in station(9) with an average of (8.049) ppm.

Table(4-8)The Concentration and Contast of Minor compounds in ppmfor Water Samples (IQS,2009) and(WHO,2011)limits.

St.No	NO ₃ ⁻ (ppm)	PO ₄ ⁻³ (ppm)
1	16.796	12.360
2	18.203	8.088
3	19.453	10.149
4	16.953	11.623
5	18.984	3.817
6	16.484	10.768
7	17.734	9.646
8	19.765	4.621
9	22.265	1.371
Average	18.515	8.049
IQS,2009	50	...
WHO,2011	50	50

4-8-4 Heavy Metals(Trace Elements):

1- The zinc (Zn) concentration in Table (4-9) ranges from the maximum value of (0.2898) ppm in station No.1 , to the minimum value of (0.0116) ppm in station No.2 , and the average value is (0.12493) ppm.

2- The lead (pb) concentration in Table (4-9) ranges from the maximum value (3.5644) ppm in station No.8, to the manimum value of (3.3196) ppm in station No.9, and the average value is (3.4691) ppm.

3- The cadmium (cd) concentration in table(4-9) ranges from the maximum value (0.2463) ppm in station No.1, to the manimum value of (0.1087) ppm in station No.8 , and the average value is (0.14448) ppm.

4- The copper (Cu) concentration in table (4-9) ranges from the maximum value (2.5099) ppm in station No.1 , to the manimum value of (2.3760) ppm in station No 9, and the average value is (2.4151) ppm.

5- The cobalt (Co) concentration in table (4-9) ranges from the maximum value (2.3192) ppm in station No.1 , to the manimum value of (2.0816) ppm in station No.5 , and the average value is (2.1951) ppm.

6- The Iron (Fe) concentration in table (4-9) ranges from the maximum value (0.4780) ppm in station No.4 , to the minimum value of (0.0) ppm in station No.6 , and the average value is (0.1618) ppm.The results are showin in the Table(4-9)

Table (4-9) The Concentration and Contast of Trace Elements in ppm for the Water Sample (IQS,2009) and (WHO,2011)and (EPA,2011)limits.

No	Zn ppm	Pb ppm	Cd ppm	Cu ppm	Co ppm	Fe ppm
1	0.2898	3.396	0.2463	2.5099	2.3192	0.1082
2	0.0116	3.457	0.1376	2.4579	2.2479	0.4464
3	0.1005	3.4420	0.1354	2.4281	2.1291	0.2074
4	0.1333	3.4879	0.1509	2.4033	2.2479	0.4780
5	0.0155	3.5185	0.1376	2.3934	2.0816	0.0361
6	0.1468	3.5032	0.1354	2.3934	2.2242	N.D
7	0.0985	3.5338	0.1198	2.3884	2.2479	0.0857
8	0.1391	3.5644	0.1087	2.3859	2.1053	0.0225
9	0.1893	3.3196	0.1287	2.3760	2.1529	0.0722
Average	0.1249	3.4691	0.14448	2.4151	2.1951	0.1618
IQS,2009	3	0.01	...	1	...	0.3
WHO,2011	3	0.01	0.003	2	...	<3
EPA,2011	5	0.015	0.005	1.3
EPA=Environmental protection Agency						

4-9 Water suitability for irrigation purposes

EC values of water samples in the study area are compared with standard of (Todd, 2007). It is clear that all water samples of the study area are suitable for all kinds of crops Table (2-8).

4-9-1 Sodium Adsorption Ratio(SAR):

According to Table (4-10) and Table (2-9), it was found that all water samples in the Musaiyb water Project are (Good), as the SAR ratio lies between (10-18).

Table(4-10) The value of SAR,Na% in the water samples.

St. NO	SAR(epm)	Na%
1	12.380	40.312
2	12.913	41.930
3	10.978	37.75
4	11.061	37.52
5	11.198	39.078
6	10.984	38.628
7	11.022	46.109
8	11.278	40.744
9	10.111	36.293

4-9-2 Soluble Sodium Percentage(Na%)

According to Table (4-10) and Table (2-10), the water samples in the stations (3,4,5,6,9) are (Good), as the Na ratio lies between (20-40), while the water samples in the stations (1,2,7,8) is (Permissible) where the percentage of Na falls between (40-60) .

4-10 Soil Stabilization

The following table presents the most important procedures and proposed methods for stabilizing the soil of river bank slopes in the study area and the reasons for using them.

Table(4-11) The Stabilization Technique of Soil Slope.

Stabilization Techniques	Location	Explanations for use
Stabilization by Calcium Hydroxide(CaO)	Some Stations	It is used for high plasticity clays, when calcium hydroxide is added to the soil, this increases the calcium ions (Ca) in the double ion layer around the clay particles, causing a charge around them, thus reduced water absorption, i.e. reduced its substrate.
Stabilization by cement	Some Stations	Cement is used in clay and sandy soils, stabilized by adding a limited percentage of cement and water, and left for a certain amount of time.
Stabilization by Arming the soil	All Stations	Reinforcing soil is one of the newest stabilization methods and is very expensive, so it is exclude
Stabilization by rock masses	All stations	A very practical method for covering heavily corroded bank slopes and has specifications that resist water wave movement.
Stabilization by vegetation	All stations	Plant cover (afforestation) is a soil support factor as it protects the soil from collapse and erosion, giving it long-term stability and is one of the cheapest methods of stabilization .

Chapter Five

Conclusions and Recommendations

5-1 Conclusions:

Through field visits and studying the soil properties of the study area for the Great Musaiyab project / Babylon Governorate, the following conclusions can be drawn:

- 1- Large parts of the slopes have unstable conditions and the reason is due to landslides resulting from the weight of the soil mass, and the banks area suffers from erosion due to the lower bottom of the slope, where the decrease in water speed affects the increase of sediments, which leads to the erosion of both sides of the river.
- 2- There are many failures in the slopes of the studied area, the most important of which is soil fall.

3- Climate

A-The temperature ranged between (11.9-35.36C), where the temperature contributes through its daily and seasonal fluctuation to the mechanical breakdown of soil masses and particles due to the expansion and contraction associated with the change in temperature.

B-Rainfall ranged between (0.0-28.52 mm), as the rain affects greatly in the erosion of the canyons that include large areas of the slopes of the banks.

C-Wind the average wind speed is (1.829)m/s, as the wind has an effect on the erosion of the banks through the continuous erosion of the slopes, especially in the dry period.

4- Physical Tests:

A-Through the results of the examinations and the graphs of grain size distribution show an increase of silt and clay along Al- Musaiyab Water Project.

B-Through the USCS Standard Classification System, it was found that:

1-Soft soils are mostly Silty soils of High plasticity MH, Silty soils of Low plasticity (ML) and Silty clay soils of low plasticity CL-ML .

2-The coarse soil was Silty sand SM

C-From the atterberg limits experiment, It was liquid limit (27.01) is classified as the Intermediate liquid limit , and the plasticity limit an average of (18.88). The plasticity index a rate of (8.13).

D-The maximum dry density it falls within the ideal density values.

E- The percentage of difference in specific gravity values is small due to soil formation in the same sedimentary area.

5- Engineering Tests:

A. Through the direct shear the high(C) values are due to the presence of clay and silt, where the value of the cohesion resistance is affected by the type of soil. The higher the Clay material,the higher the cohesion.As for the internal friction angle (ϕ) depends on the plasticity index (PI), which decreases with the increase in the plasticity index, it is also affected by the percentage of clay materials, as it decreases with the increase in clay materials

B. The Uniaxial Compressive Strength of Soil bank river is (Very Soft- Soft).

6- mineral Tests of Soil

Using X-ray diffraction, it was found that the soil consists of the following minerals: calcite, quartz, and feldspar and clay minerals.

7- Hydrological Properties

- The water discharge ranges between the highest value (34.74 m³/s) in 2019 and the minimum (24.72 m³/s) in 2021 depending on the water supply during the month and according to the variation in the natural conditions, foremost of which is the climatic conditions of heat, rain and humidity and evaporate.

8- Physical and Chemical Tests of Water:

A. Average EC value for the water samples (1250) $\mu\text{hs/cm}$ and classified as (Excessively mineralized water), It was found that pH of the sample is classified as basic, Average TDS value for the water samples (854.222) ppm and classified as (fresh water). It was found that TH of the sample water is classified as (Very hard)

B-The results of the analysis of the major elements (cations and anions) showed that the percentages of the (Cations) fall within the permissible limits, except for the Calcium Ion. AS for the anions the percentages of HCO_3^{-1} and sulfate SO_4^{-2} Ions exceeded the permissible limits.

C-By examining the Minor elements, It was found that all Nitrate and phosphates values are within the acceptable limits.

D- By examining the trace elements, it was found that the percentage of zinc (Zn) and iron (Fe) is within the ideal limits, The percentages of lead (Pb), cadmium (Cd) and copper (Cu) exceed the maximum ideal limits.

9- Water Suitability for irrigation purposes

A- It was found that all water samples are suitable for all types of crops

B-Asodium Absorption Ratio (SAR) It was found that all water samples in the study area were (good), As the SAR rate ranged between (8-10).

C-Soluble Sodium Percentage(Na%)the water samples in stations

(3,4,5,9)are (good), While water samples in stations (1,2,7,8) are (Permissible).

5-2 Recommendations

- 1- Treating river banks due to erosion and collapse by reducing slopes and paving rock blocks to protect it from erosion and collapse in the future.
- 2- Using the afforestation to reduce the bottom erosion to support and stabilize the soil along the river banks.
- 3- Conducting a similar study on other areas to complete the clear view and determine the failure of the soil of the banks.

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المستخلص

تضمن البحث دراسة جيوتكنيكية وهيدروكيميائية لتربة ومياه مشروع المسيب الكبير في محافظة بابل - العراق ويهدف هذا البحث إلى دراسة الخصائص الفيزيائية والكيميائية والهندسية والمعدنية لمنحدرات تربة ضفاف مشروع المسيب الكبير ودراسة هيدروكيميائية للمياه وكذلك إقتراح الإجراءات العلاجية لحماية ضفاف النهر واستقراره لضمان الاستثمار الامثل للموارد المائية للنهر نوعا وكما.

تم تحديد 10 محطات على طول مشروع المسيب الكبير ضمن مقطع الدراسة وقد اشارت نتائج الفحوصات الفيزيائية و التوزيع الحجم الحبيبي ان معدل نسبة الغرين (36.88%) ومعدل الطين (31.9%) ومعدل الرمل (31.06%). كان معدل قيم الكثافة الجافة العظمى (1.9125)غم/سم³ حيث تقع ضمن قيم الكثافة المثاليه اما معدل الوزن النوعي (2.69) . تظهر نتائج الفحوصات الكيميائية إن نسبه تركيز الكربونات(CaCO₃) تتراوح ما بين (8-35)% وبمعدل (17.98)% والكبريتات(SO₃) ما بين(0.085-0.698)% وبمعدل(0.3288)% والجبس ما بين (0.184-1.5007)% وبمعدل (0.7076)% والمواد العضوية ما بين(1.407-3.869)% وبمعدل (2.7435)% اما قيم الاملاح الكليه الذائبه(TSS) تتراوح ما بين (0.295-3.9)% وبمعدل (1.7205)% .

اوضحت نتائج الفحوصات الهندسيه لتربه منطقه الدراسة حيث ان فحص القص المباشر بلغت فيه نسبه التماسك (C) بين (0-50) كيلو نيوتن/ متر² وزاويه الاحتكاك الداخلي (Ø) ما بين (7-37) وان مقاومه الانضغاط احادي المحور ما بين (3-48) كيلونيوتن/ متر² .

تشير الفحوصات المعدنية باستخدام الاشعة السينيه إن المحتوى المعدني للتربه يتكون بصورة اساسيه من معادن الكالسايت والكوارتز والفلسبار والمعادن الطينيه.

توضح الخصائص الفيزيائية والكيميائية للمياه إن التوصيلية الكهربائية تتراوح ما بين (1196-1250)µS/cm ودالة الحامضيه ما بين (6.44-7.46) وبمعدل (7.06) ونسبه TDS ما بين (720-914) ppm اما قيم العسر الكليه تراوحت بين (420-576) ppm.

تظهر نتائج تحليل العناصر الرئيسييه (الموجبه والسالبه) إن الايون السائد هو الكالسيوم والصوديوم والانيونات البيكاربونات والكبريتات اما العناصر الثانويه بلغ تركيز النترات بين

ppm(22.265-16.484) وبمعدل (18.515) ppm والفوسفات ما بين (1.371-
ppm(12.360) وبمعدل (8.049) ppm.

اما العناصر الثقيله فيبلغ تركيز الرصاص (Pb) بين (3.3196-3.5644) ppm وبمعدل
ppm(3.4691) و النحاس (Cu) بين (2.3760-2.5099) ppm وبمعدل (2.4151) ppm
والكاديوم (Cd) بين (0.1087-0.2463) ppm وبمعدل (0.1444) ppm والكوبلت (Co)
بين (2.0816-2.3192) ppm وبمعدل (2.1951) ppm و الزنك (Zn) بين
ppm(0.2898-0.0119) وبمعدل (0.1249) ppm والحديد (Fe) بين (0.0-0.4780)
ppm وبمعدل (0.1618) ppm.

كما اوضحت الدراسة طرق لمعالجة وتثبيت التربة لكل محطة ضمن منطقه الدراسة.



وزاره التعليم العالي والبحث العلمي
جامعة بابل / كلية العلوم
قسم علم الارض التطبيقي

دراسة جيوتكنيكية وهيدروكيميائية لترب ومياه مشروع نهر
المسيب الكبير في شمال محافظة بابل – العراق

رساله مقدمه الى
مجلس كلية العلوم جامعه بابل
كجزء من متطلبات نيل درجه ماجستير علوم
في علم الارض التطبيقي

من قبل
نجلاء كاظم مطر عبود
بكالوريوس علم الارض التطبيقي

2017

أشرف

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