Geotechnical and Hydrological Study of Dewerige Dam Project in Missan Governorate/Southern of Iraq

A thesis
Submitted to Council of Collage of Science / University of Basrah in Partial Fulfillment of the Requirements for The Degree of Master in Engineering Geology

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2018

بسم الله الرحمن الرحيم

(وهــو الذي ينــزل الغـيث من بعــد ماقنطوا
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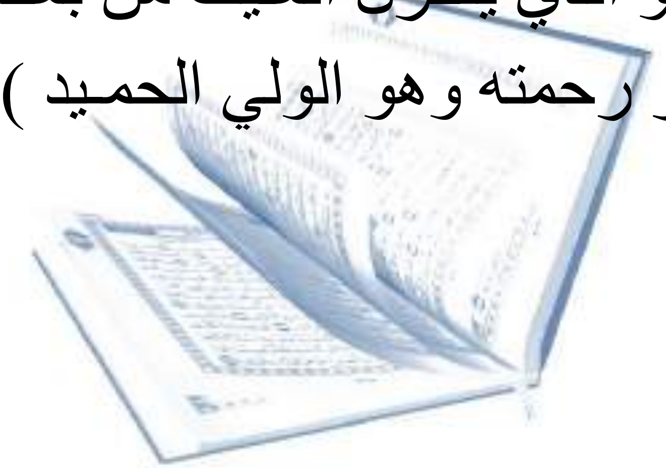

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We certify this thesis entitled (Geotechnical and Hydrological Study of Dewerige Dam Project in Missan Governrate/Southern of Iraq), which is submitted by (Zahraa Resul Al-Sudani), has been carried out supervision at Department of Geology, College of Science, Basrah University as apart fulfillment of the requirement of the master degree in geology (engineering geology).

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Dedication…

To my wonderful family … especially to my teacher, friend & mother… with my love and respect...

Zahraa ...

Acknowledgment

I would like to thank all of those people who help me:

- First, I wish to thank my advisors, Dr. Hussein B. Ghalib and Dr. Riaed S. Jassem for all their guidance, encouragement, support, and patience. I am very lucky to have advisors who give me the freedom to explore on my own and at the same time the guidance to recover when my steps faltered. Their patience and support helped me overcome many crisis situations and finish this dissertation.

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ABSTRACT

The study deals with the geotechnical and hydrological problem in Dewerige dam. It's a new hydraulic structure constructed on Dewerige river in the south east of Missan governorate, which represent amulti-purpose dam used for flooding control, water storage for irrigation and recharge ground water.

The objectives of this study is building a geotechnical assessment approach to estimate the serviceability and stability of the project. Serviceability include: accumulation of silt in dam reservoir and The effect of dispersive soil erosion on the project, while estimation of stability based on : sulphates attack on the dam body, piping erosion impact on the dam foundation and safety factor against uplift pressure in the dam foundation.

Geological map for dam site with scale 1: 50,000 is compiled using satellite images and field survey. The soil types are identified in this map. The previous site investigations, hydrological and hydrogeological reports are studied carefully to understand the geotechnical and geological parameters controlling the stability of dam structure units.

A direct method is adopted to calculate siltation in dam reservoir, by developing quantitative method based on initial elevations of dam reservoir and the measured siltation level during the draught season, therefore the actual volume of siltation is calculated and the economic life of the dam is recomputed.

The instability of the dispersive soils represent serious problems affecting on stability of engineering projects. The Bird-eye satellite images show the effects of dispersive soil near the dam site and surrounding areas. The field survey for dam site is conducted the problem is identified in the embankment and shoulders. Soil samples are collected from dam shoulders for laboratory test. Emerson's test are used to determine the degree of dispersion in soil. The results were drawn on a map showing the severity of dispersive soil in each area of the dam shoulders, and several methods were proposed to address the problem.

The sulphates attack on the concrete structure of the dam was studied optically through field survey, and the impact divided into three zones

in terms of the effect of sulfates. ZoneIII was the most affected area in dam body by concentration of sulphates in the water as a result of water evaporation.

Numerical model was created using SEEP/W software to calculate amount of seepage, distribution of pore-water pressure under the dam, seepage velocity and hydraulic gradient, which used to calculate the actual safety factor of the dam.

The outputs of simulation model indicate the difference in total head between upstream and downstream at flooding condition increasing seepage velocity in soil under dam body and increasing pore-water pressure in downstream (toe).

The safety factor of the dam was also calculated, which showed that the dam body was relatively stable, but plans have to proposed to protect the dam in the future.

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CHAPTER ONE

Introduction

CHAPTER ONE
INTRODUCTION

1.1 Preface

The study area is also characterized by the Dewerige river, it's a seasonal river and due to torrents from Iranian territory, the river is flooded every year, therefore it is necessary to build a dam on the Dewerige river to avoid flooding risk and water harvesting for irrigation and recharge ground water.

This dam called ' Dewerige dam'. It's a small scale dam or weir.Weir is a vital hydraulic structure that can be defined as small concrete dam with overflow and low-head, which used for decreasing flooding risks, recharge ground water, navigation, and environmental enhancement (Bligh ,1915). Dewerige dam play an important economic and environmental rule for the future development of eastern Mayssan area.

After the first season of Dewerige dam operating several geotechnical problems encountered the project as amount of siltation in the reservoir, sulfate attack, dispersive soil and seepage in the downstream side at toe.

The geotechnical problem in the dam and dam reservoir are investigated and computed during this study by using: fieldwork , laboratory work and office work, also numerical modeling. Dewerige dam play an important economic and environmental rule for the future development of eastern Mayssan area.

1.2 Location of Dewerige dam site

Dewerige dam located in south eastern part of Mayssan province, south of Iraq Fig.1.1. The coordinates of dam axes are (E746239.862, N3551456.909) - (E746256, N3550931).

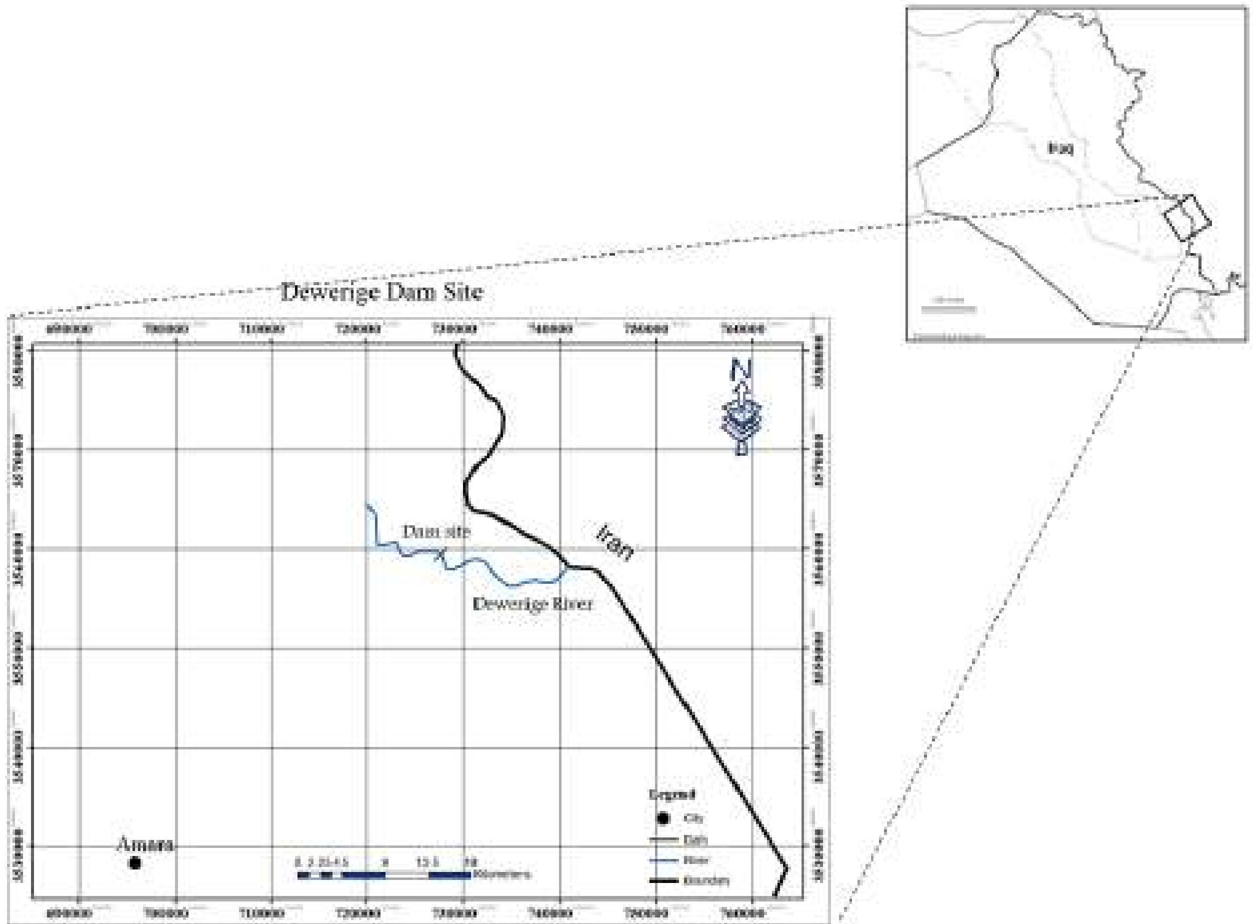

Fig. 1.1 Location of the study area

1.3 Objectives of the study

The main objectives of the study are as following:

1. Estimating the serviceability of Dewerige dam by:
   a. Computing the volume of siltation and the economic life of the reservoir.
   b. Study the dispersive soil erosion in the reservoir and dam shoulders.

2. Analysis the stability of the dam body by:
   a. Sulfate attacks on the concrete structure of the dam body.
   b. The seepage erosion (piping) and uplift pressure under the dam structure.

1.4 Engineering specifications of Dewerige dam

The main Dewerige dam structural parts shown in Fig.1.2 (Ministry of water recourses, center of studied and engineering design, 2009).

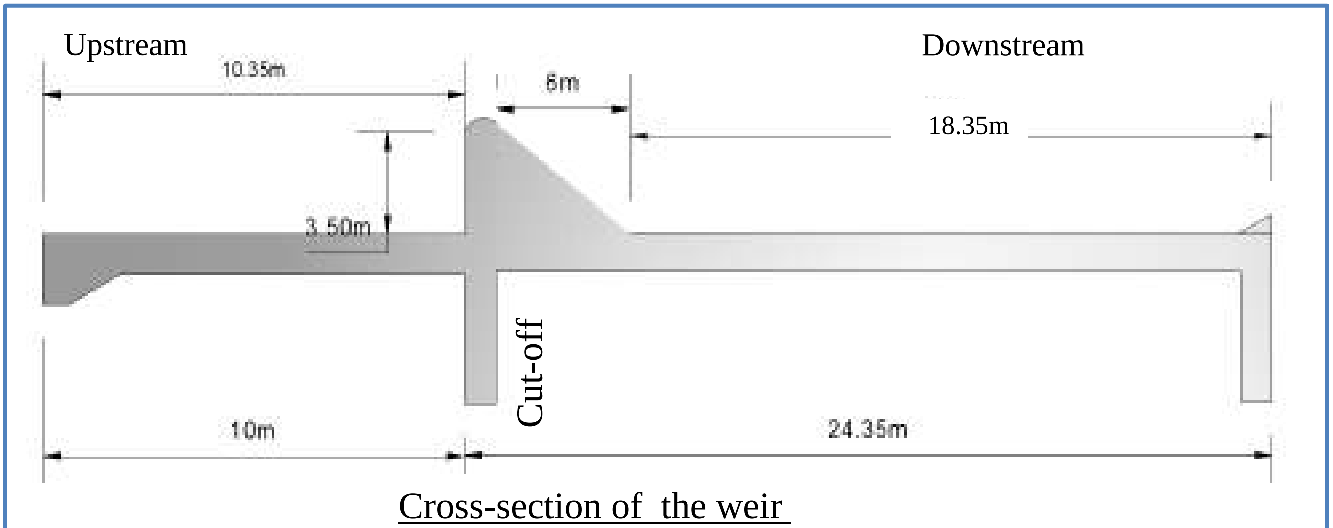

Fig. 1.2 Geometry of Dewerige dam (Ministry of water resources, center of studies and engineering designs, 2009)

- Dam type / gravity small dam (weir).
- Dam length / 512m.
- Total storage capacity / 1,870,000$m.^3$
- Operation date / 2013 – 2015.
- Cost / 11.370.675.100 IQD.
- Purpose / Dewerige dam is amulti-purposes dam, used for flooding control, water storage for irrigation projects.

1.5 Hydrological properties of Dewerige river

1.5.1 Description of river basin

Dewerige river stems from Iranian territory, about 90% of the river lies within Iran. It is a common border river between Iraq and Iran. Length of river is about 202 km and width is less than 800m and catchment area 3270km^2. The river enters Iraq from South - Eastern part at elevation 35m (Ministry of water resources, center of studies and engineering designs, 2009), Fig. 1.3.

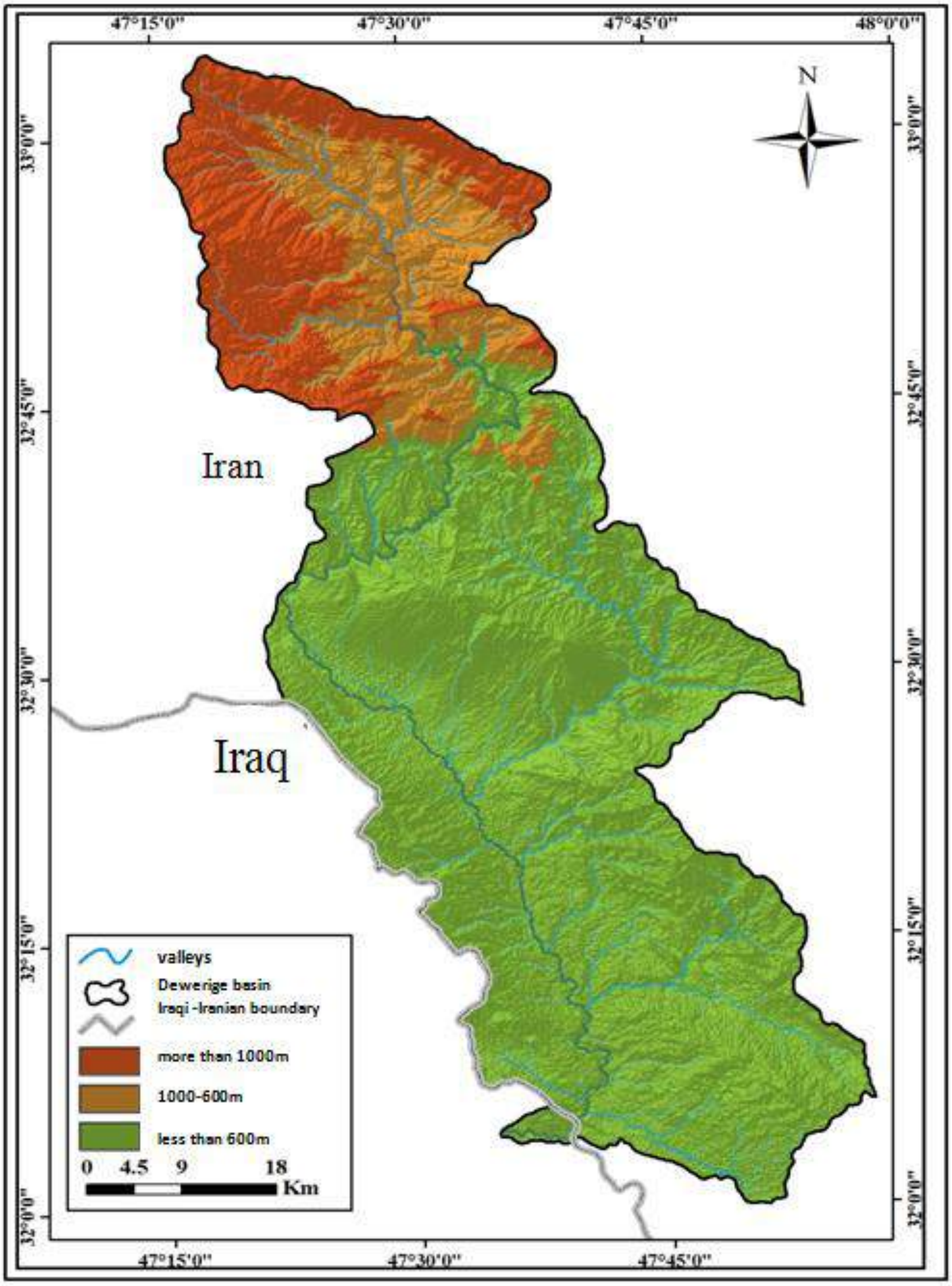

Fig. 1.3 Hydrologic map for Dewerige river (Alwan,2014)

The average length of river in Iraq is about 35 km. Dewerige river is a seasonal river and its discharge average about zero in summer because it is dry, however flooding occurs during the winter season . The discharge reaching about 994 m^3/s (Ministry of water resources, center of studies and engineering designs, 2009). The topography of study area explained in Fig.1.4.

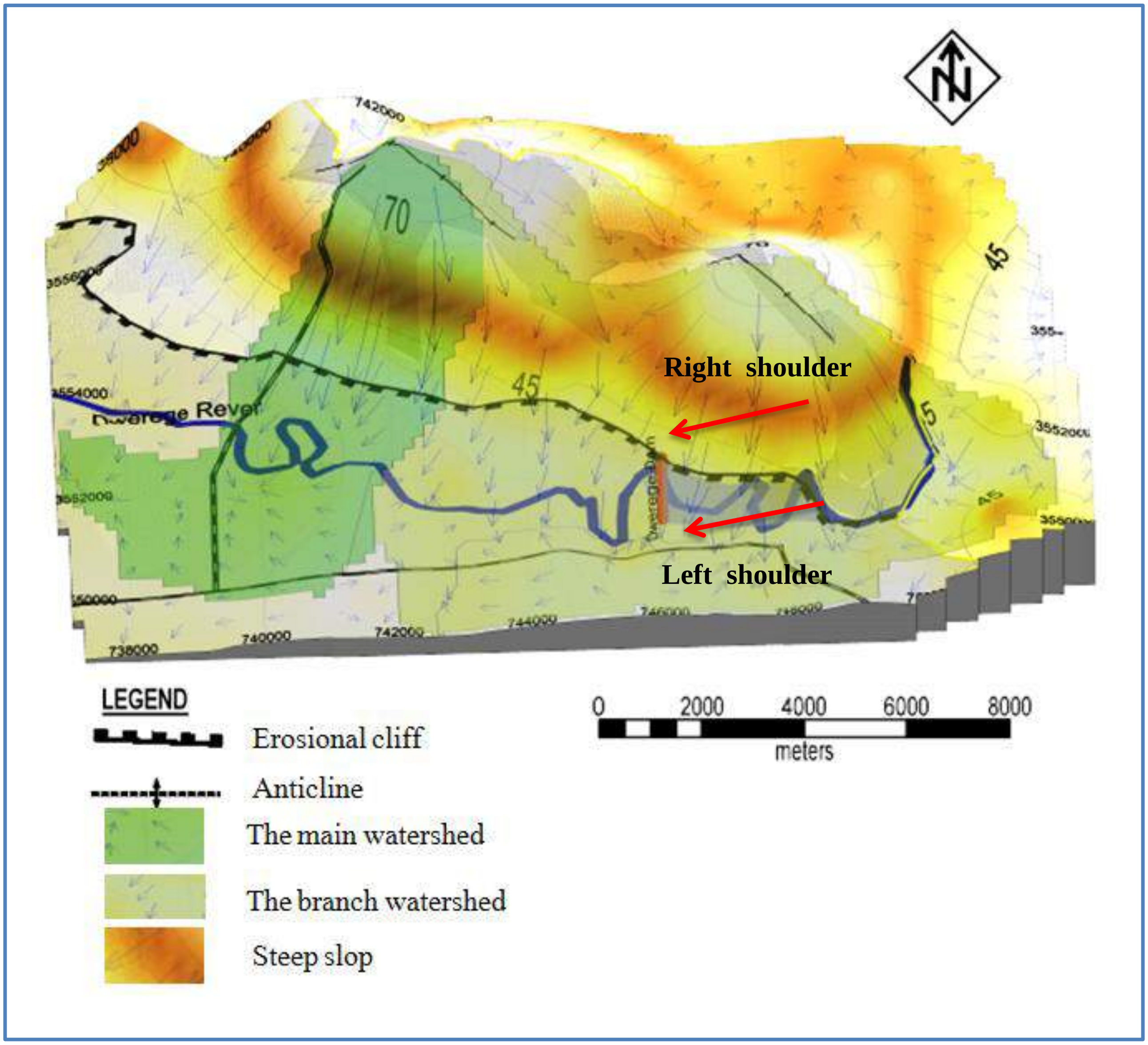

Fig .1.4 The 3D topographic map of study area

The topographic map of study area shows steep slope beside the dam site, especially in right shoulder, that is a very important guide in explaining concentration of dispersed soil effect in dam shoulders.

1.5.2 Climate

a. Rainfall

The mean annual rainfall are variable for the period 1985-2015 in Al- Amara station was studied to understand the rainfall duration in each season. The average annual rainfall in the study are 152.5mm and the maximum annual rainfall rate was recorded in March as 173.3 mm, while the minimum was in October 45 mm. Fig.1.5.

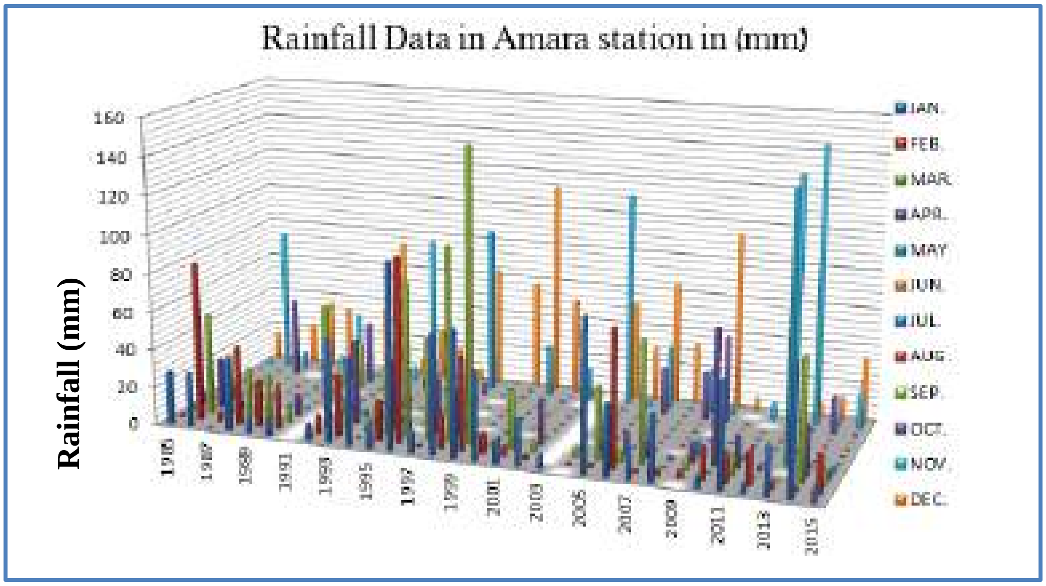

Fig .1.5 Mean of the annual rainfall data of Al-Amara station (1985-2015)

b. Wind

The (NW , N and W) are the recorded wind directions in the study area. The average wind speed about (3.1 m/sec). The maximum wind speeds are recorded in (January and July), while the minimum speeds is in (December. and January), Fig. 1.6.

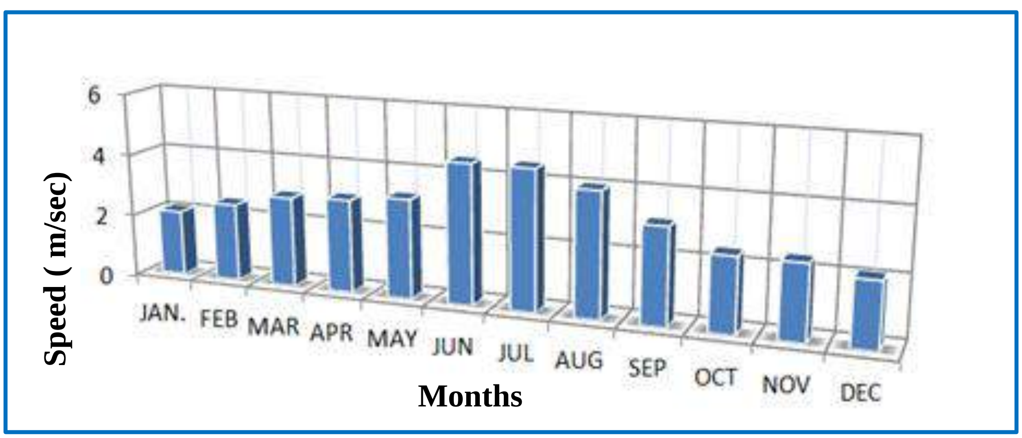

Fig. 1.6 Mean of annual wind speed of Al-Amara station (1980-2015)

c. Temperature

Based on data of Al-Amara metrologic station the maximum mean monthly temperature recorded in July, nevertheless the minimum recorded in January. Fig.1.7.

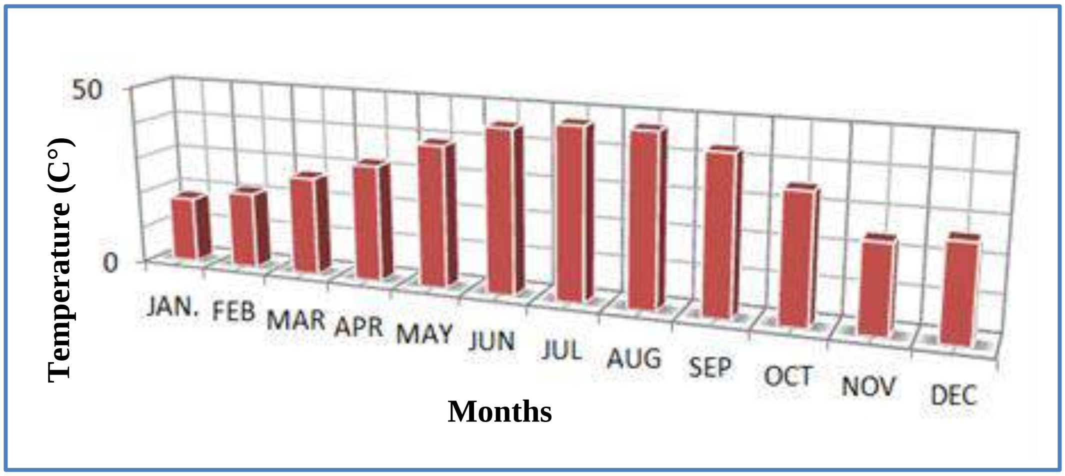

Fig. 1.7 Mean of annual temperature of Al-Amara station (1980-2015)

d. Evaporation

The evaporation data in Missan is recorded by Al-Amara station for the period 2000-2015. Data are represented in Fig.1.8, the maximum average of evaporation was detected in July 479.1 mm, while the minimum was in December 59.9mm.

Fig. 1.8 Mean of annual evaporation of Al-Amara station (1980-2015)

1.6 Geology of dam site

1.6.1- Stratigraphic of studied area

Lithology of dam site consist mainly of Quaternary deposit, especially flood plain sediments : sandstone, siltstone and claystone, as shown in Fig. 1.19, which is covering Tertiary deposit Mukdadya and Bai Hassan Formations.

Mukdadya (lower Bakhtiari) lithologically consists of: gravely sandstone - sandstone – claystone, with fining upward grained. There are conglomerate beds represent the border between Mukdadya and Bai Hassan, however Bai Hassan formation comprise (conglomerate - claystone - sandy conglomerate) (Aqrawi,*et at*,.2010).

Dam site is covered with recent alluvial and aeolian deposits with some Quaternary and Tertiary outcrops (Jassim and Goff,2006), especially in construction materials quarries south of the dam.

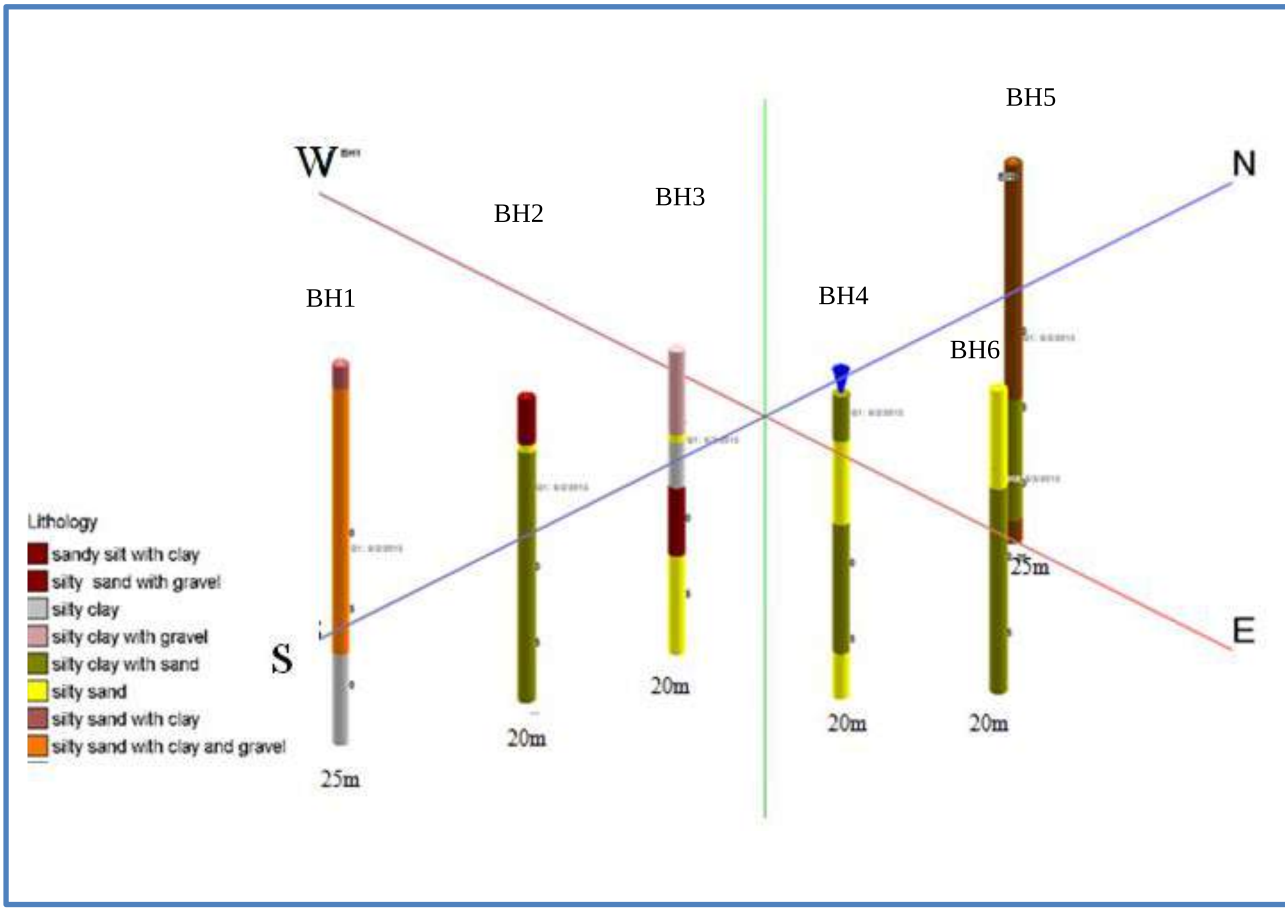

Fig.1.9 Boreholes lithology of dam site

1.6.2 Tectonic setting of study area

Dewerige dam is located in flat terrain, Himreen subzone, foothill-zone in south- east part of Iraq next to Mesopotamian zone as shown in Fig.1.11. The study area comprise faulted structure beneath Quaternary cover (Buday and Jassim,1987).

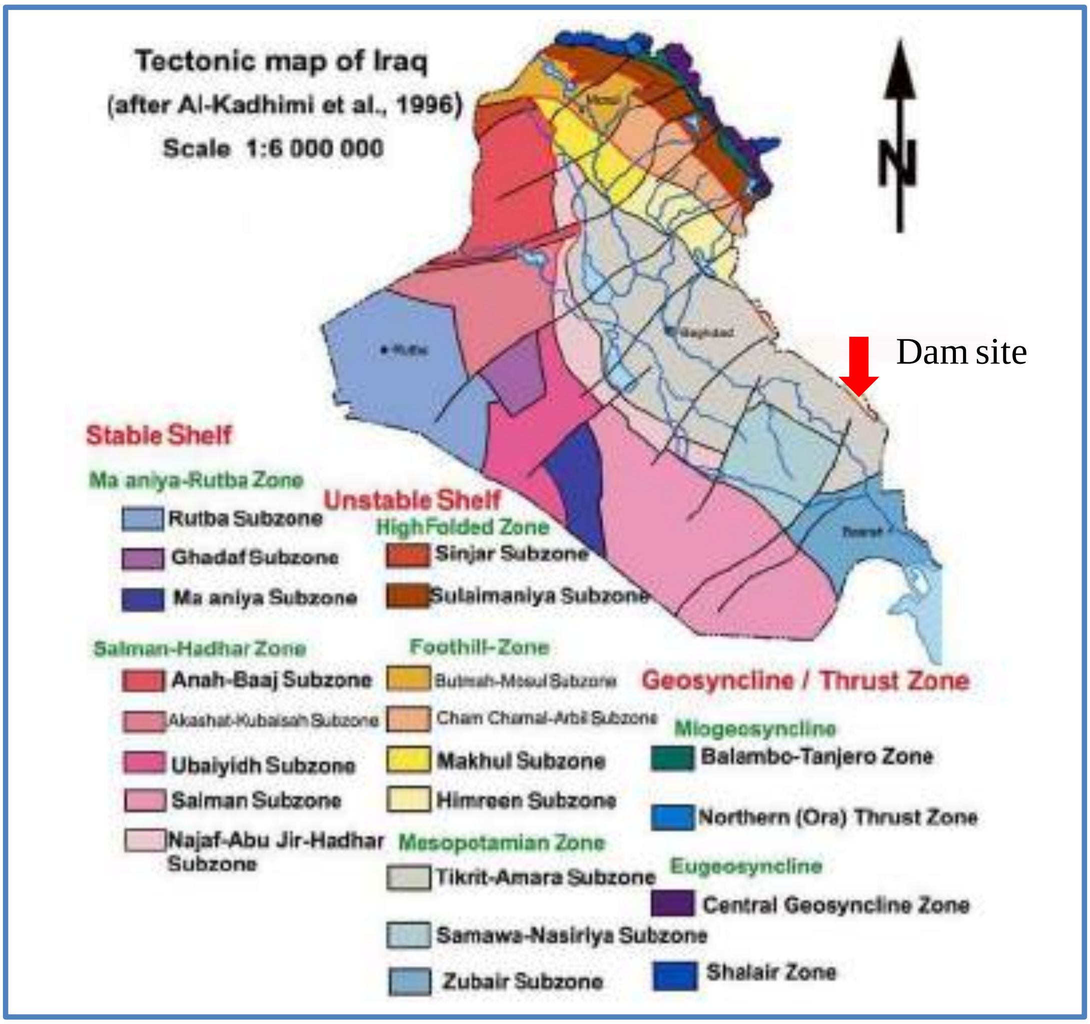

Fig .1.10 Tectonic map of Iraq (Al-Kadhimi,et al,1996) showing location of dam site

1.6.3 Geotechnical properties of dam site

According to the geotechnical investigation report of Dewerige dam site (Missan consultant engineering bureau, 2009) geotechnical cross-section is identified based on six boreholes are selected in dam site and locations of sand and gravel quarries. Fig.1.11 show engineering geological map of study area.

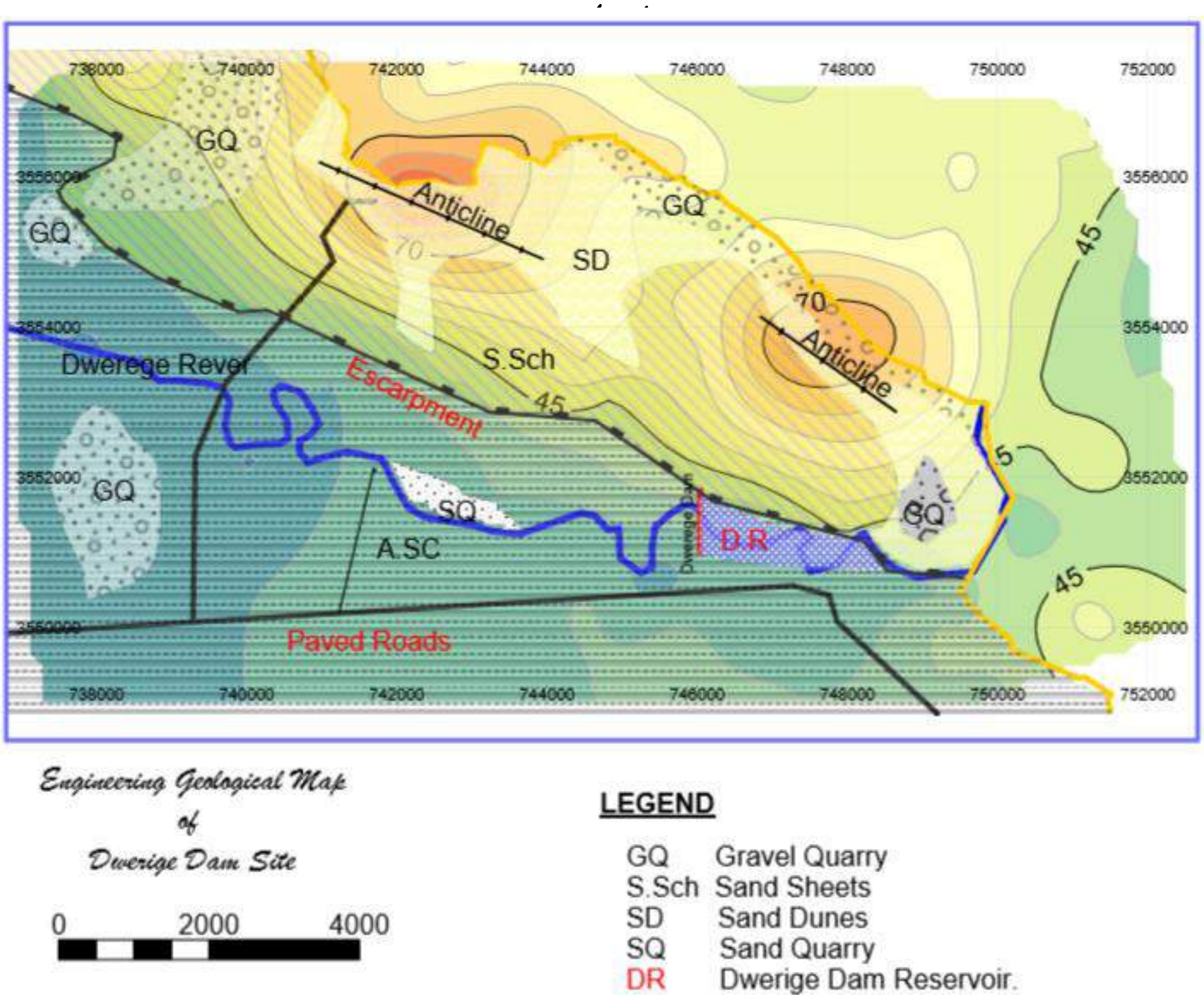

Fig .1.11 Engineering geological map of study area

1.7 Previous Studies

1- Chanson and James (1999) studied siltation of Australian reservoirs, the study concluded that many of reservoir in Australian dam had been totally filled by the action of siltation.

2- Rickard,*et al*, 2003. established general practical guide for classification and general properties of weir.

3. Khan, et al,2007. studied sediment load assessment of small embankment dams in southern regions of Pakistan, the study concluded that increasing siltation in embankment dam decrease reservoir capacity.

4. Gandhi (2009) deals with geotechnical aspects of dam safety and foundation problems, the study indicate seepage problem occurs by the action of geological properties of dam site.

5. Noori and Ismaeel (2011) studied evaluation of seepage and stability of Duhok dam, the study observed increasing seepage through the dam with increasing the difference between horizontal and vertical conductivity Kx/Ky.

6. Alahiane *et al*. (2014) studied practical method proposed to estimate siltation in small and hillside dams. The study concluded that the surveying method is low cost and an acceptable accuracy comparing with other method.

7. Nasser (2014) studied evaluation of storage for Dewerige weir and create 3D model using geographic information system (GIS). The study confirms that the real storage capacity of reservoir less than design, so the resent position of dam is incorrect.

8. Alwan (2014) estimate the volume of runoff of the basin valley Dewerige river by remote sensing techniques and geographic information system (GIS).The study explains that geological conditions have a significant impact on amount and volume of runoff in Dewerige basin.

9. Ljungblad and Bäckström (2016) studied safety evaluation of the Zhaoli tailings dam: a seepage, deformation and stability analysis with GeoStudio. The study concluded that the Zhaoli tailings dam was safe from seepage and stable.

1.8 Procedure of the study

The summery of geotechnical and hydrological study of Dewerige dam project simplified in flow chart Fig.1.12.

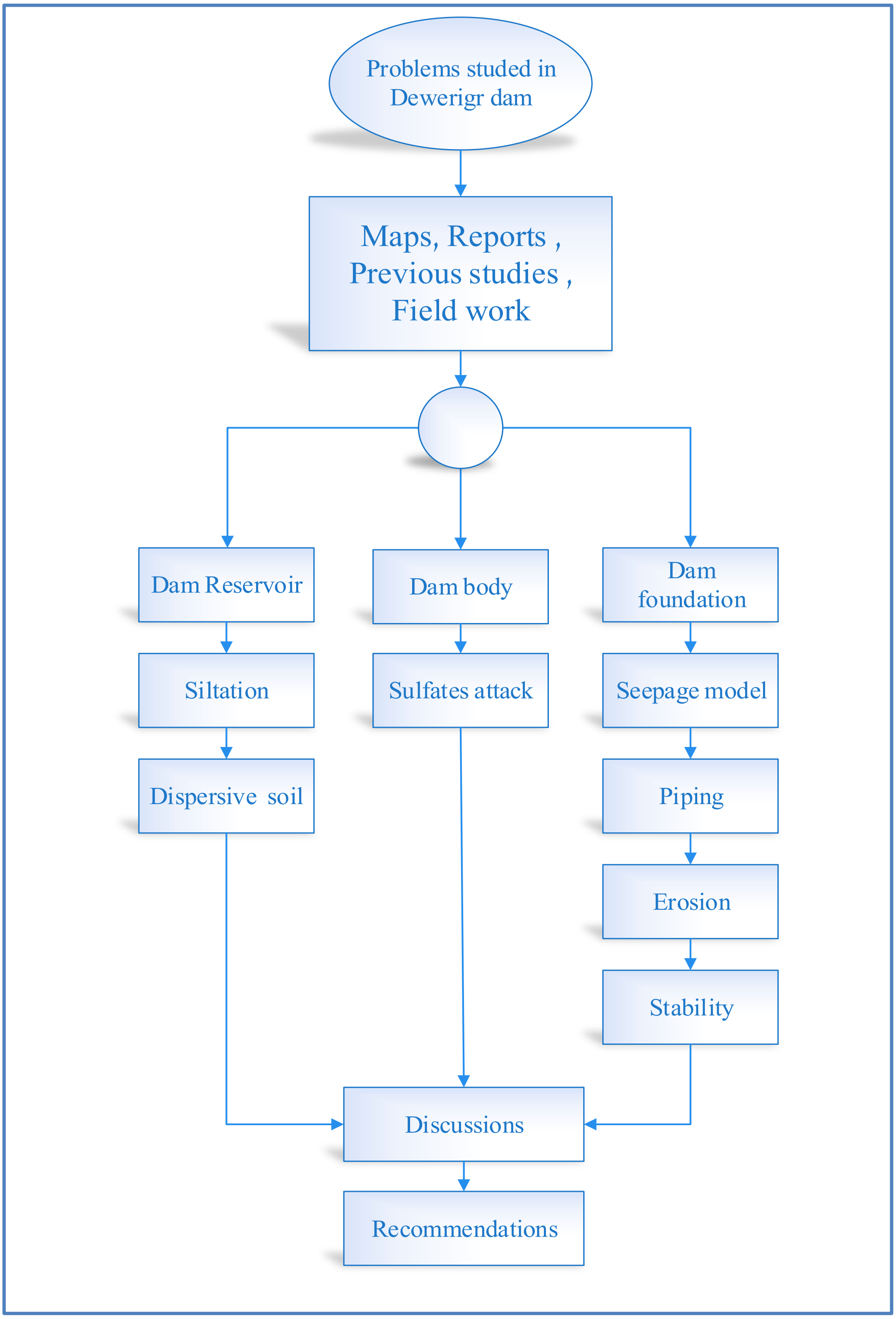

Fig.1.12 Procedure of study

CHAPTER TWO

THEORETICAL BACKGROUND

CHAPTER TWO
THEORETICAL BACKGROUNG

2.1 Introduction

This chapter explains classification of weirs, and discusses the main geological problems in the dam body, dam shoulder, and reservoir.

2.2 Weir definition

Weirs are known as engineering structures that similar to dams in terms of flood water storage function and ground water recharge, also called submerged dam or small dams, however it differs from dams that water flux over the weir and water outlets located under the weir (Bligh,1915).

2.2.1 Weirs fundamental parts

The main parts of weir are explained in Fig.2.1.

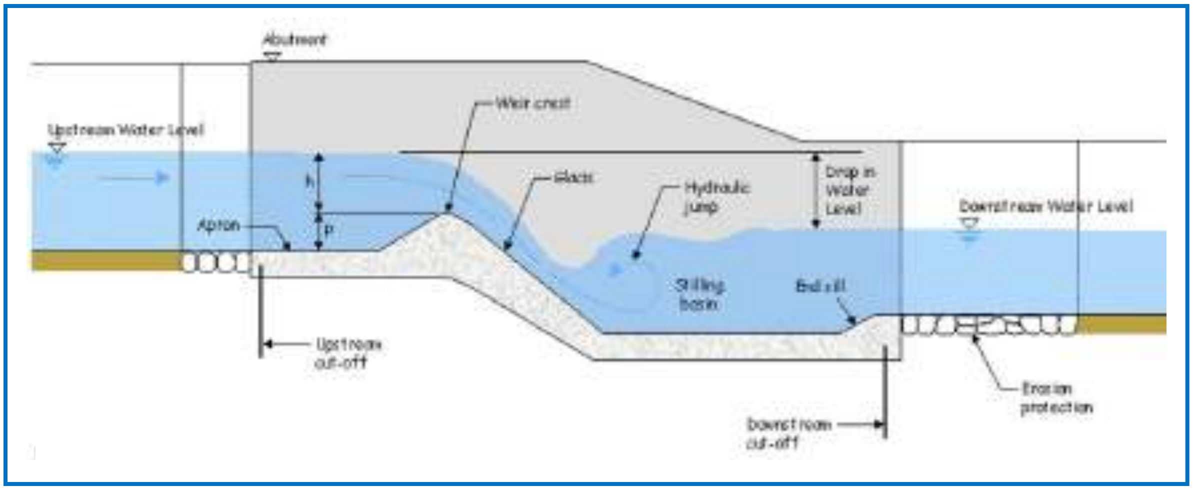

Fig.2.1 Parts of weir (Rickard,*et al*.,2003)

2.2.2 Effect of weir construction

The mainly influence of weir on dam is increasing water depth in upstream side as shown in Fig.2.2 and explained in Table :2.1.

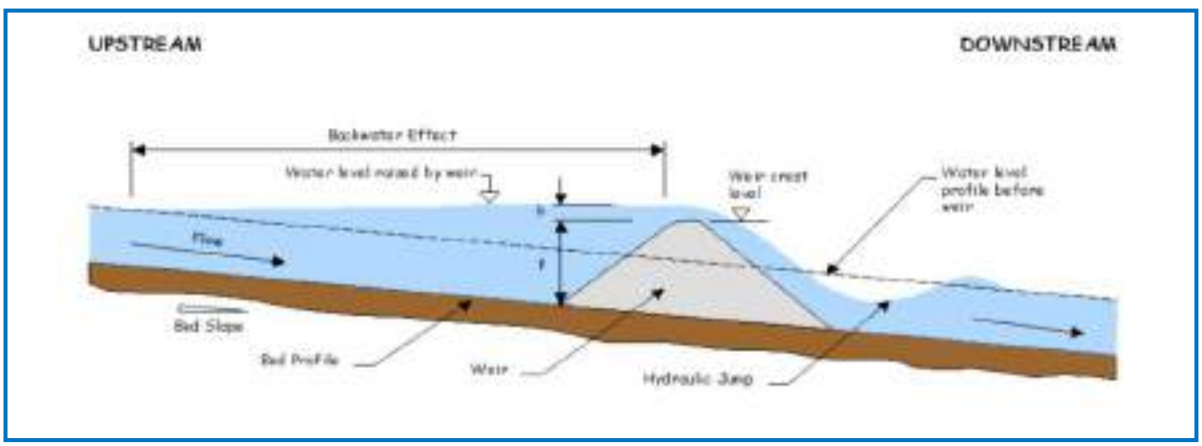

Fig.2.2 Influence of weir (Rickard,*et al*.,2003)

Table : 2.1 General effects of weirs (Kay and Melvyn, 2007)

WEIR EFFECT	NAGATIVE	POSITIVE
Increased depth upstream	Increased flood risk. Loss of marginal vegetation. Loss of *ranunculus* vegetation. Increased risk of death by drowning. Reduced biodiversity. Raised groundwater level may have negative impacts (such as restricted drainage).	Visual appearance. Improved amenity. Improved navigation. Improvement to some fisheries. Raised groundwater level may have positive impacts (such as improved wetland).
Drop in water level at weir	Barrier to fish migration. Noise. Barrier to navigation.	Amenity value. Ability to measure flow accurately. Potential for power generation.
Reduction of water velocity upstream	Algal blooms. Loss of some angling opportunities.	Safer navigation (except that the weir itself may be a hazard).
Turbulent flow downstream	Bank and bed erosion. Dangerous conditions for canoeists and swimmers.	Visual appearance. Aeration of water. Attractive conditions for canoeists.
Physical barrier across the river	Trapping of debris. Siltation of channel upstream. Fish migration inhibited.	Opportunity to create a crossing point.

2.2.3 Classification of weir

Weirs vary in size and design according to the purpose built for it.The following mainly classification of weirs:

a. According to crest elevation: horizontal, shallow V-shape, and compound types, Fig.2.3.

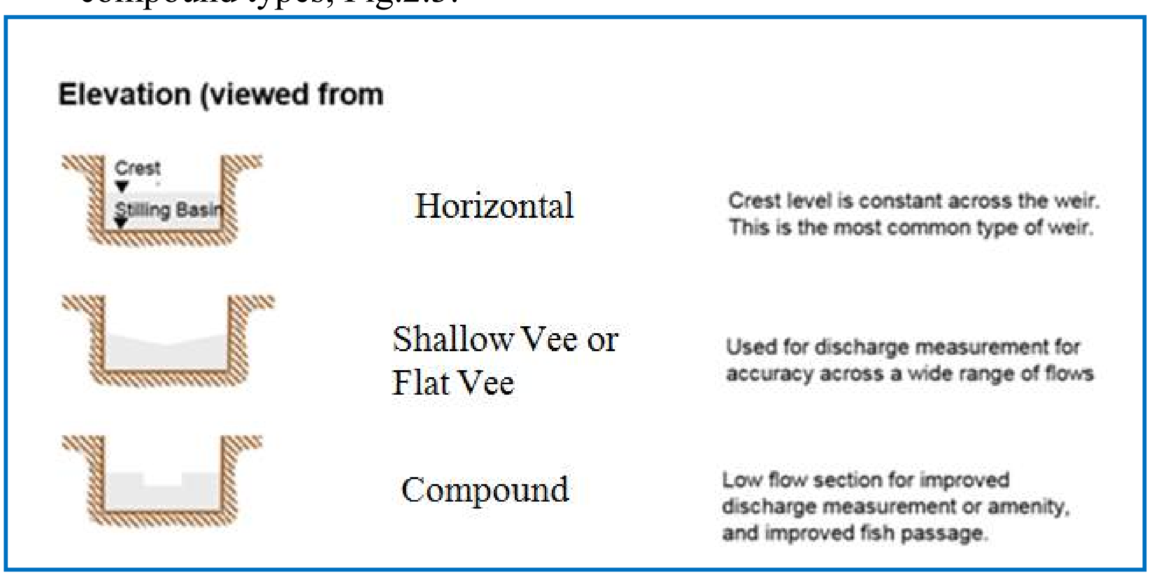

Fig.2.3 Weir type based on crest elevation (Rickard,*et al.*,2003)

b. According to extension of the weir axis: classified as : orthogonal, diagonal, curved, labyrinth, and side weir, as explained in Fig.2.4.

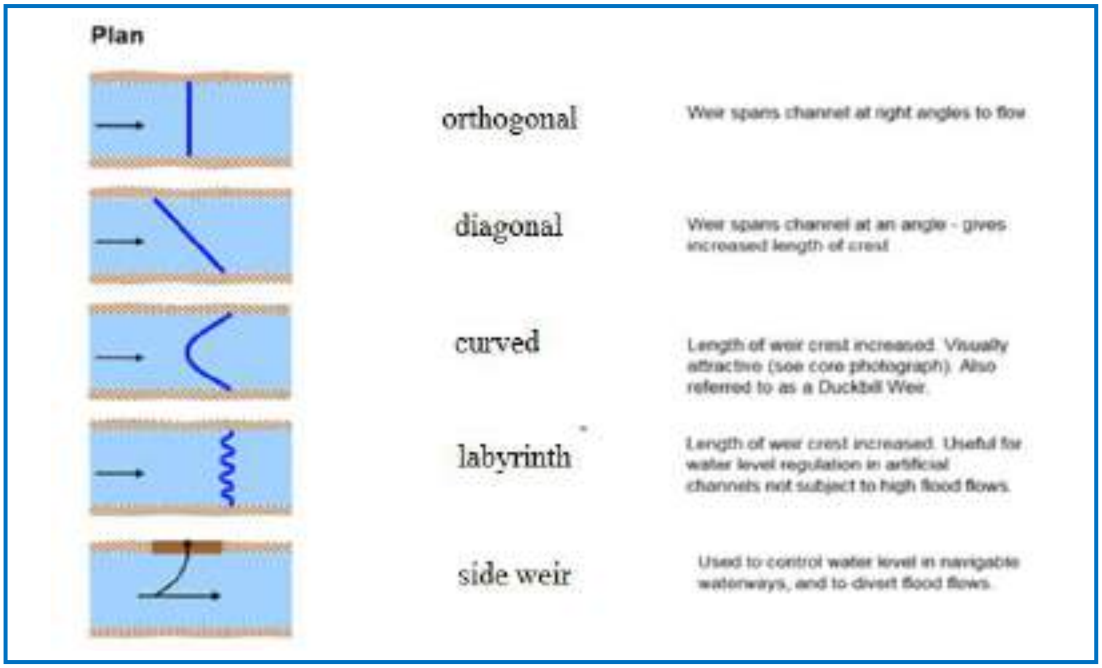

Fig.2.4 Weir type based on extension of axis (Rickard,*et al.*,2003)

c. According to crest shape: broad crested, sharp crested, crump, ogee, straight drop, stepped, dumped stone or rock, tilting, gated, Fig.2.5.

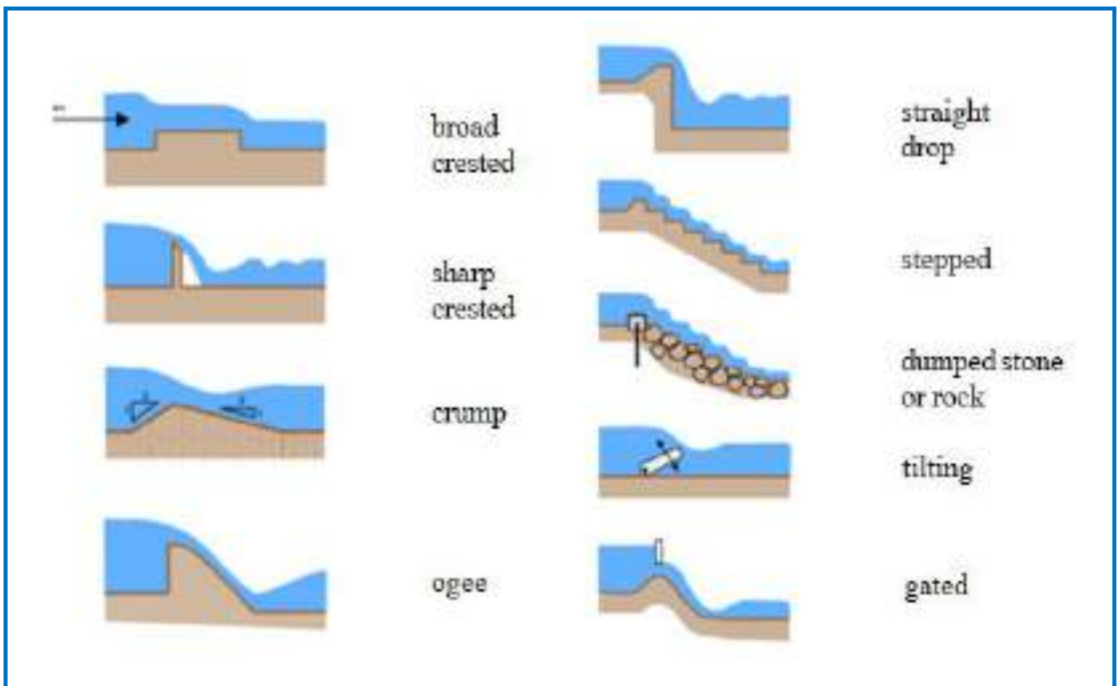

Fig.2.5 Weir type based on crest shape (Rickard,*et al.*,2003)

2.2.4 Classification of Dewerige dam or weir

Dewerige dam can be classified according to its design into 'ogee' type weir with orthogonal plan & horizontal crest, Fig. 2.6.

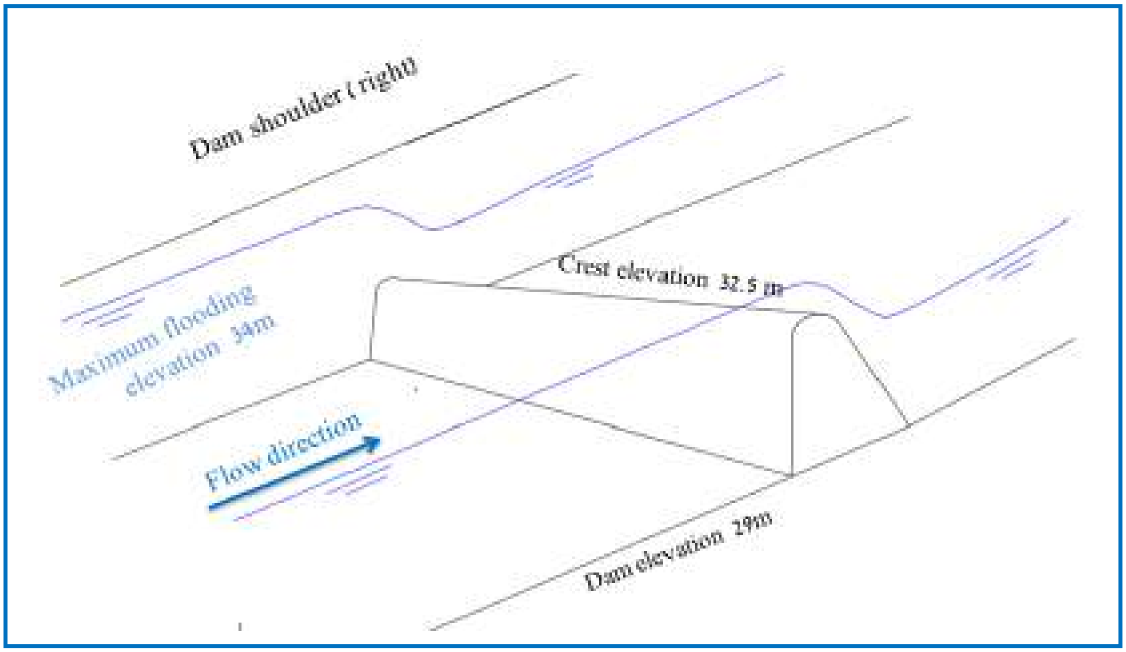

Fig.2.6 Side view show design of Dewerige dam

2.3 The main geological problems in dam and reservoir

2.3.1 Sulfate attack

Represents a commonly problem in concrete, especially in hydraulic structures as shown in Fig.(2.7, 2.8). Sulfate attack defined as a chemical or physical reaction between sulfates in soils or groundwater with concrete or mortar. Sulfate attacks occur especially in arid area when salts can be deposited on concrete and cause unusual cracking and discoloration (Ouyang, *et al*,1988).

Chemical reaction /

Sulfate + calcium hydroxide ⟶ Gypsum + calcium aluminate → calcium sulfo aluminate (Ettringite)

$SO_4 + Ca(OH)_2 \longrightarrow CaSO_4 \cdot 2H_2O + 3CaO \cdot Al_2O_3 \longrightarrow Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26H_2O$ ....(2-1)

Physical reaction /

crystallization of sulfates in pore of concrete → growth of crystal cause cracking in concrete.

These reactions produce internal stresses which cause expansion and cracks (Taylor, 1997).

Fig.2.7 Effect of sulfate attack on hydraulic structure

Fig.2.8 Cracks in the concrete by the action of sulfate attack

Sulfate ion can be originate from internal or external source. The external is found in the (ground or surface water) and soil surrounding the concrete, while the interior sulfate ion is found in the structures of construction materials used to produce concrete mix (Marchand *et al*., 2003).

2.3.2 Dispersive soils

a. Introduction

Soil characterized by dispersion structure without influence of water and be unstable when wet, almost dispersive soil be sodic and rich in silt. Type of clay minerals indicate of degree of dispersion, for example content of Na-montmorillonite increase dispersion in soils (Fell *et al*.,2005).

The strength of soil are important to support the engineering structure on or in it. The failure of soils different according mineralogy and structure of its particles. Some failure can be expected and controlled like settlement and consolidation, other failures like quicksand, mudflow and dispersive happen suddenly Fig. 2.9 and need careful understanding of soil properties before constructing the engineering structure which using these soils as construction material (Sheraed *et al*.,1976).

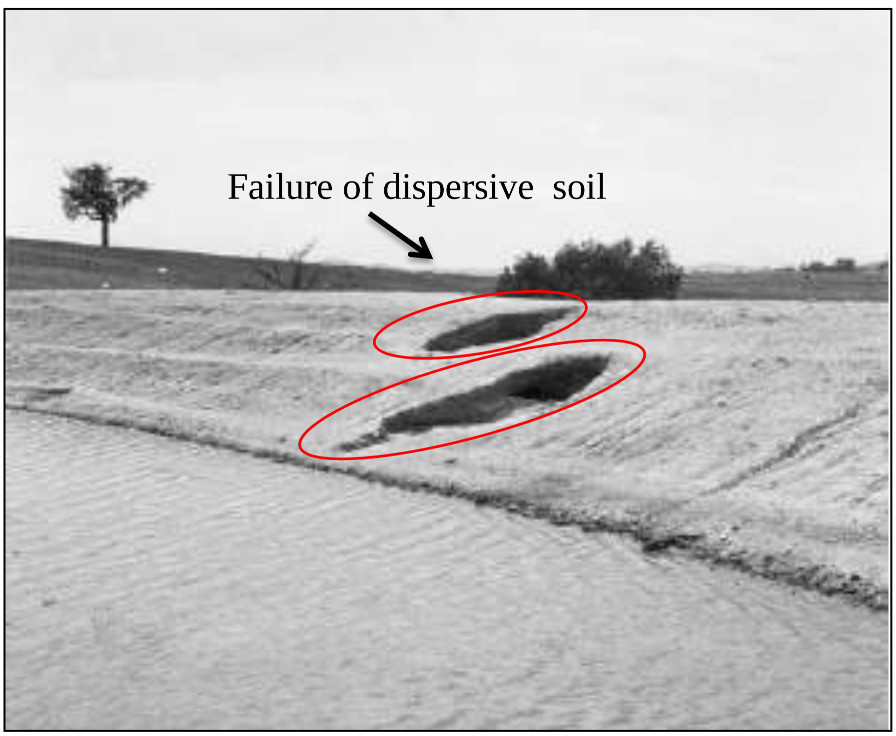

Fig. 2.9 Example for dispersive soil failure in earth fill dam (Fell *et al*.,2005)

b. The main sources of dispersive soils

There are several causes represent the sources of theses soils as the following (Hardie *et al*.,2009) :

- High sodium content in weathering rocks.
- High saline water seepage through soil.
- High water table form concentration of Na near the surface.
- Increasing salinity as a result of evaporation.

c. Factors control the dispersion of soils

There are several agents control dispersion in soil (Valentin *et al*.2005):

- Chemical content of water that seep through soil, especially Na content.
- Amount of dissolved salts in soil decreasing strength of soil and cause dispersion.
- Amount of calcium in soil decrease and treat dispersion .
- Presence of montmorillonite in clay soil transform soil to dispersive soil.

2.3.3 Siltation problem

a. Introduction

Deposition of large amount of silt sediments in reservoir at flooding condition as can be seen in Fig. 2.10. Saturated silt sediments causing pressure more than hydrostatics pressure about (1922.4 kg/m^3). Siltation has direct impact on safety of dam reservoir as shown below (Swenty and Westphal,1989):

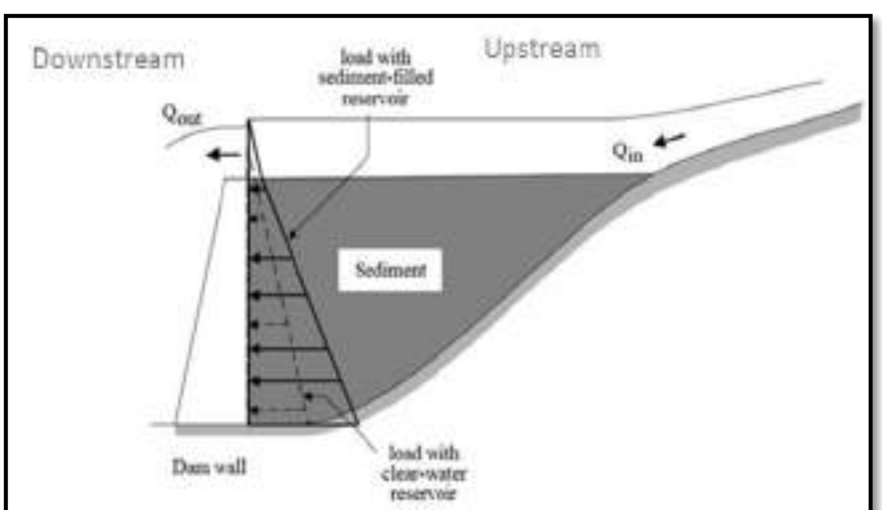

Fig. 2.10 Accumulation of silt in dam reservoir (Chanson and James, 1999)

b. Siltation effect on dam safety, (Bruk,1985)

1. Effect of sediment deposits on outlets:

Block out the bottom outlets of dam is the most dangerous problem of sedimentation by accumulation sediments, in addition to the remains of trees and plants in the reservoir.

2. Effect of sediment deposits on gates and valves:

The flow occurs at high speed through bottom outlets more than (40 m/s), therefore that causes scratch and bore by the action of the sediments particles, which effects on underlay and concrete surfaces, especially if the sediment contain heavy metals. Remove pressure and mud can emission gas (hydrogen sulphide gas) which may cause eroded metal parts of gates and instrument located in gate chamber.

3. Effect of sediment deposits on the dam:

Sediment deposit produce pressure should be taken into account in structural design of dam, also its important to sureness the properties of designed structure are not change by impairment of concrete. Furthermore chemical interaction in sediment, especially the sulphur cycle and corrosion in water.

4. Effect of sediment deposits on monitoring of the dam:

Sediment deposits prevent the monitoring of the dam by disturb using subsurface instruments of monitoring for example: submersible, divers. They can prevent visual observation after avoiding reservoir (Bruk,1985).

c. The effect of siltation on economic and social aspects, (Bruk,1985)

1- Shortage Storage capacity

One of important effects of siltation is decreasing storage capacity of dam reservoir, which is the axis of reservoir. Lack of storage reflected on energy product, water supply for domestic use, and control of discharge, Furthermore siltation will effect on the surface area of reservoir with time by reducing the depth of water. The impact of siltation in decreasing reservoir storage capacity can be summarized in the following points:

a. Decrease power generation:

Dams usually be multi-purpose, so siltation problem will be reflected on power generation, any reduce in reservoir storage capacity will decrease the power output of hydroelectric station.

b. Impact on agriculture and industry:

There is no alternative for water in irrigation, so reduce reservoir storage will effect crop production. Industry is the biggest consumer of water. Water used in industrial process and cooling. Lack of water may be very costly for industry.

2- Impact of the shortage of water surface

Influence of siltation in water surface is happened by appearance of sediment deposits near the surface and growth weeds in shallow depth.

a- Impact of boats and river navigation:

Both of sediment deposits and aquatic vegetation can hamper river navigation. Mud is a real problem for shoreline but, from the other hand represent a suitable environment of swimming and water spots. Aquatic vegetation represent a good refuge for aquarium and birds.

b- Impact on public health:

The shallowest of surface water by the action of siltation, and aquatic vegetation help the presence and proliferation of insect. The seriousness of these insects carry disease like: yellow fever, Malaria and Onchocerosis.

2.3.4 Seepage and Piping

a. Seepage

Movement of water through soil called seepage. It is the most commonly problems in dams both of earth fill and concrete. This study concerned with seepage problem under the concrete dam foundation. Water flow through low permeable media in slow velocity, This flow can be defined as 'laminar flow'. Increasing flow velocity could change flow pattern to turbulent flow. The Reynolds number is used to identify the type of flow, if it laminar or turbulent (Tomlinson and Vaid, 2000).

$$R = VD\rho/\mu \quad \text{(2-2)}$$

Where:

V = velocity of discharge (cm/sec)

D = average diameter of soil particles (cm)

ρ = water density (g/cm^3)

μ = water viscosity (g sec^{-1} cm^{-2}).

Generally, water flow through most soil in low velocity, therefore Reynolds number will be 1.0 or less (Wahlstrom and Ernest,2012).

b. Flow net

Hydraulic net within vertical section in permeable media, illustrate water flow in lines called 'flow lines', which be perpendicular to equipotential line (pressure line) at a right angle (Das and Sobhan,2013) as illustrate in Fig.2.11.

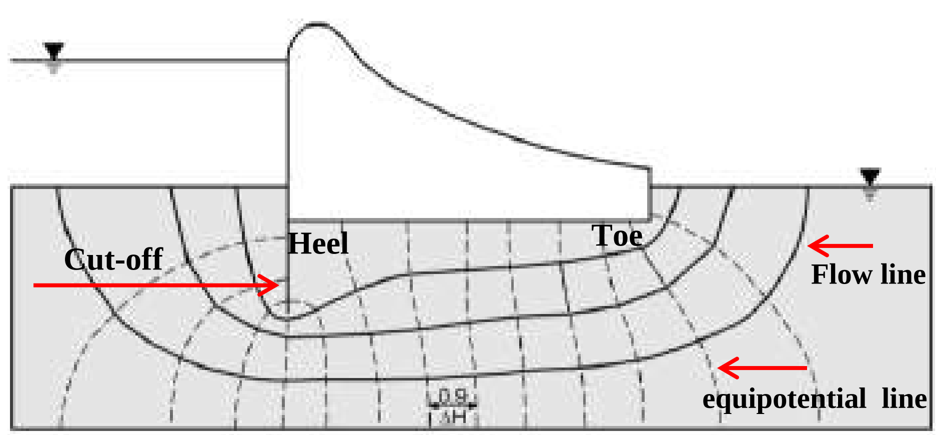

Fig.2.11 Flow net beneath concrete dam (Wahlstrom and Ernest, 2012)

In saturated soil under the dam there is upward pressure defined as 'uplift pressure', which produced by pore - water in permeable material uplift pressure in maximum at (heel), while minimize about zero at (toe) as illustrate in with details in chapter five. Causing rotate and coup in the dam body, however flow velocity at toe in maximum which constitutes a threat to the foundation of the dam by weathering and piping in foundation.

Therefore concrete dams base are rarely built at elevation of reservoir, and instead of cut-off constructed to control on seepage problem .Cut-off is a wall constructed below the dam Fig.**2.11**, it's a narrow concrete wall (Wahlstrom and Ernest,2012).

The benefits of cut-off are (Hinchberger and Newson,2010).

1. Decreasing the dangerous of piping and erosion at dam toe.
2. Decreasing uplift pressure at dam heel, and uplift pressure at toe.
3. Increases the length of the flow lines and thus reduces the velocity of the flow downstream, which reduces seepage beneath the dam.

c.Piping problem

Piping occur by the action of seepage flowing through erodible soil causing transporting of particles with flow direction. There are three factors for piping: intensive seepage, progressive erosion (back direction), and washing of fine particles of erodible soil (Wahlstrom and Ernest,2012). The following chart Fig.2.12, explained the stages of piping failure :

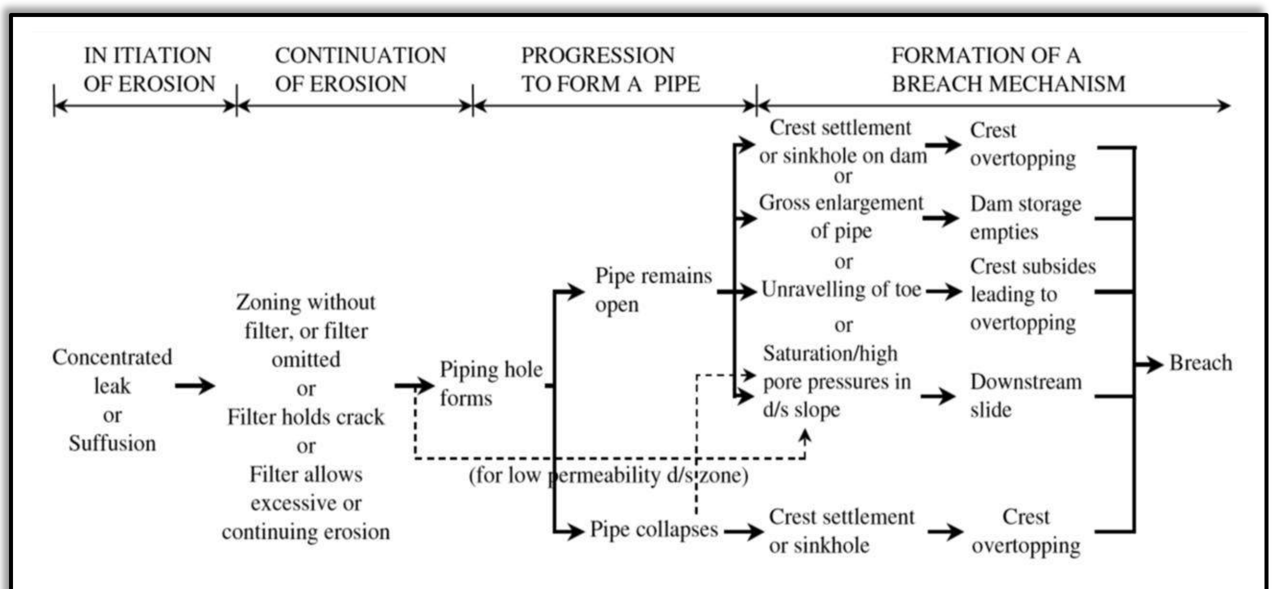

Fig.2.12 Stages of piping failure (Fell *et al* ,2005)

Dams foundations have to be able to resistant forces, which acting on as shown Fig.2.15. Dams are exposed to horizontal forces make it move toward downstream and produce a horizontal stress on the dam base. Identify the forces that would affect the stability of structure is very important when study the safety of gravity dam. These forces are (Bureau, 1977) :

a.Reservoir water pressure.
b. Pore- water pressure.
c. Pressure of siltation.
d. Pressure of ice accumulation.
e. Force of earthquake.
f. Dam weight.
g. Force that result from gates.

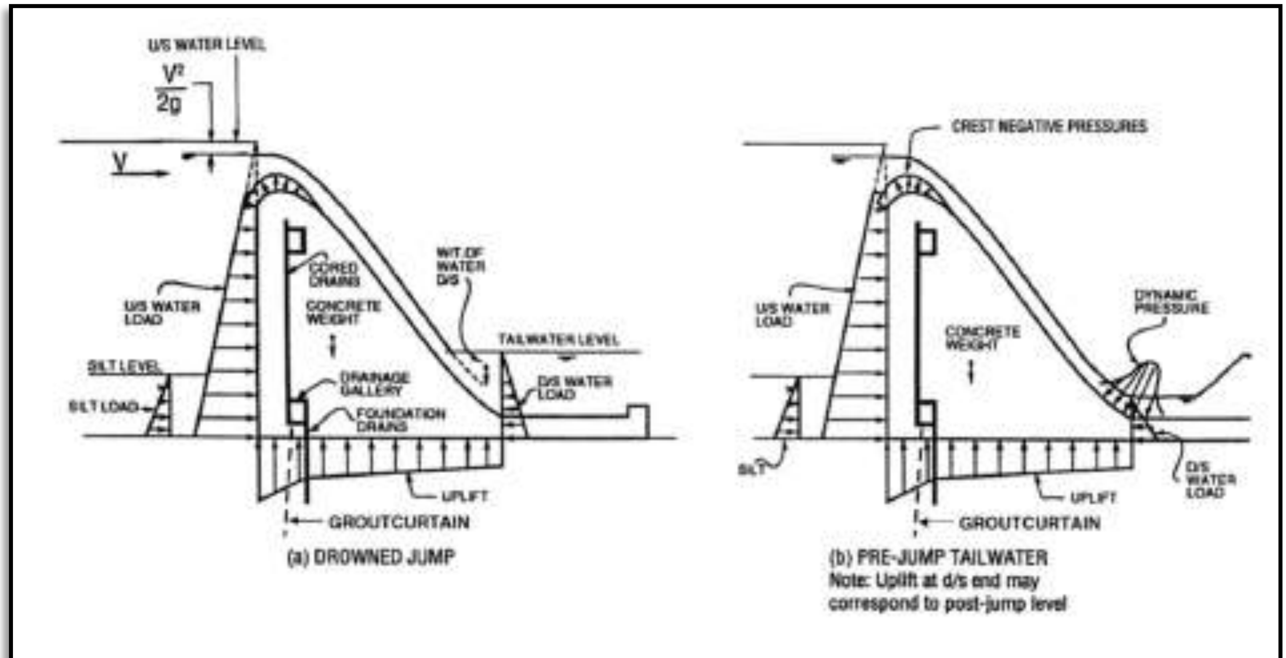

Fig.2.13 Forces influence in dam body (Bligh,1915)

2.5 Numerical model

Numerical model is an important tool for understanding the physical phenomena, and can be defined as numerical simulation of physical processes. The results of mathematical models must analyze and compared with available practical results. The most important characteristics of numerical models (Atkinson, 2008):

- Numerical model can be prepared faster than physical model (minute or hours).
- Physical model have specified certain condition, while the mathematical model have a wide and different ranges.
- Mathematical models the gravitational effects are not taken into consideration, opposite of the physical model.
- In mathematical models there is no risk to the safety of workers, while the physical model damage is caused by heavy equipment.
- Numerical model presents accurate data at any point within the model.

2.5.1 Modeling in geotechnical engineering

The importance of mathematical models in geotechnical engineering is illustrated by professor **Burland** through a lecture in 1987, in which he explain the geotechnical engineering consists of three main compounds: the ground profile, the soil behavior and modeling. Geotechnical engineering compounds called Burland triangle (Ayyub,1987), Fig.2.16

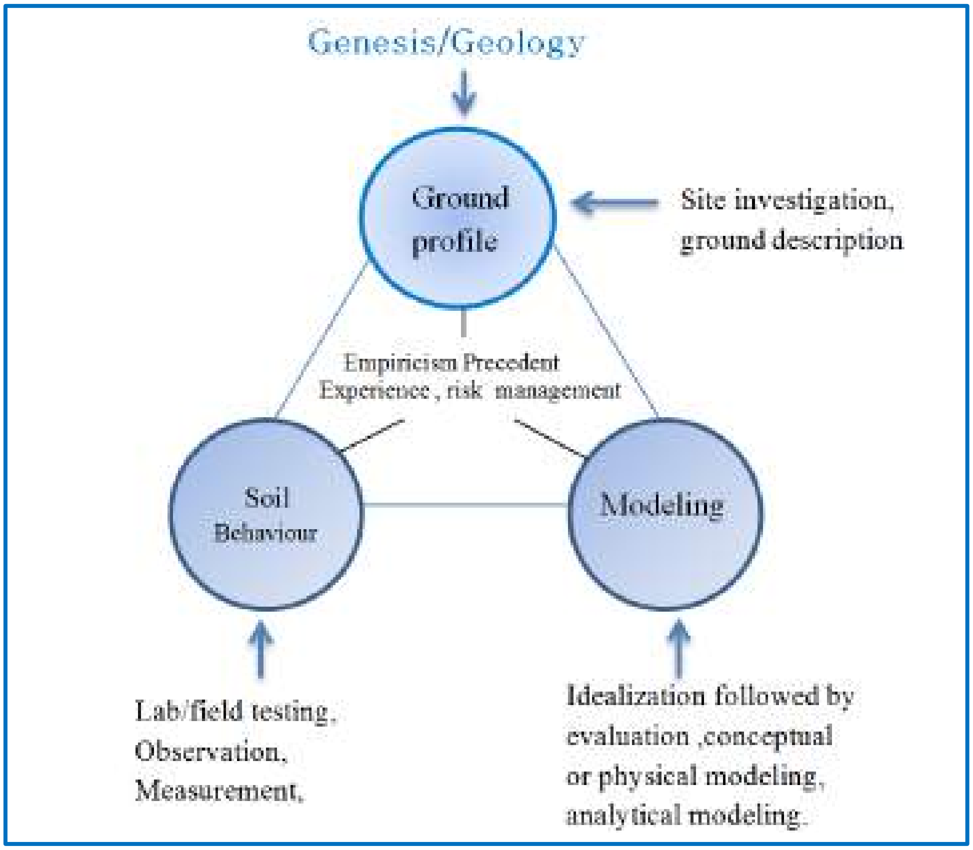

Fig.2.14 The enhanced Burland triangle (modified after Anonymous, 1999)

The ground profile explain site properties, both of definition and description. The soil behavior contain : laboratory test, in-situ test and field measurement. The Burland triangle has been studied extensively by (Anonymous,1999) and (Morgenstern, 2000), so Burland triangle has been expanding and improving.

The triangle illustrates the important role of modeling in geotechnical engineering. Modeling require planning and careful analysis of all the field measurements and the characteristics of the soil (Krahn, 2004).

2.5.2 Modeling by using GeoStudio 2012

Modeling in GeoStudio based on finite element method (FEM) to geotechnical and geological problem modeling in two- dimension. GeoStudio in a package software (Krahn, 2004), Fig. 2.17. In this study SEEP/W are used to simulate seepage under the dam.

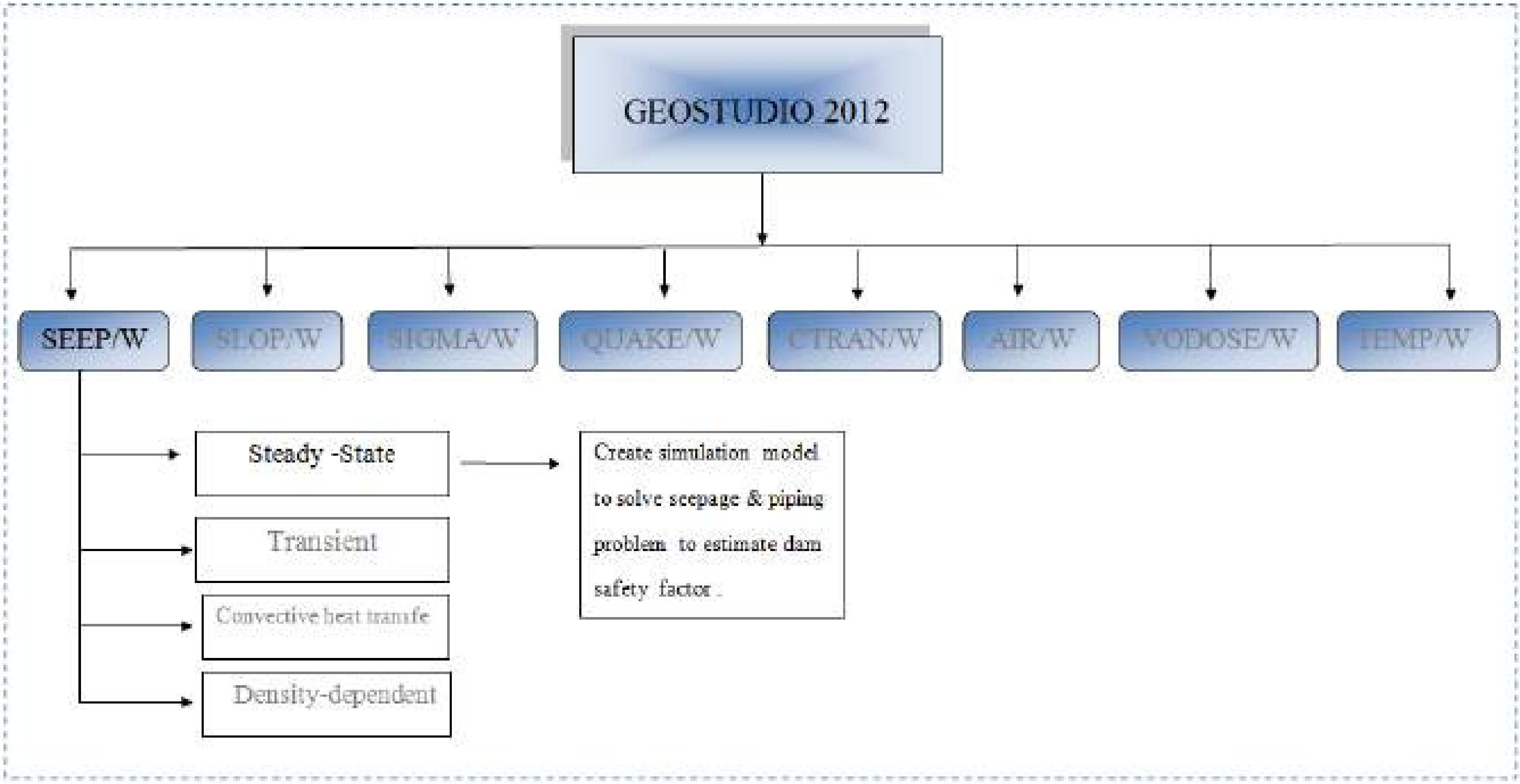

Fig. 2. 15 Approach of modeling by using Geostudio2012

2.5.3 Principle of SEEP/W modeling

The purpose of Seep/w analysis to simulate seepage flow through soil in saturated & unsaturated soils, The outputs of seep/w are (Krahn, 2004):

i. Seepage flow or discharge .
ii. Distribution of pore-water pressure (very important in stability analysis).
iii. Water velocity and pathway .

It's very necessary to categorize problem that studied in Seep/w. In the Dewerige dam case, the problem represent as confined flow to use seep/w effectively its essential to have a clear understanding of some key fundamentals:

A. Darcy law.
B. Basic finite element equation.
C. Define total head.

A. Darcy low :

Darcy low applied in case of saturated flow conditions (Whitaker,1986). As explained in Fig.2.18 and equations below:

$$q = Aki \quad \text{......} \quad (2\text{-}3)$$

$$v = \frac{q}{A} = ki \quad \text{......} \quad (2\text{-}4)$$

Where:

q= specific discharge .

A= cross-section area.

k= permeability .

i = Hydraulic gradient .

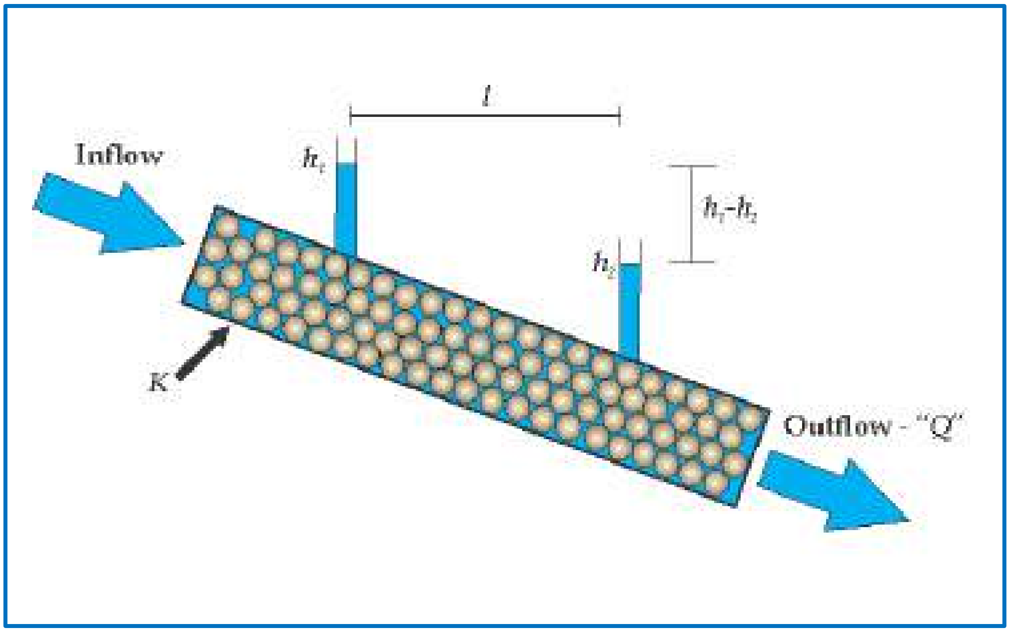

Fig. 2.16 Water flow through soil (Das and Sobhan,2013)

Where:

h_1- h_2= hydraulic gradient.

Q= discharge.

Also, differential equation is used to estimate seepage flow in 2D in transient flow (Pollock, 1988):

$$\frac{\partial}{\partial x}(Kx\ \frac{\partial H}{\partial x}) + \frac{\partial}{\partial y}(Ky\ \frac{\partial H}{\partial y}) + Q = \frac{\partial \emptyset}{\partial t} \quad \text{(2-5)}$$

Where:

H= total head.

Kx= horizontal conductivity

Ky= vertical conductivity .

Q = flux

ɵ = water content (volumetric) .

t= time

In steady-state flow the equation will be (Pollock, 1988) :

$$\frac{\partial}{\partial x}(Kx\ \frac{\partial H}{\partial x}) + \frac{\partial}{\partial y}(Ky\ \frac{\partial H}{\partial y}) + Q = 0 \quad \text{(2-6)}$$

B. Finite element equation / general finite element method applied in seep/w simulation model (Krahn, 2004) :

$$[K]\{H\} = \{Q\}\ldots\ldots(2\text{-}7)$$

Where:
K= nodes material properties .
H= nodes total head.
Q= water flow at node .
Components of finite elements / there are four components to finite element method(Krahn, 2007):

- Geometry: including dimension (length & area), subdivisions of space .
- Material properties: in Seep/w there are two material properties in saturated & unsaturated conditions include:
  - Volumetric water content .
  - Conductivity .
- Boundary condition: total head specified as a boundary condition of problem.
- Time – temporal integration
  - Specified only in transient flow.
  - In steady–state analysis the time will be infinite.

A. Total head (H):
Seep/w is formulated in term of total head, boundary condition is specified according to total head (Goldstein, 1936):

Total head (H) = pressure head (u) + elevation head (h)

$$H = \frac{u}{\gamma w} + h \ldots\ldots (2\text{-}8)$$

2.5.4 The main model parameters in SEEP/W

The following parameters are used to build the numerical model in the SEEP/W software, and explained in Fig. 2.21 (Krahn,2004).

1. Analysis type
   There are two fundamental methods for seepage analysis.
   Steady state analysis
   Transient analysis
   In the steady state seepage analysis, the water pressure and water flow are not change with time. In transient analysis, the pressure conditions are changed with time.

2. The model geometry
   To build the model geometry in order to represent soil conditions there are two main steps, as following:
   a. Create a scaled model of the soil and structure cross-section.
   b. Define the soil regions in the soil cross-section.

3. Define materials
   The materials simulated in the software using one of three types;
   a. Saturated only- the materials are remains saturated in the duration of the simulation.
   b. Saturated/ unsaturated- if unsaturation zones are expected during simulation.
   c. Interface- using for zero hydraulic conductivity materials.

4. Assign Boundary Conditions
   In Seep /w, two types of boundary conditions can be specified;
   a. H (Head); the difference in head between downstream and upstream.
   b. Q (Total Flux) ; the quantity of water passing through the soil by seepage.

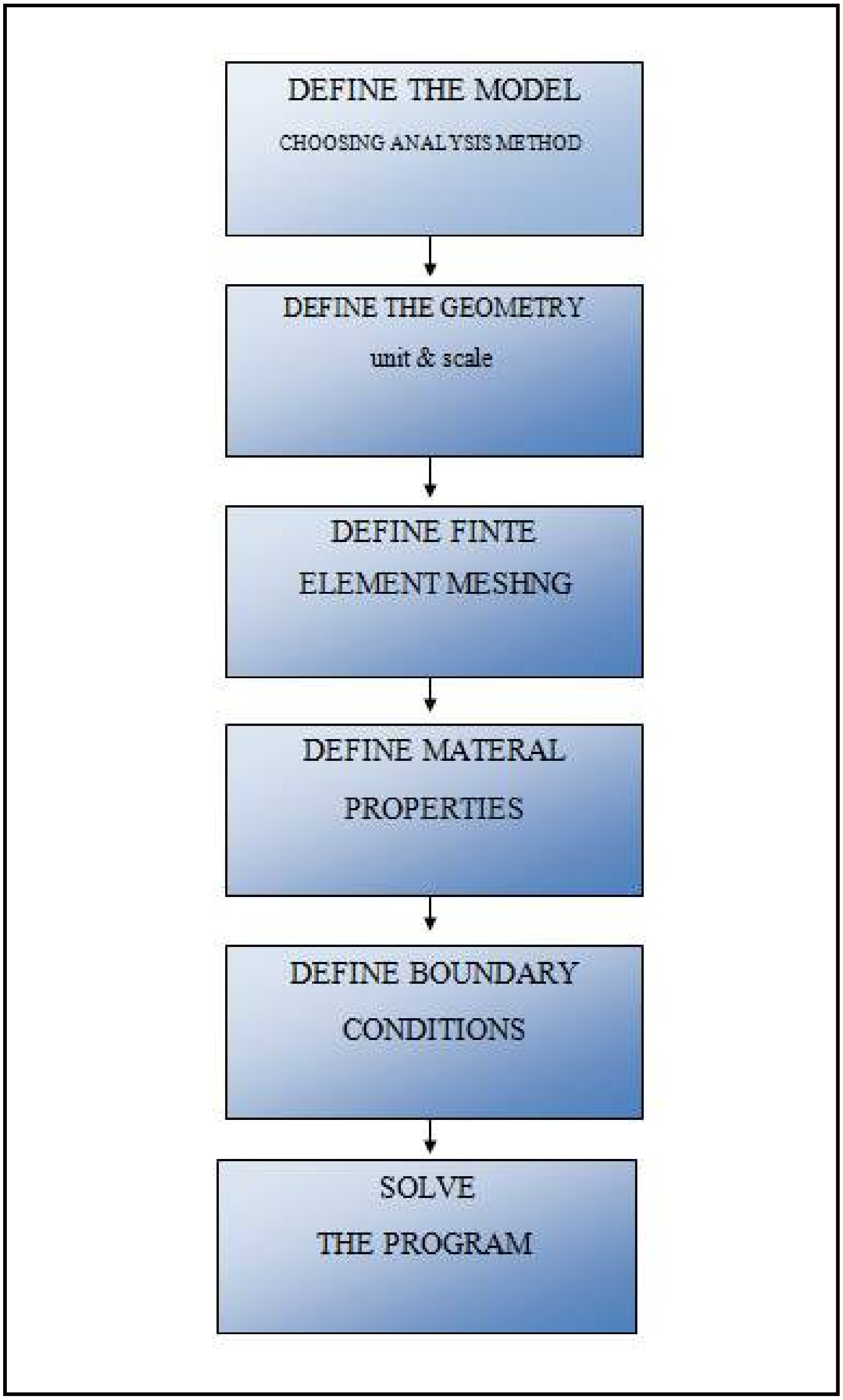

Fig. 2. 17 Main components to create Seep /w model

2.5.5 Seep/w Results Analysis

When the software solves the problem, the results must analyzed and make conclusions;

The seepage analysis used to solve three essential variable requirements:

a. Calculating flow rate.
b. Gathering hydraulic data for determining factor of safety against piping.
c. Use as apparent analysis for slope stability estimation.

In this study the first two items were studied in chapter three.

2.6 Calculating the factor of safety against piping

The downstream toe of any dam is the most critical area for blow out, piping and excessive seepage. The Seep/w can be used to compute the factor of safety by indirect method. This done by studied the finite element nodes and the average of hydraulic gradient over the entire surface of required location. Factor of safety against vertical piping computing by the equations (Duncan, 2000) (2-8 and 2-9);

$$FS_{EXIT} = \frac{gravitational\ pressure}{Seepage\ pressure} \qquad \text{(2-8)}$$

$$FS_{EXIT} = \frac{\gamma\ sub}{i\ \gamma w} \qquad \text{(2-9)}$$

Where:

γ_{sub}= submerged unit weight of the soil (the saturated unit weight minus the unit weight of water).

γ_w= the unit weight of water.

i = hydraulic gradient.

CHAPTER

THREE

METHODOLOGY

CHAPTER THREE
METHODOLOGY

3.1 Introduction

The approach used in this study depend on field work measurements, mathematical equations, reviewing the theoretical studies of dam site, and numerical model to study geotechnical and hydrological problems of dam site, Fig.3.1.

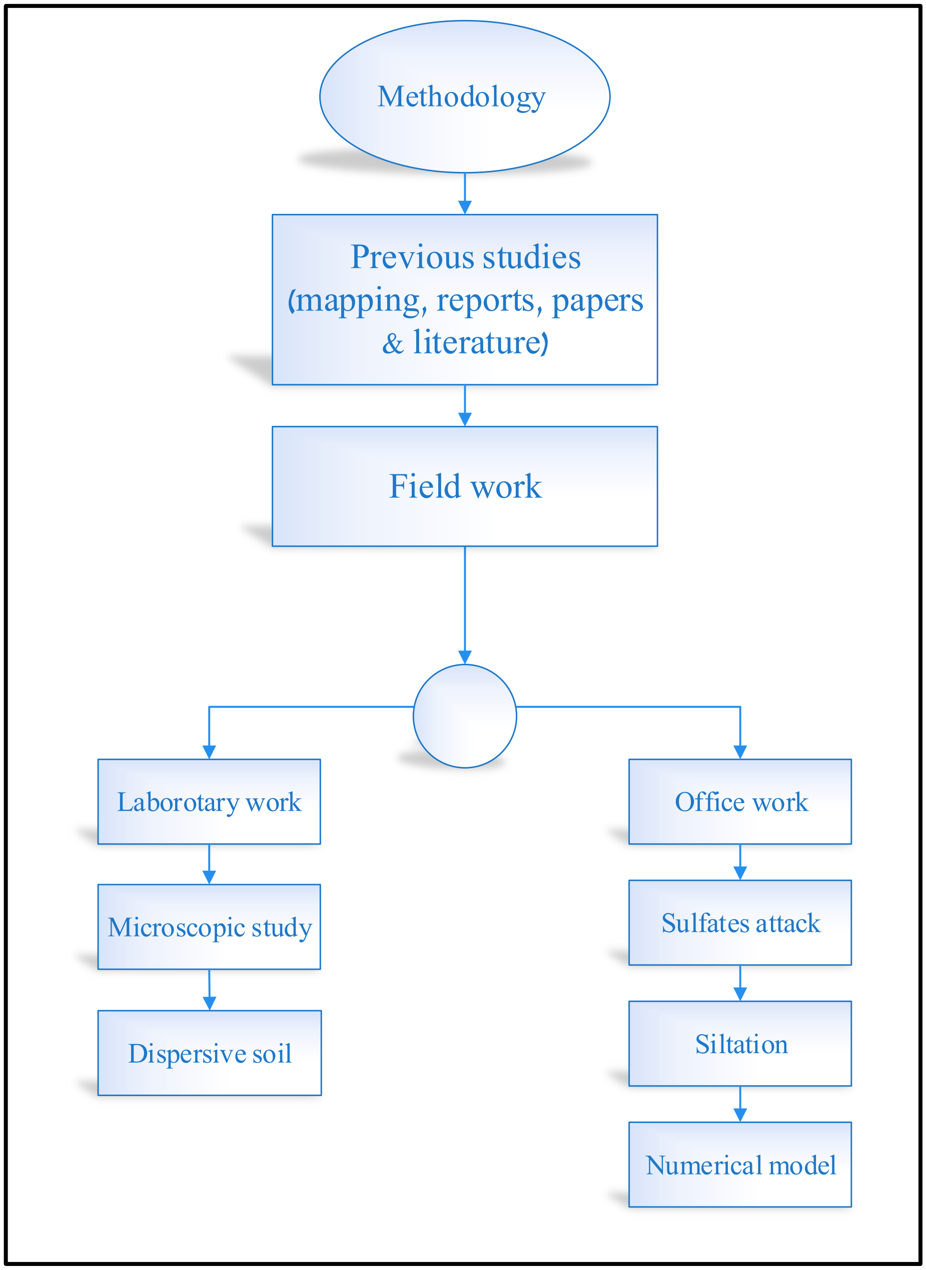

Fig. 3.1 Method of study

3.2 Sulfate Attack in Dewerige dam

Study sulfate attacks in Dewerige dam depond on field survey and optical identification, according to the procedure which explained in following flow chart Fig.3.2.

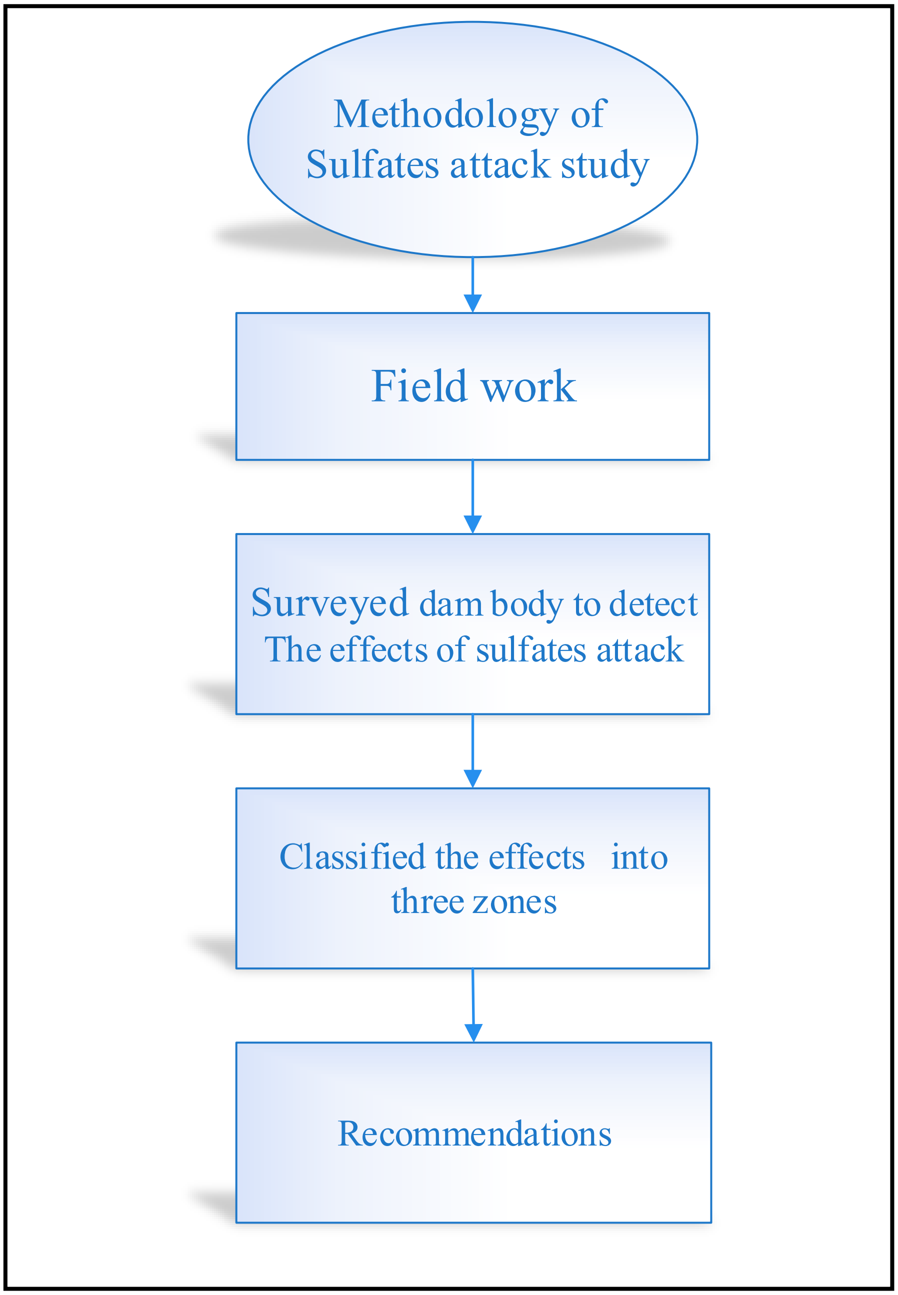

Fig. 3.2 Procedure of sulfates attack study

3.3 Dispersive Soils

Dispersive soil study included: field survey to dam shoulders and laboratory test to detection degree of dispersion in soil samples. Fig. 3.3 show the the procedure of dispersive soil study in Dewerige dam shoulders.

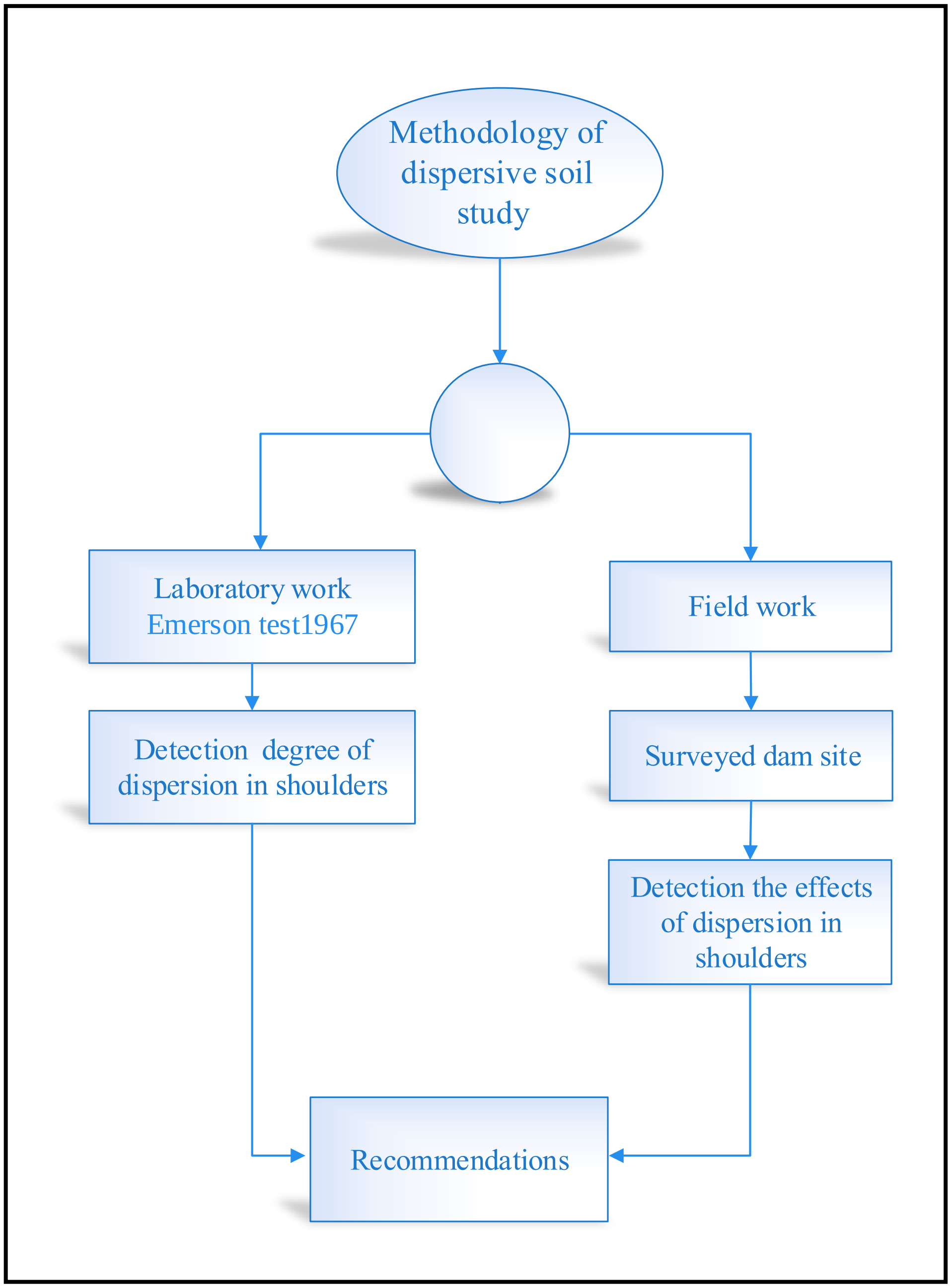

Fig. 3.3 Procedure of dispersive soil study in Dewerige dam

3.3.1 Identify dispersion of soil in dam shoulders

Classification of dispersion class in soil of Dewerige dam shoulders:
The procedure of used test (direct test, Emerson 1967) as illustrate in Fig.(3.4, 3.5, 3.6, 3.7 and 3.8) and procedure :

1. Crushing dispersive soil sample using crushing device.
2. Sieving the sample by sieve 4.75mm diameter (sieve no.4) and measuring the weight.
3. putting the sample in clean plate.
4. adding distilled water to the sample.
5. leaving it about two hours.

Fig. 3.4 Crushing soil sample

Fig. 3.5 Sieving the sample

Fig. 3.6 Measuring the weight of the sample

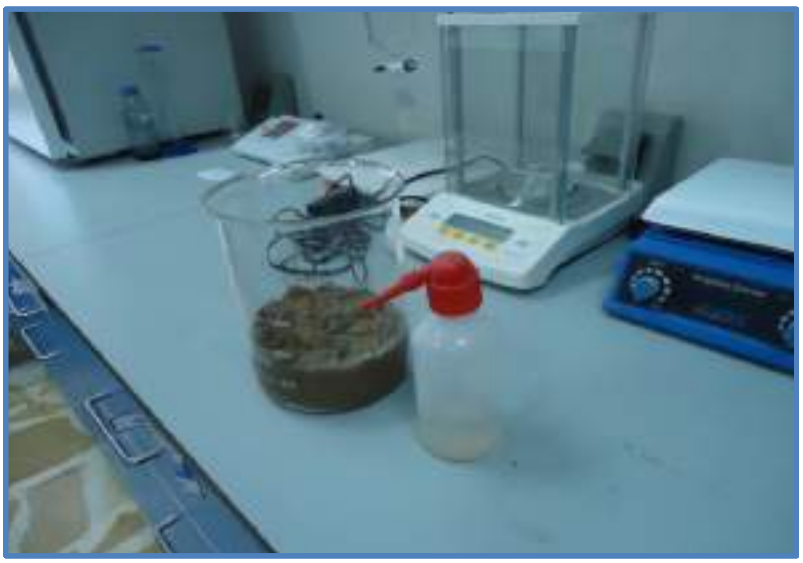

Fig. 3.7 Adding distilled water to the sample

Fig.3.8 Soil sample after about two hours

3.4 Microscopic Study

Dino capture Microscope (version 1.4.0.B) is used to study mineralogy of collected soil samples, Fig. 3.9.

Fig. 3.9 Microscopic study of soil sample

3.5 Method used to calculate siltation in reservoir of Dewerige dam

A / Estimate siltation volume in dam reservoir by creation two layers in Surfer software represent the initial elevation of reservoir and siltation elevation and calculate the difference between them which represent the volume of total siltation in reservoir, Fig. 3.10 and 3.11:

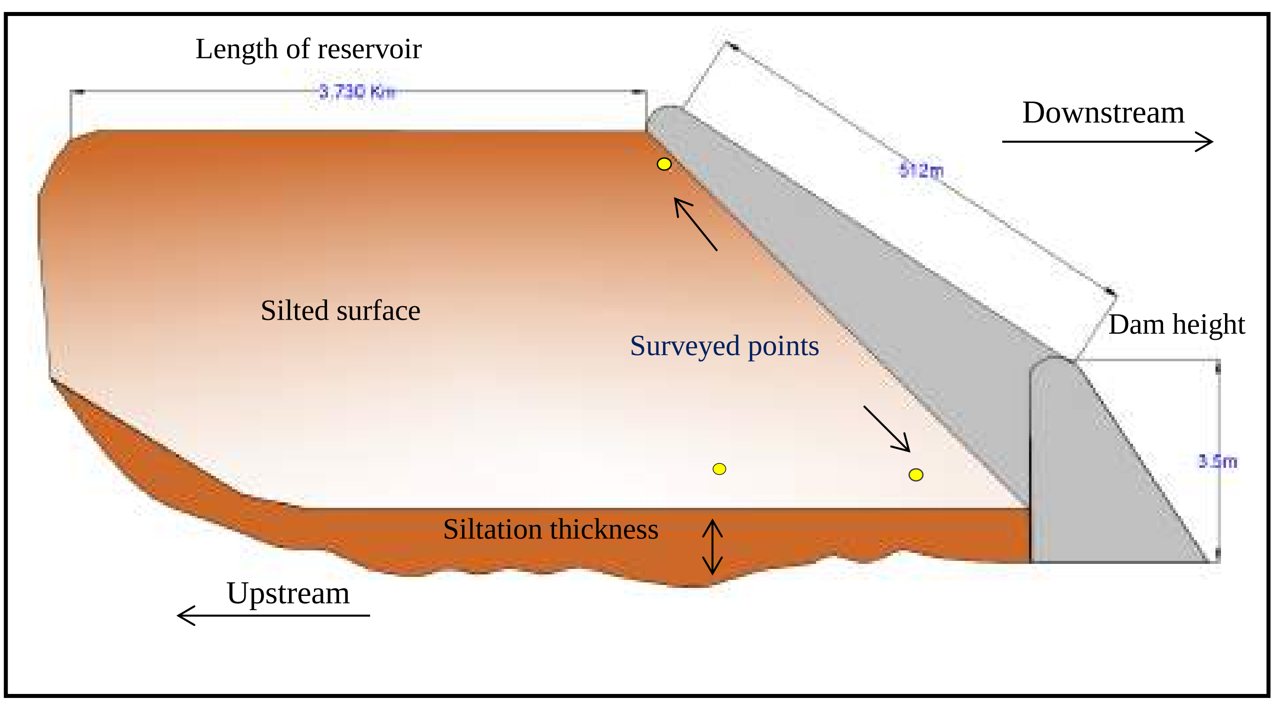

Fig. 3.10 Calculate siltation in reservoir of Dewerige dam

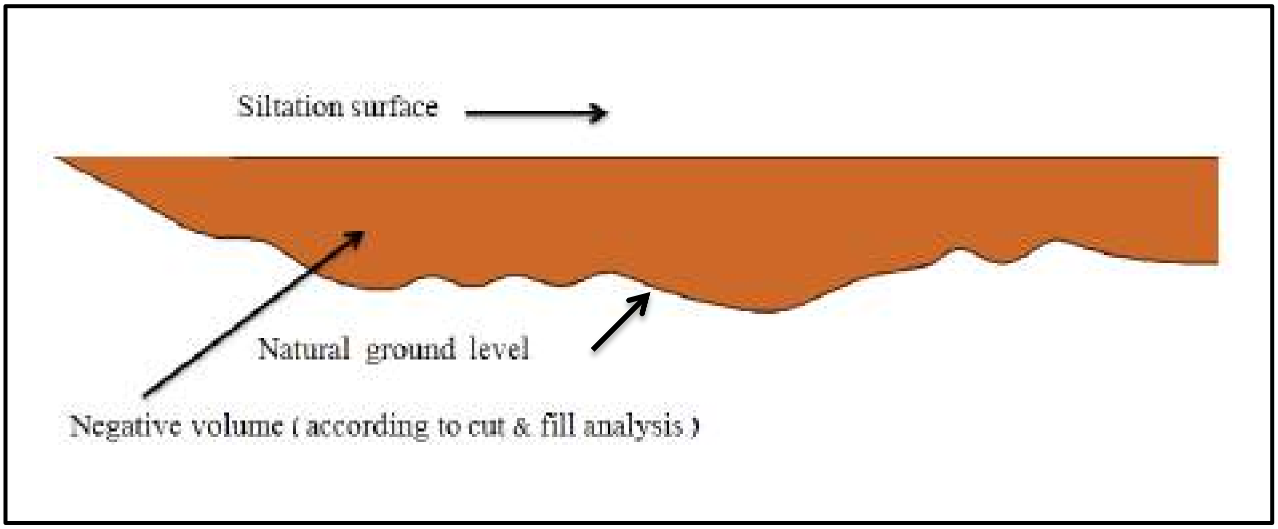

Fig. 3.11 Analysis of reservoir elevation

B / Procedure of siltation study :

1. Field work /visiting dam site in draught period to able to surveyed some points at silted surface by GPS and measuring tape.

2. Using initial survey data, which provided by (Ministry of water resource /center of studies & engineering designs, 2011).

3. Software process including :
   - Using the initial survey data to create grid data (grid1) in Surfer 12 software.
   - Using GPS coordinates & elevation of surveyed point to create grid data (grid 2 siltation horizontal plan).
   - Using volume option in Surfer to calculate difference between two surfaces (grid 2 - grid 1= grid 3), grid3 represent siltation volume in Dewerige dam Fig.3.12.

C / Engineering calculation of reservoir / after calculate siltation volume in reservoir there are important factors have to calculated such as: rate of sediments, economic life time and sediment yield (Tigray,2006) as explained in the following equations:

Rate of sediment (SR) = silt volume (SV) / age of reservoir (y) ....(3-1)

Economic life time (LE)= reservoir storage capacity(dead) / SR...............................(3-2)

Sediment yield (SY) = silt volume (SV) × dry bulk density (DBD)...........................(3-3)

3.6 Redrawing reservoir map

Based on topographic map (base map, CAD file) the reservoir map has been drawing by using software according to the following procedure Fig.3.12, (as explained in details in chapter four):

Fig. 3.12 Software are used

Procedure of redrawing reservoir map:

- Base map georeferenced using SURFER.
- Exporting the topographic map (base map) CAD file to Google Earth.
- Redrawing contour lines by polyline tool in Google Earth for each contour line in topographic map and save it as KML file.
- KML files exported to TCX to extract coordinates (longitude and latitude) only.
- CVS files exported to Excel, then altitude field added to Excel sheet from base map.
- Using extracted data in SURFER to draw a contour map, which represent natural ground elevation to dam site.

3.7 Field work

1-Field trip (1)

Date: 19-9-2016 .

Objective : investigate the geological condition of the dam site as illustrate in Fig. (3.13, ,3.14, and 3.15) :

Fieldwork equipments : GPS, high resolution camera.

Result : Insitu-tests and observation damages in dam body and reservoir.

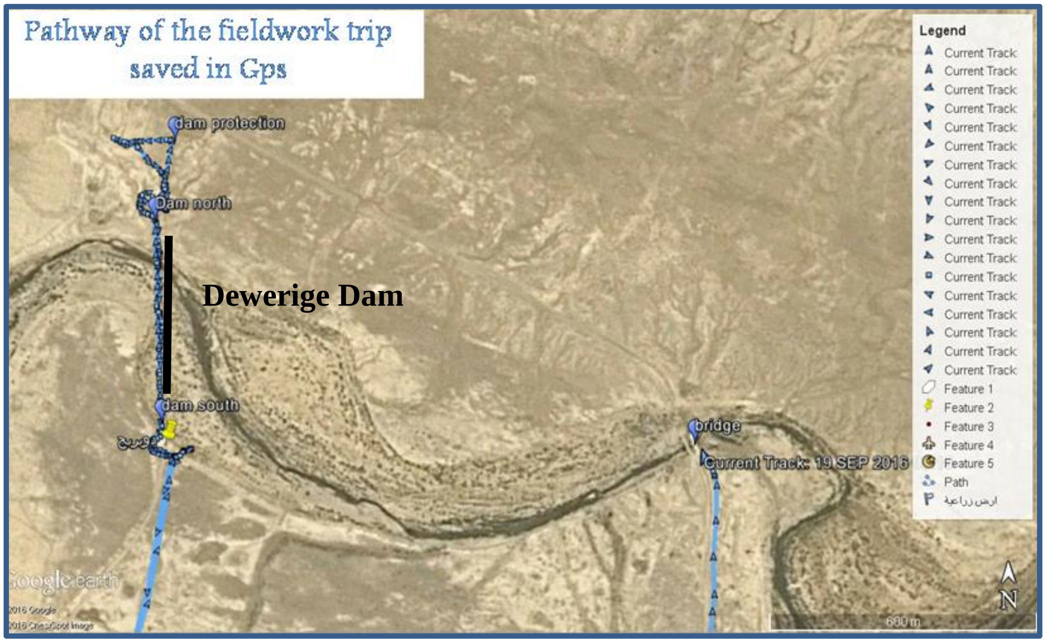

Fig.3.13 Pathway of field work in GPS on Google Earth

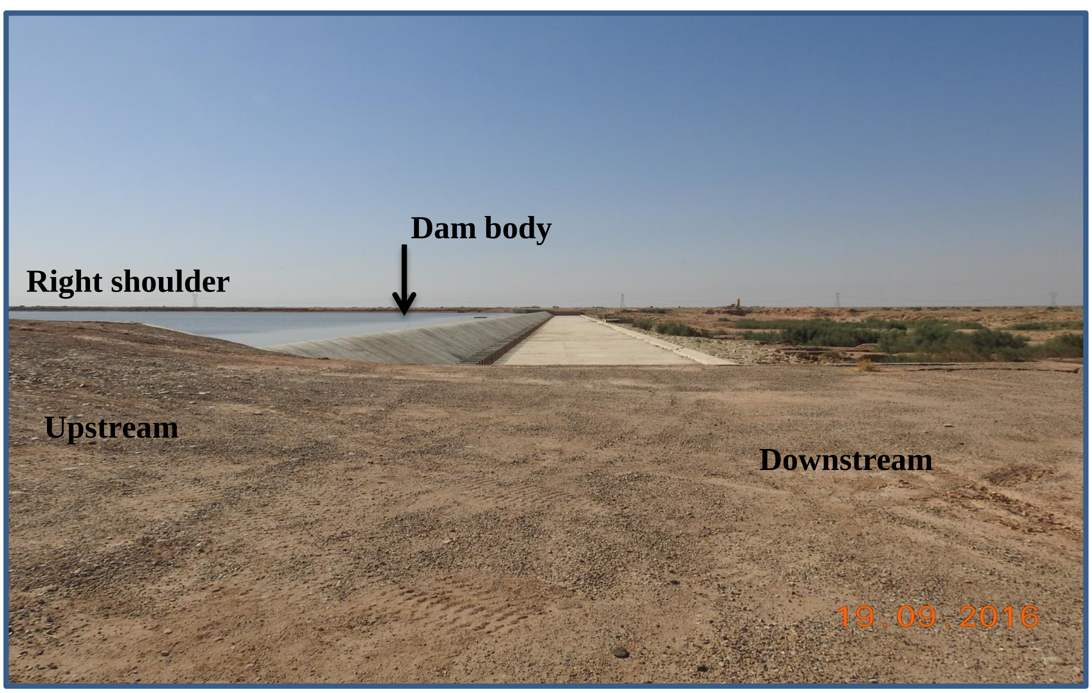

Fig.3.14 Reservoir of Dewerige dam (in Aug. ,2016)

Fig.3.15 Dam site (in Augest,2016)

2-Field trip (2)

Date: 11-1-2017.

Objective : Dam site surveying at draught period to measuring elevation of silt in reservoir, as shown in Fig. (3.16, 3.17, and 3.18) :

Fieldwork equipments :GPS, high resolution camera, measuring tape, plastic bags, marker.

Result : collection soil samples for laboratory test & surveyed point at silted surface.

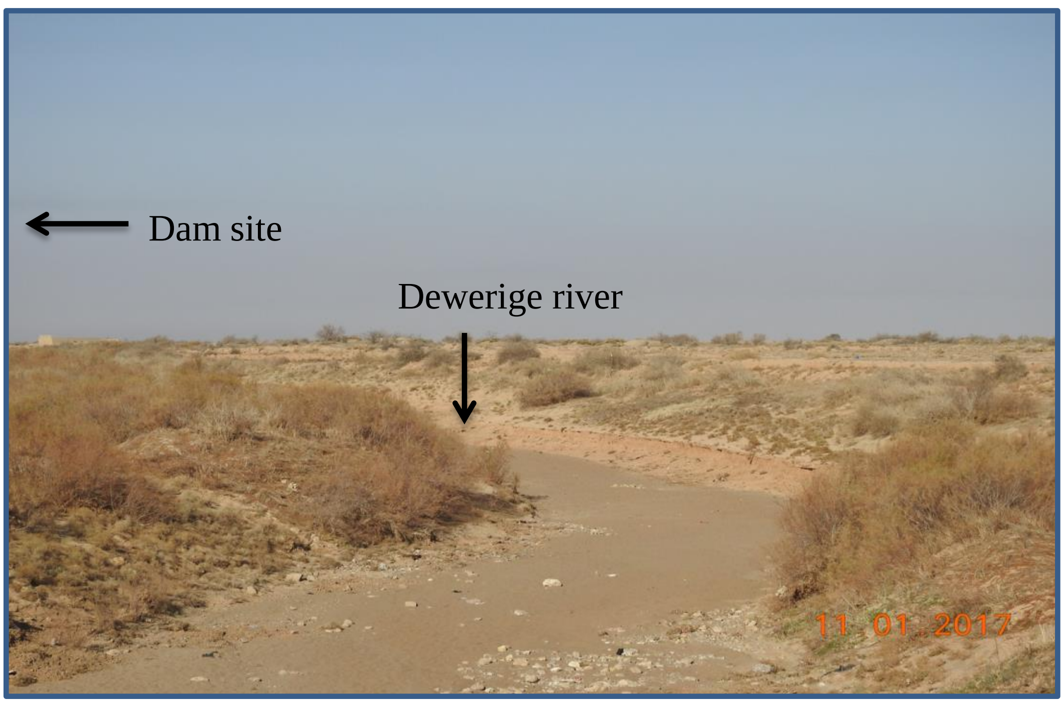

Fig. 3.16 Dewerige river in draught period

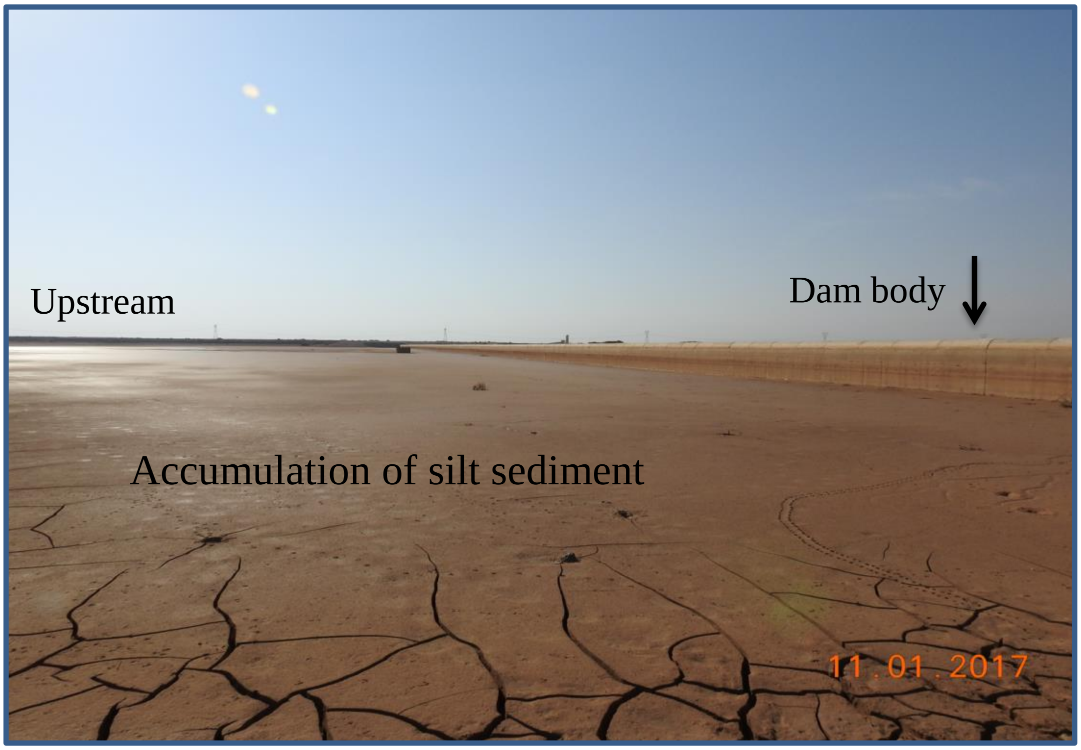

Fig. 3.17 Dewerige dam reservoir in draught period

Fig. 3.18 Collection soil samples

3.8 Modeling by SEEP/W

To create numerical model by using Seep/w the following procedure are used (Krahn,2004) :

a. Geometry

To simplified the cross-section of the dam, Fig. (3.19, 3.20) are drawn as explained:

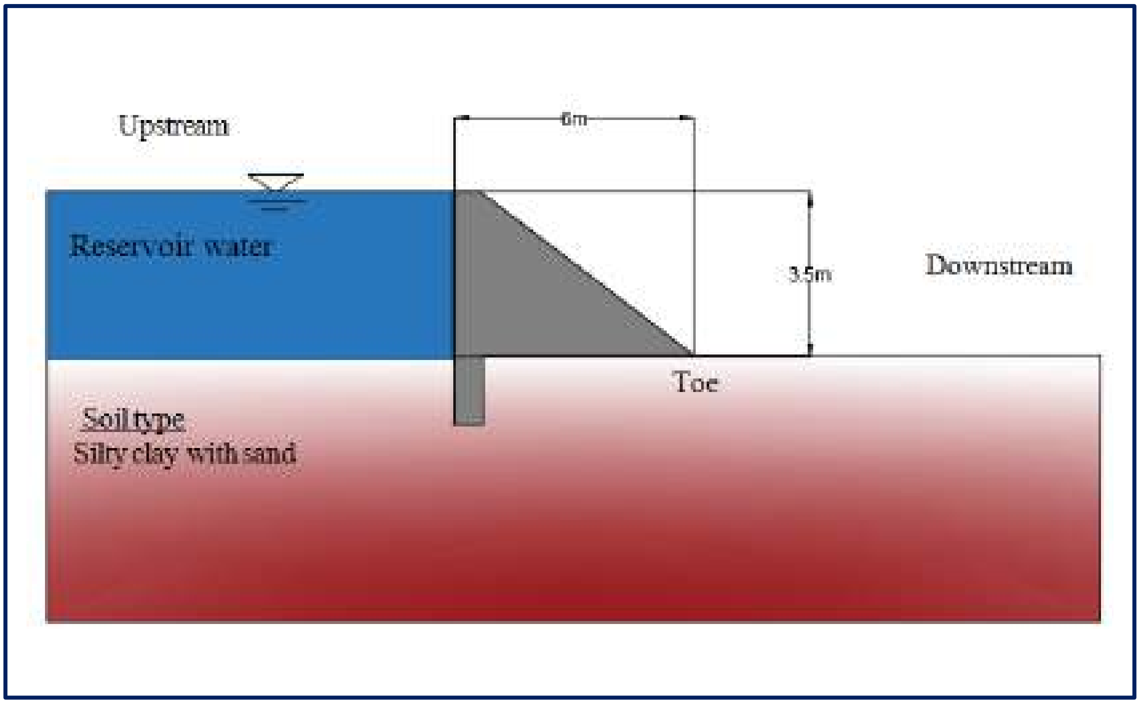

Fig.3.19 Cross-section of Dewerige dam by AutoCAD

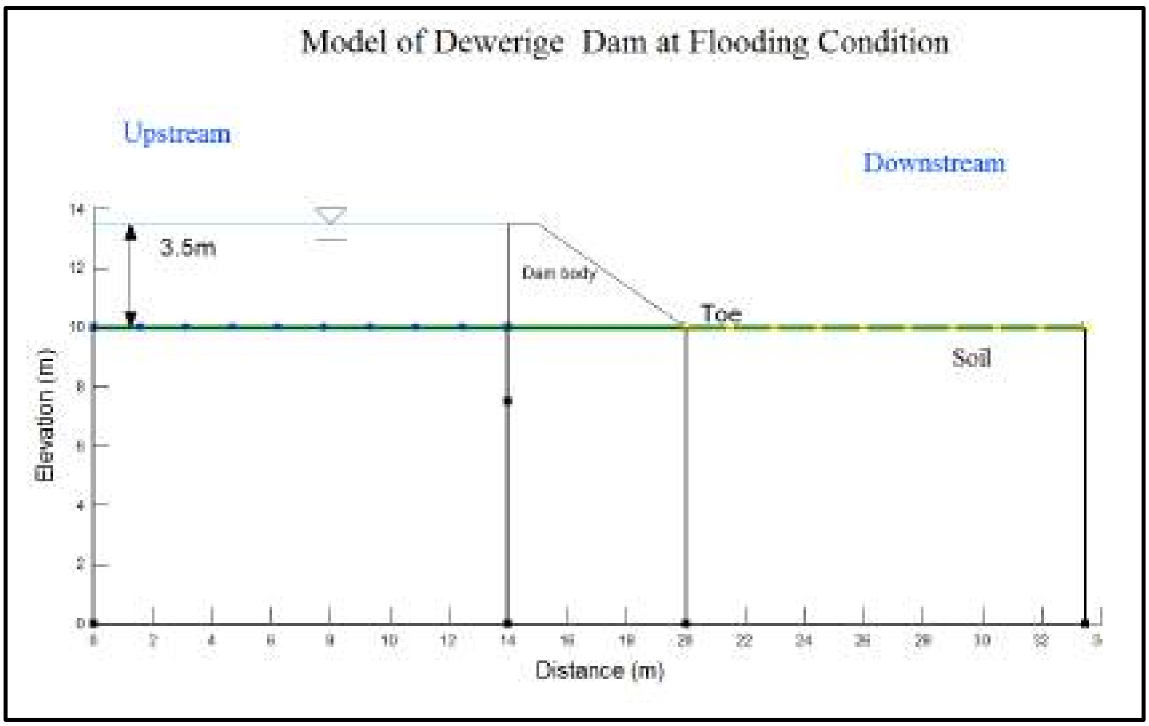

Fig. 3.20 Cross-section of Dewerige dam by Seep/w model

b. Meshing

The meshing of finite element method used in this study comprises 517 nodes and 463 elements with quadrilateral and triangular pattern. Element size approximately 1.5m. The problem geometry consist of three regions represent the basic soil divisions Fig.3.21 :

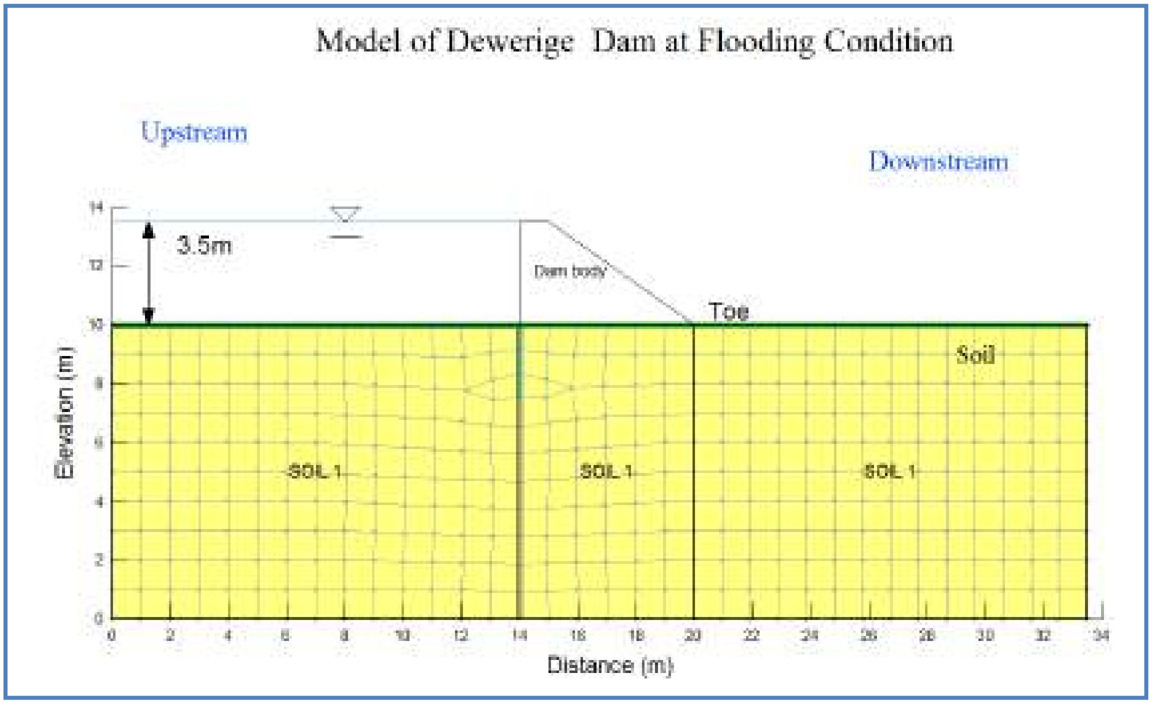

Fig. 3.21 Sketch Cross-section of Dewerige dam and geological material in SEEP/W

c. Material properties

Material properties is a fundamental part of finite element equation for setting of seepage simulation model. Hydraulic parameters are used in Seep/w explained in details in Table: 3.1.

Table :3.1 Hydraulic parameters in Seep/w software

Geological Region	Hydraulic Saturated conductivity (m/day)	Saturated water content	Material type
Region1	0.5002559	0.427	Saturated only
Region2	0.5002559	0.427	Saturated only
Region3	0.5002559	0.427	Saturated only

d. Boundary condition:

Total head define a boundary condition of the Seep/w problem in normal and flooding condition.

e. Outputs of Seep/w model:

Distribution of: pore water pressure, pressure head, total head, hydraulic gradient and flow velocity, in soil foundation of Dewerige dam.

f. Summary of SEEP/W modeling:

- ✓ Steady-state selected as analysis methods in Seep/w.
- ✓ Draw dam body and detect material properties / saturated material.
- ✓ Seepage finite element mesh consist of : 517 Nodes, 463 element and element size 1.5m.
- ✓ The model using steady-state which represent the flooding condition in dam study.
- ✓ boundary condition is defined according to total head, in normal condition and flooding condition.

3.9 The most important software which used :

- ✓ ROCKWARE V.16.
- ✓ SEEP /W V. 2012 .
- ✓ AUTOCAD V. 2016 .
- ✓ BRISC CAD V.2008 .
- ✓ Arc GIS 10.1.
- ✓ SURFFER V. 14.
- ✓ GRAPHER V. 12.
- ✓ VISO.
- ✓ TCX.
- ✓ GOOGLE EARTH PRO.

CHAPTER FOUR

GEOTECHNICAL ASSESMENT OF DAM SITE

CHAPTER FOUR
GEOTECHNICAL ASSESMENT OF DAM SITE

4.1 Geotechnical properties

The geotechnical and hydrological properties of dam foundation and reservoir were analysis to understand the behavior of these materials (Geotechnical investigation report for Dewerige dam site, Missan consultant engineering bureau, 2009) based on:

- ✓ Reviewing literatures and previous geological and geotechnical report.
- ✓ Field work / initial surveying for dam site and reservoir.
- ✓ Six boreholes had been drilled in dam site to depth 20 -25m, five boreholes at dam axis and one in dam reservoir, Fig.4.1.
- ✓ In-situ test / standard penetration test (SPT), observation of groundwater level.
- ✓ Laboratory tests / by selection samples from each boreholes with various depths. The laboratory test based on American Society for Testing and Materials (ASTM) and British Standard (BS), including : index properties, moisture content, grain size analysis, consolidation test, permeability and chemical test, as shown in Table: 4.1.

Table :4.1 The geotechnical test which used in dam site (Missan consultant engineering bureau, 2009)

Test type	Standard
Classification tests	
Liquid limite (L.L), Plastic limite (P.L)	ASTM D-423 , ASTM D-424
Grain size analysis	ASTM D-422
Hydrometer test	
Moisture content (wc)	ASTM D-2488
Unite weight (γwet ,γdry)	ASTM D-2488
Specific gravity (Gs)	ASTM D-854
Engineering properties tests	
Standard Penetration Test (S.P.T)	ASTM D-1586-99
Unconfined compressive strength (q_u)	ASTM D-2166
Consolidation test	ASTM D-2435-02
Permeability Test	ASTM D2434
Chemical tests	
CaCO3 content	ASTM D-4373
Organic content (OM)	ASTM D-2974
Gypsum content	BS1377
Total soluble salts	B.S. 1377: 1990 Part 3

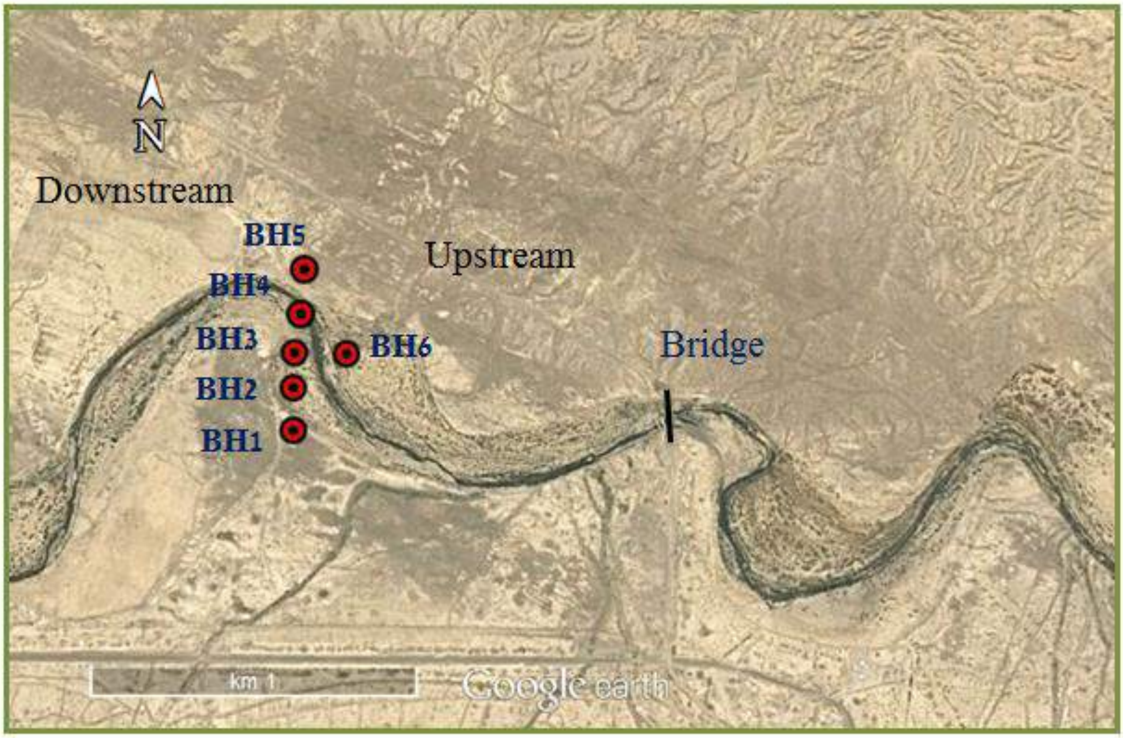

Fig. 4.1 Boreholes location

Table :4.2 Properties of boreholes in dam site (Missan consultant engineering bureau, 2009)

Borehole No.	Depth	Elevation	Samples type
Borehole 1	25m	+ 35m	Undisturbed, disturbed
Borehole 2	20m	+ 29.5m	Undisturbed, disturbed
Borehole 3	20.5m	+ 29.25m	Undisturbed, disturbed
Borehole 4	20m	+ 23m	Undisturbed, disturbed
Borehole 5	25m	+ 33m	Undisturbed, disturbed
Borehole 6	20m	+ 30m	Undisturbed, disturbed

4.2 Geotechnical cross-section

The geotechnical investigation report of dam site explains that the soils in dam site consists of : SM, ML, CL and CH. These soils divided in this study to two main types as the following:

i. Fine grain soil (clay , silt).
ii. Coarse grain soil (sand , gravel).

Each type has a different behavior with dam conditions. In this chapter, the geotechnical properties for each type are studied, and the geotechnical behavior estimated to understand the stability of the dam.

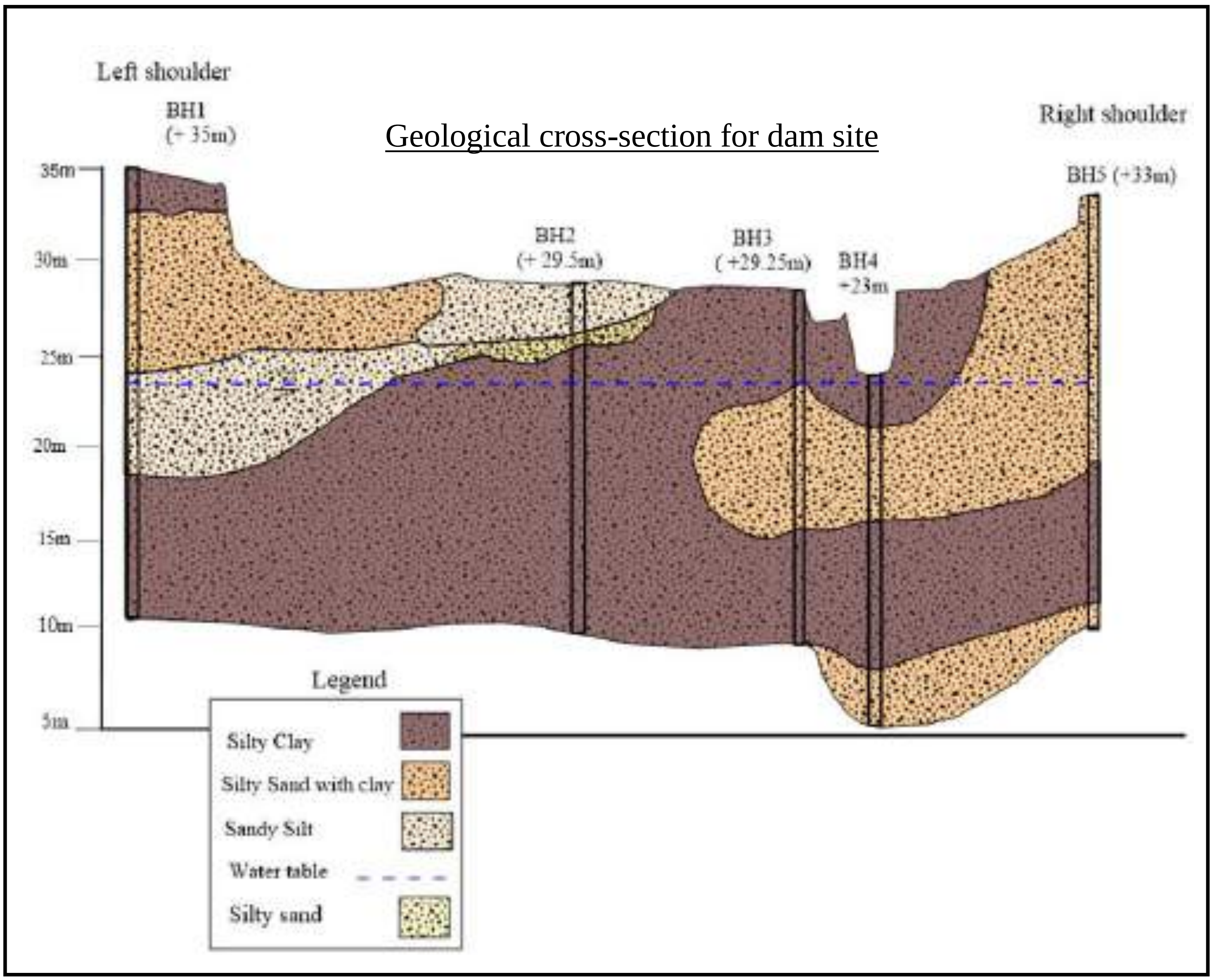

Fig. 4.2 Soil section in the dam site (Missan consultant engineering bureau, 2009)

4. 3 Geotechnical assessment

4.3.1 consistency

a. liquid limit and plastic limit / The values of LL and PL in soils of boreholes with difference depth are explained in Fig.4.3, 4.4, 4.5, 4.6, 4.7 and 4.8.

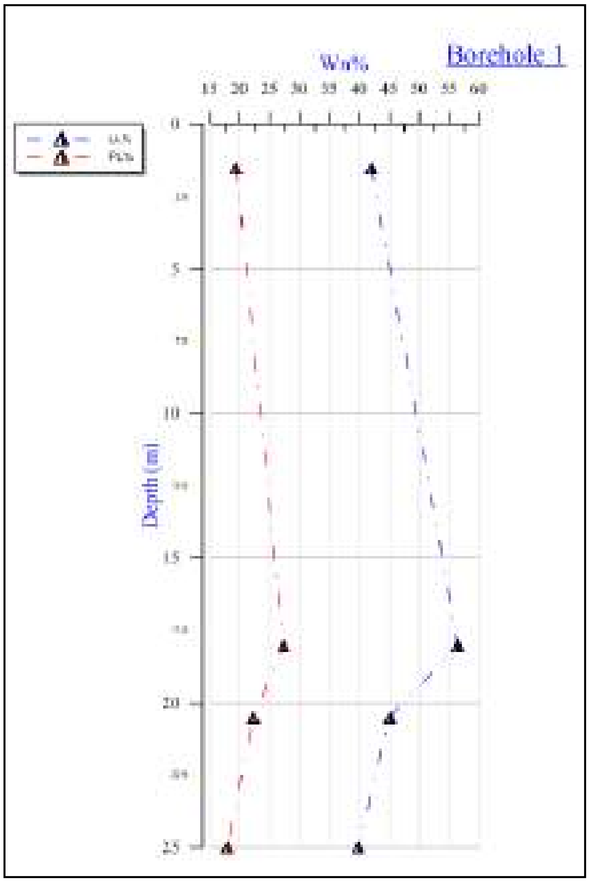

Fig. 4.3 LL and PL in BH1

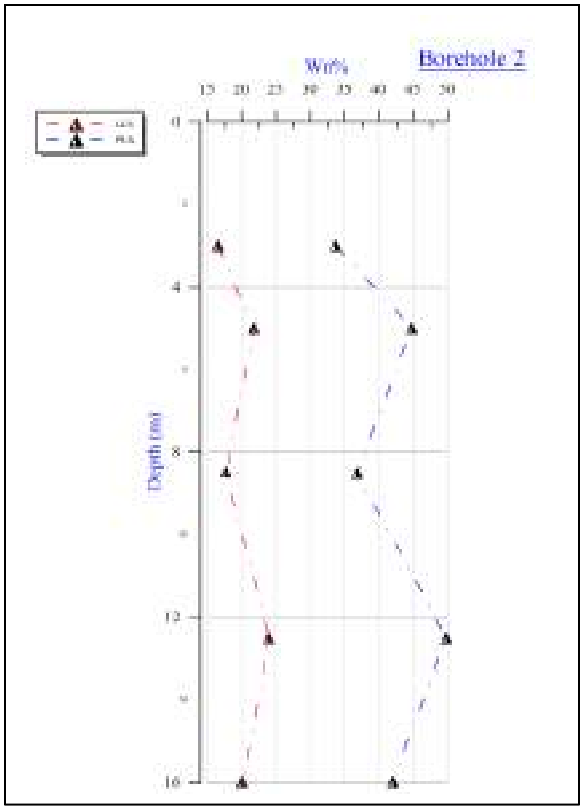

Fig. 4.4 LL and PLin BH2

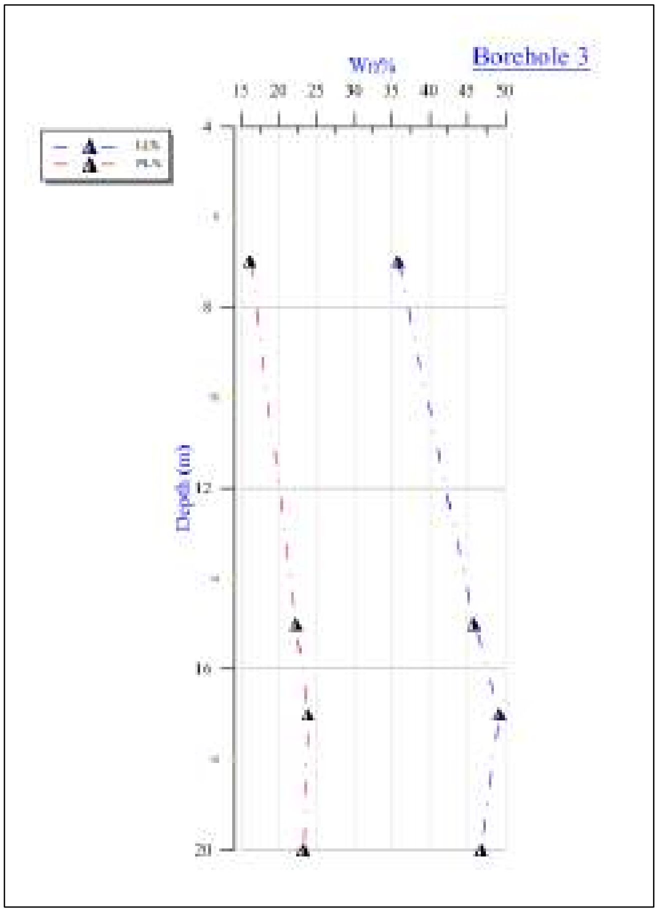

Fig. 4.5 LL and PLin BH3

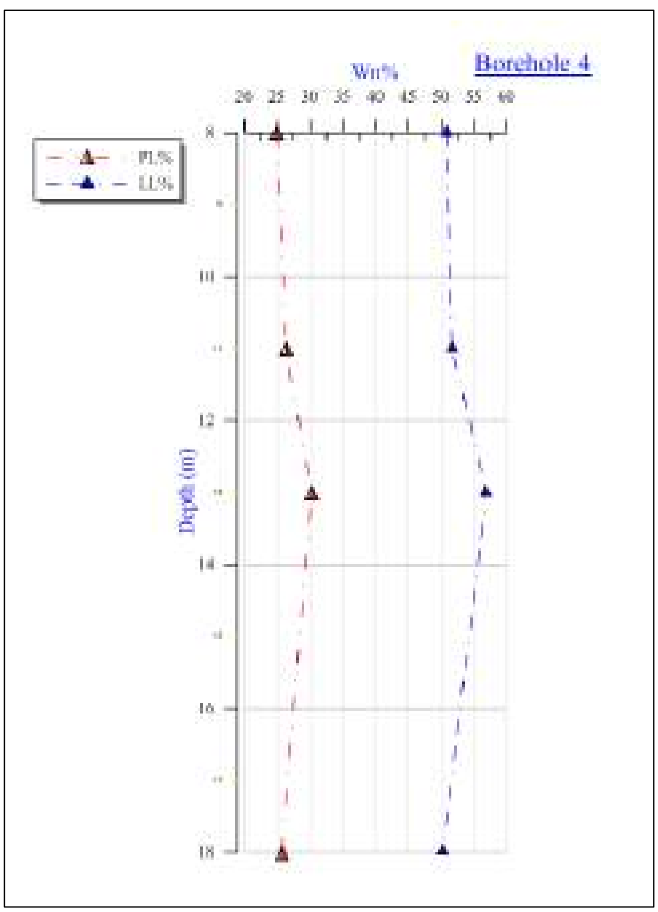

Fig. 4.6 LL and PLin BH4

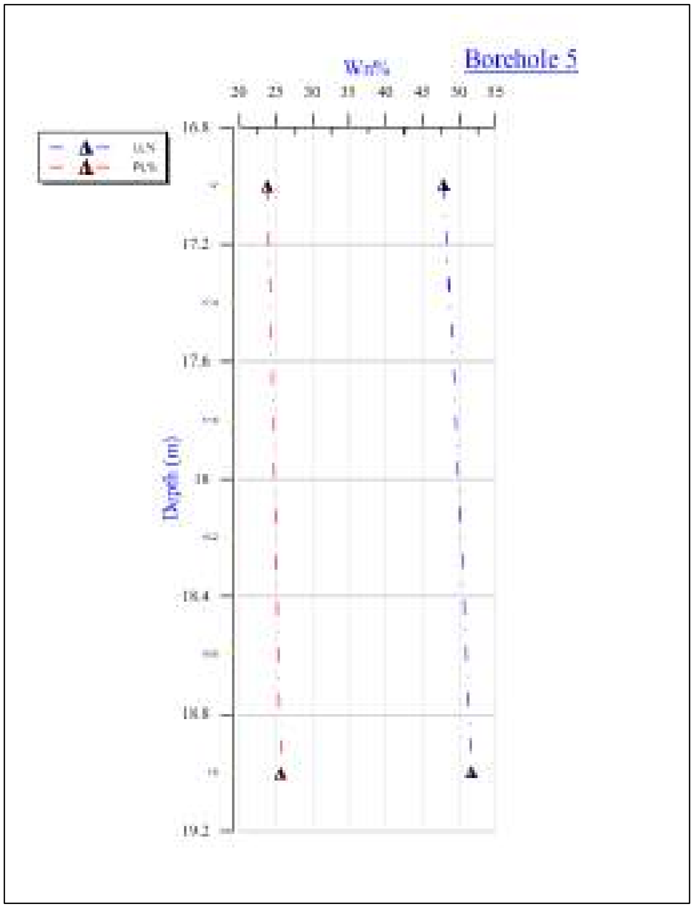

Fig. 4.7 LL and PLin BH5

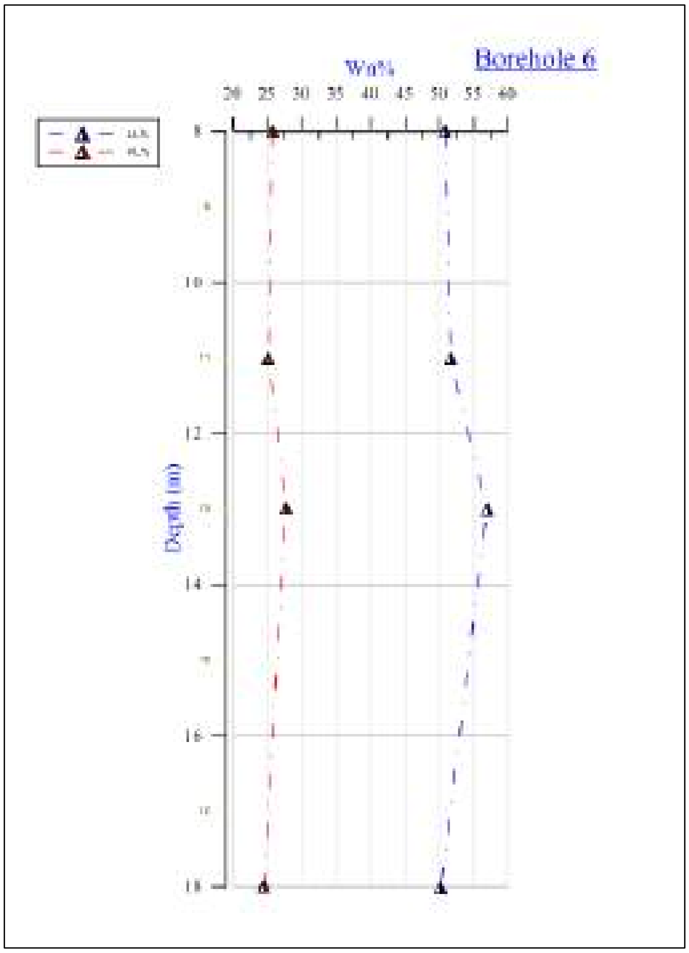

Fig. 4.8 LL and PLin BH6

b. Plasticity chart

Results of Atterberg limits for samples with difference depth based on (ASTM D-4323 and ASTM D-4324) explained in plasticity charts below Fig.4.9, 4.10 and 4.11) :

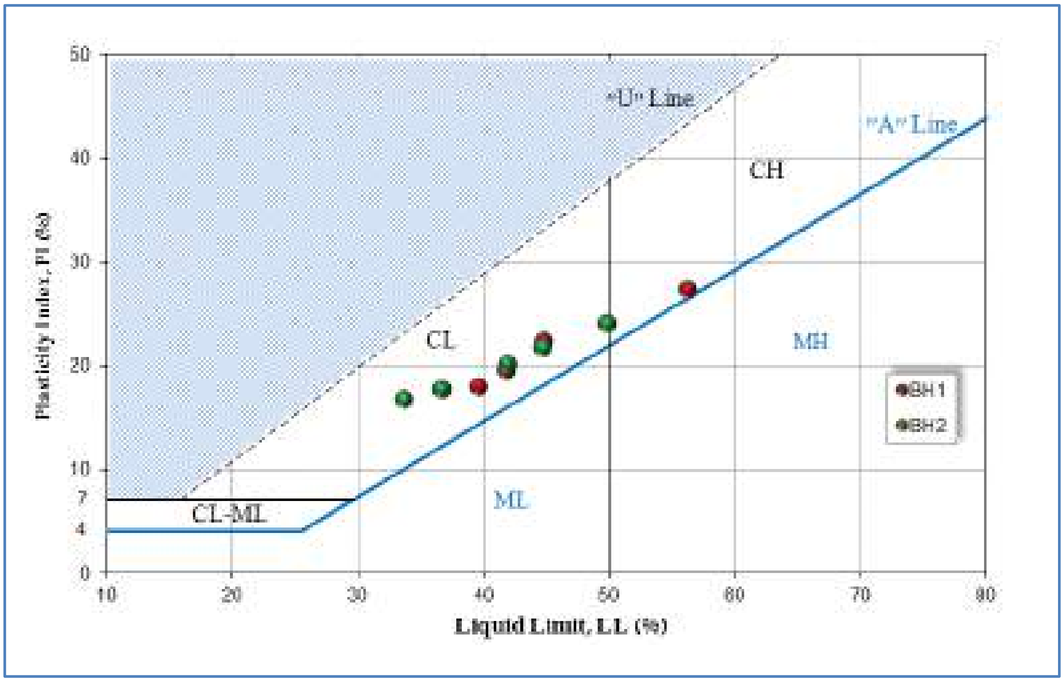

Fig. 4.9 Plasticity chart in BH1 & BH2

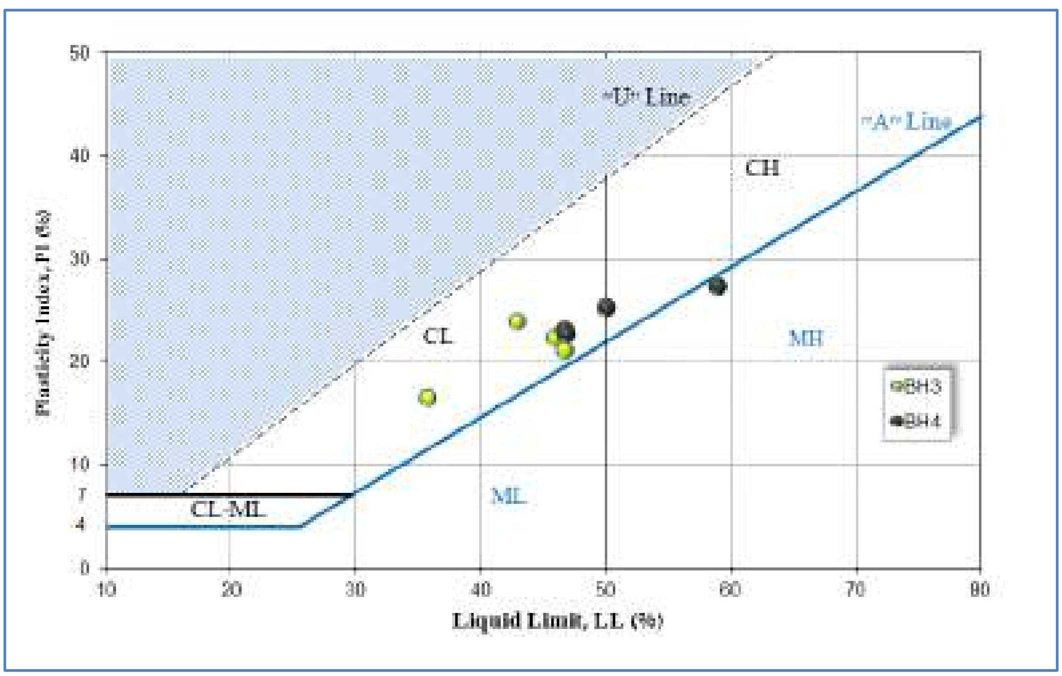

Fig. 4.10 Plasticity chart in BH3 & BH4

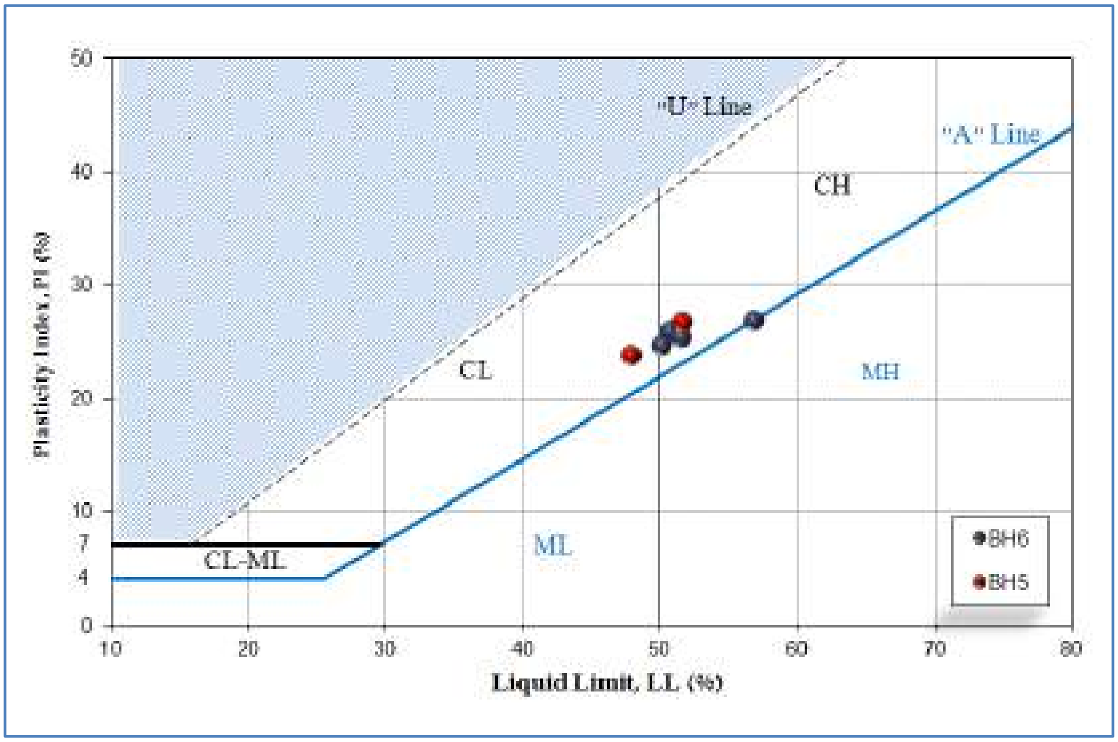

Fig. 4.11 Plasticity chart in BH5 & BH6

Plasticity charts above illustrate the relation between liquid limite and plasticity index in soil samples from different depth of boreholes. Liquid limite values ≤ 50 % , based on position of soil samples in plasticity chart the soil classified as clayey soil of low to medium plasticity (CL).

Table : 4.3 Classification of mineral according to values of LL and PI (Das and Sobhan, 2013)

Mineral type	LL	Pl
Kaolinite	35-100	20-40
Illite	60-120	35-60
Montmorillonite	100-900	50-100
Halloysite (hydrated)	50-70	40-60
Halloysite (dehydrated)	40-55	30-45
Attapulgite	150-250	100-125
Allophone	200-250	120-150

Liquid limits of the soils in study area rang from (33.76% - 59.04%), therefore soil classified as Illite clay soil, which represent a safety soil on engineering structures.

Table: 4.4 Relationship between plasticity index and swelling potential (Das and Sobhan,2013)

Plasticity Index	Swelling Potential
0-15	Low
10-35	Medium
20-35	High
More than 35	Very High

Soil of dam site classified as medium swelling potential soil, because PI values around (17.36 - 23) in all boreholes for 10m depth.

4.3.2 Natural moisture content

Moisture content in soil of dam site difference depth shown in Table:4.5, which close to plastic limits. Values of consistency index (I_C) rang from (0.8- 2.1) at depth 3m for all boreholes that indicate soils of dam site classified as stiff soils based on I_C

Table:4.5 Natural moisture content in boreholes

BH NO.	Wn%	Depth (m)
BH1	24.9	18.5
BH2	14.8	5.5
	19.7	9
BH3	22.8	5.5
BH4	27.5	10
BH5	22.4	17.5
BH6	27.5	8

4.3.3 Specific Gravity (Gs)

The results of specific gravity test in dam site soils show approximate values of specific gravities as illustrate in Table: 4.6

Table:4.6 Values of specific gravity in different depths

BH NO.	Gs	Depth
BH1	2.67	4,18 ,20
BH2	2.68	5.5 ,16
BH3	2.68	15.5 , 19
BH4	2.67	3 , 7, 10.5
BH5	2.69	3 &8
BH6	2.67	1.5 ,8 &14.5

That explain the soil have the same source and composition .

4.3.4 Activity of soil

Activity can be calculated by this formula, which studied by Skempton 1953 :

$$\text{Activity} = \frac{\text{PI}}{\text{Clay Soil \%}} \qquad \text{(4-1)}$$

Activity of clay soils in all boreholes in dam site shown in Table:4.6 compared with standard table of clay activity Table:4.7.

Table: 4.7 Standard table of clay soils activity by (Skempton 1953)

Activity values	Clay activity
<0.75	Clay (Kaolinite)
0.75-1.25	Clay (Illite)
>1.27	Clay (Montmorillonite)

Table : 4.8 Activity of clay soil in all boreholes in dam site

BH NO.	PI %	Clay %	Depth	Activity
BH1	23.89	71.7	8	0.33
BH2	21.93	70.75	9	0.30
BH3	22.81	72.33	7	0.31
BH4	26.15	79.57	8	0.32
BH5	25.15	34.45	7.5	0.73
BH6	26.74	40.32	9	0.66

Since activity in all boreholes range from 0.30-0.66 less than 0.75, so soil type is inactive soil .

4.3.5 Engineering Properties Test

a. Standard Penetration Test (S.P.T)

According to ASTM D-1586-99 standard penetration test were performed for six boreholes and calculated corresponding number of blows ("N" value) as shown in Fig.(4.12, 4.13, 4.14, 4.15, 4.16 and 4.17). N values were corrected by using the equation (Terzaghi and Peck ,1996):

$$N_{corrected} = 15 + 0.5(N \text{ measured} - 15) \quad \text{(4-2)}$$

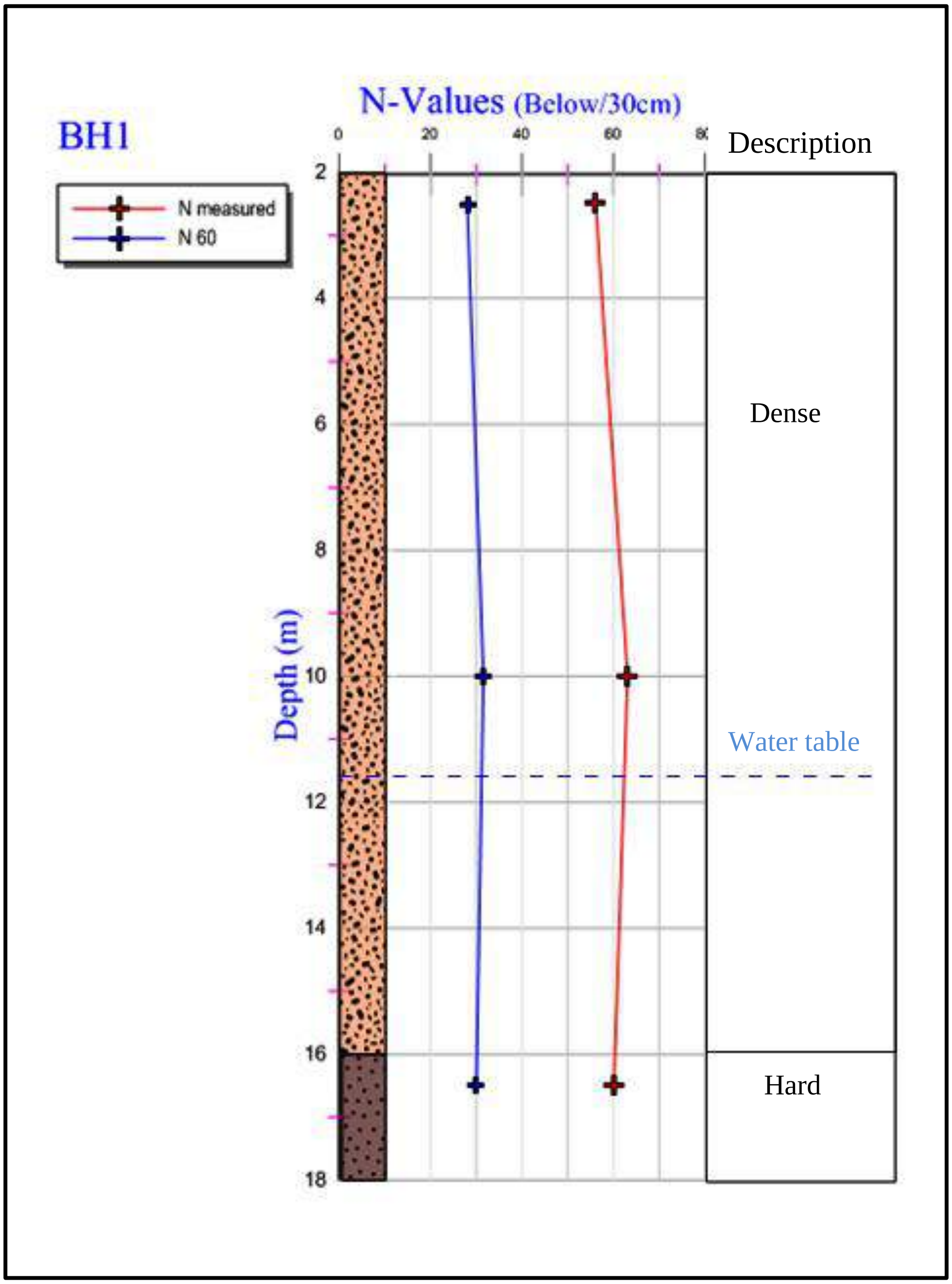

Fig. 4.12 SPT Log in borehole 1

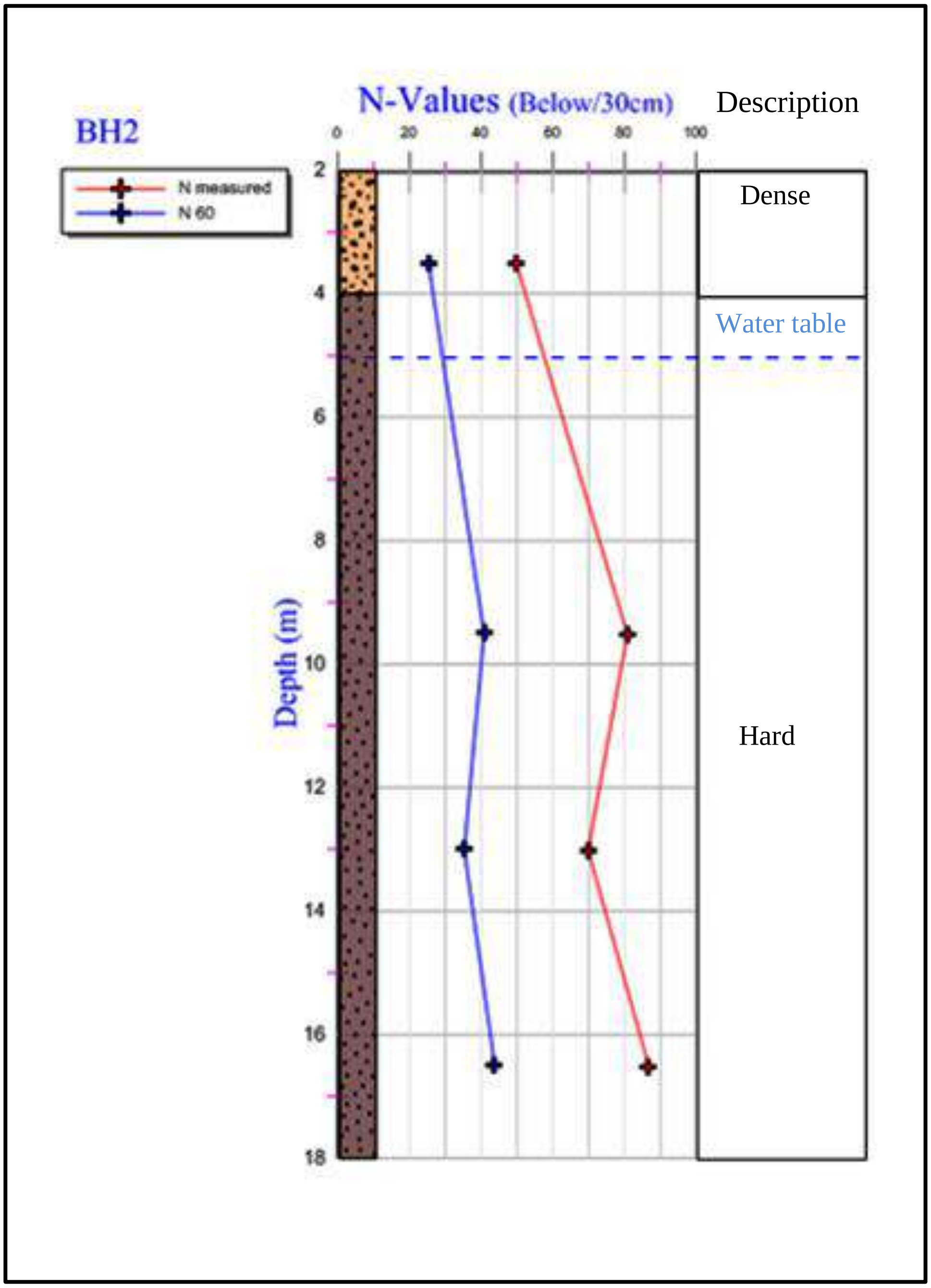

Fig. 4.13 SPT Log in borehole 2

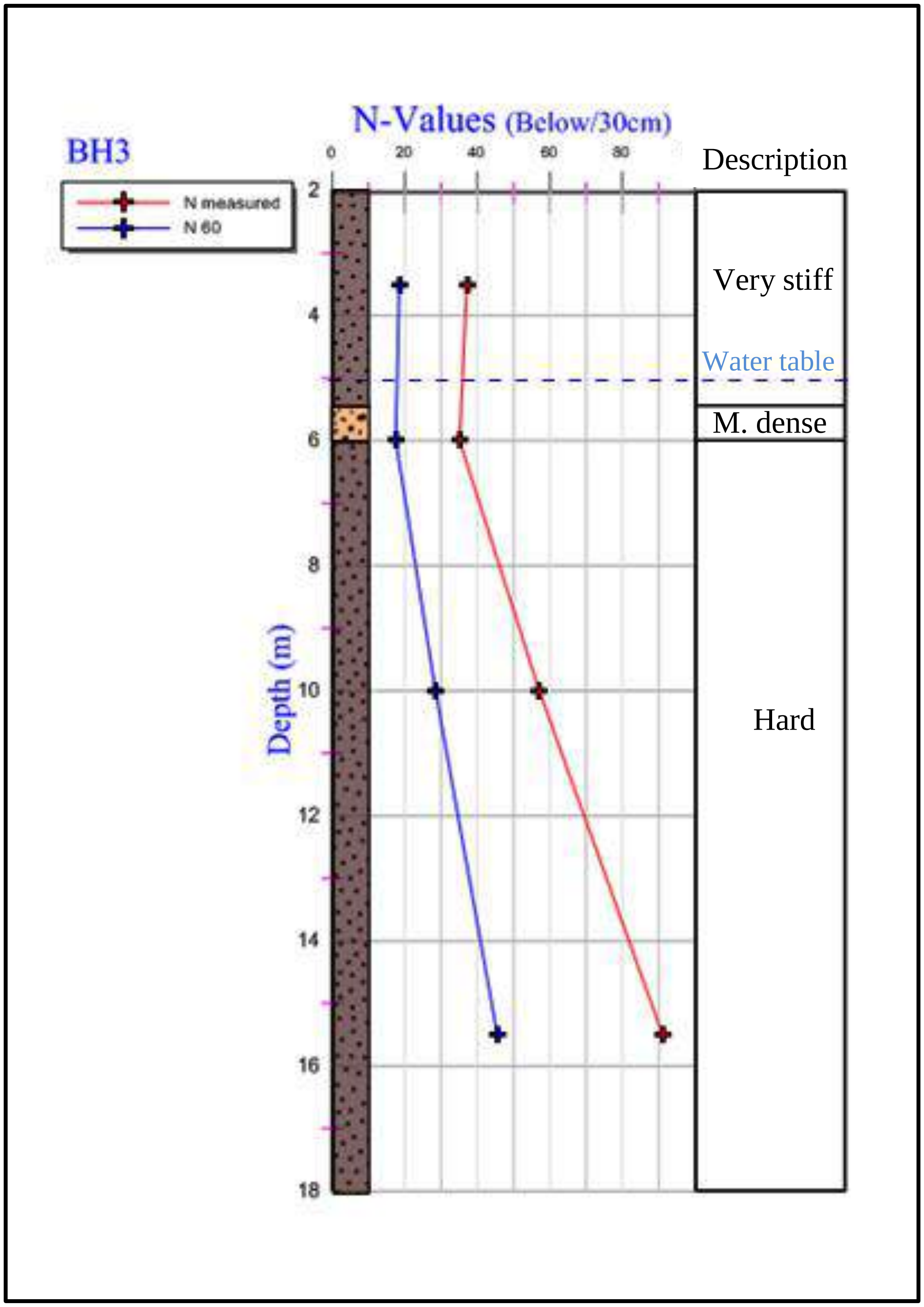

Fig. 4.14 SPT Log in borehole 3

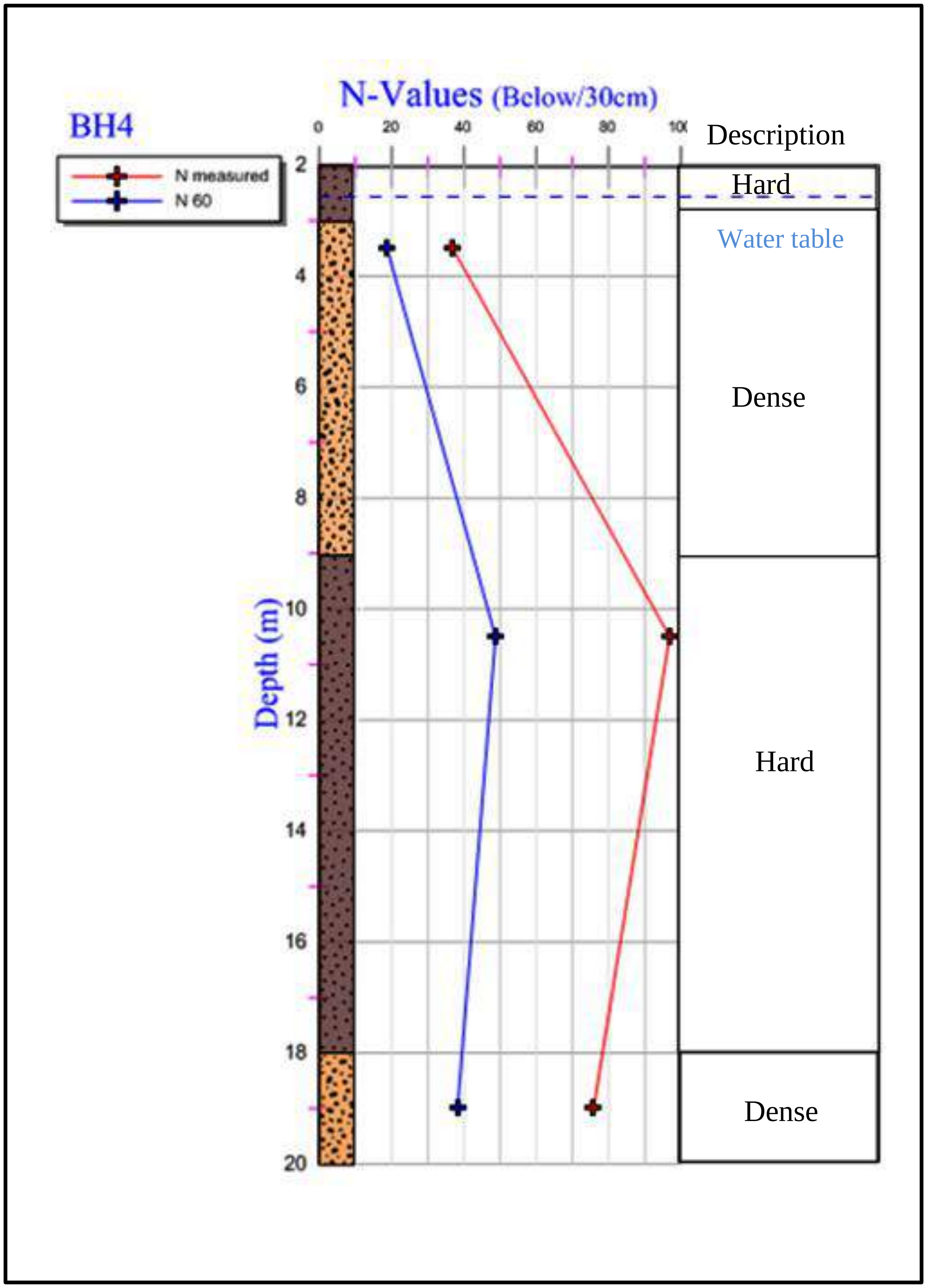

Fig. 4.15 SPT Log in borehole 4

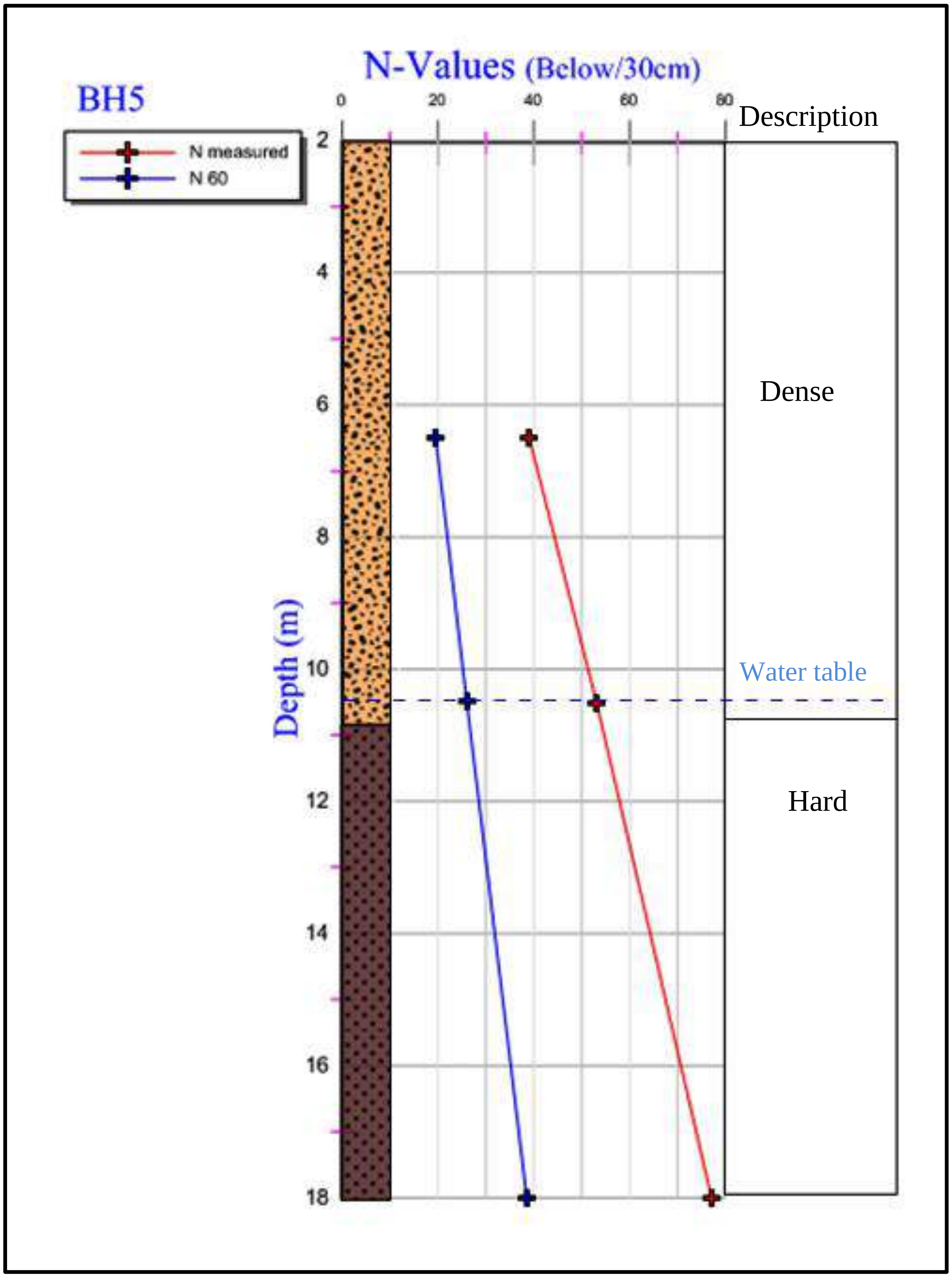

Fig. 4.16 SPT Log in borehole 5

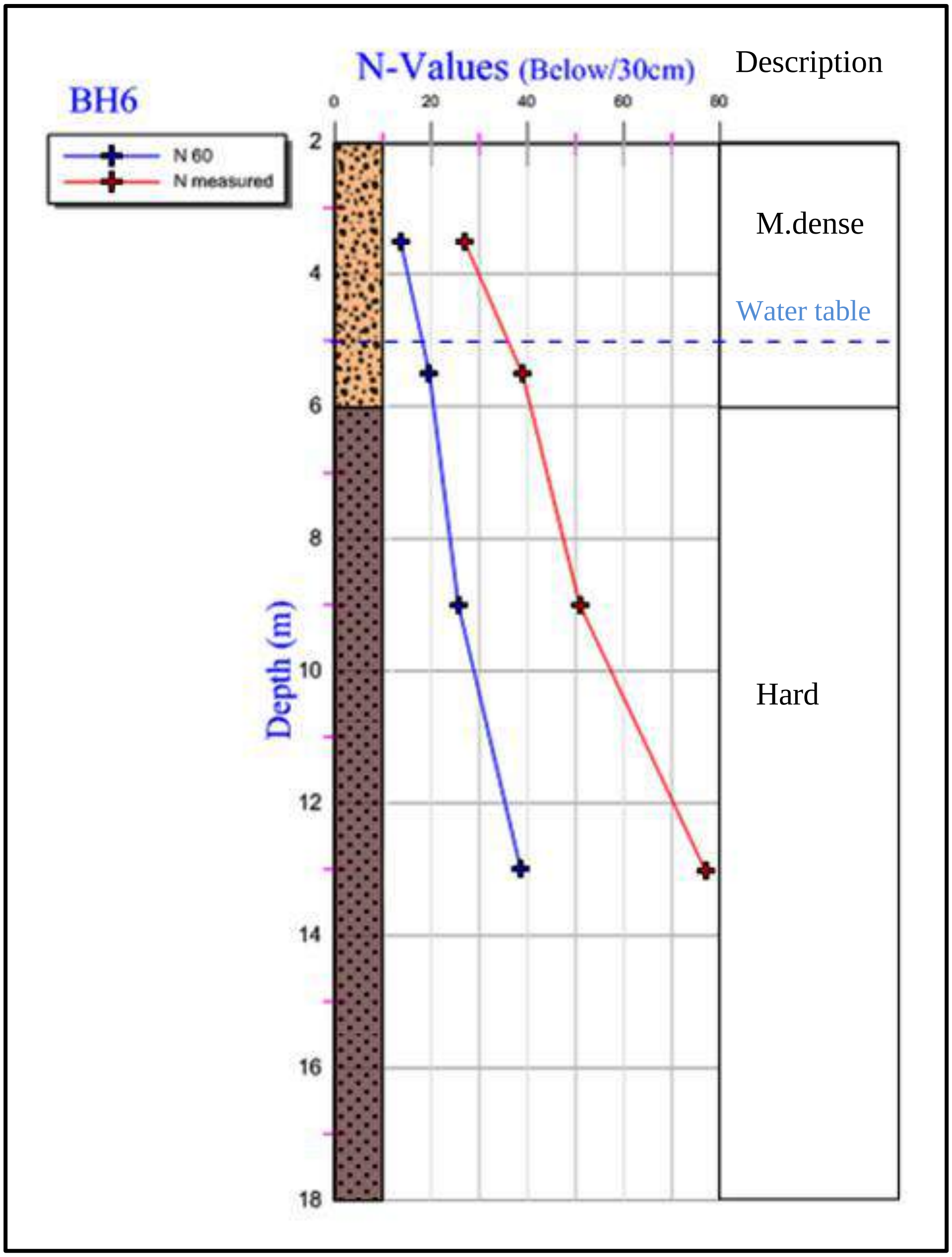

Fig. 4.17 SPT Log in borehole 6

The results of standard penetration test show the soil of dam site is strong, because the average of N-values were more than 50 in sandy soil, and more than 32 in silty clay soil. According to Table of (Rogers,2006) soil of dam site classified as :

- Very stiff – Hard, in cohesive soil.
- Dense-very dense, in non-cohesive soil.

b. Unconfined compression test (q_u) **:** unconfined compression test was performed on eight selected samples from six boreholes at different depth to evaluate the undrained shear strength of the samples. Test procedures were in general accordance with ASTM Test Method D 2166. Result of test are presenting in in Table: 4.9 and q_u classification in Table: 4.10.

Table: 4.9 Unconfined compression strength (q_u) kPa in soil of dam site

BH NO.	**Depth of samples (m)**	**Unconfined compression strength (q_u) kPa**	**C (kPa)**
BH1	18.5-18	205	102.5
BH2	5-5.5	69	34.5
	8.5-9	76	38
BH3	5-5.5	112	56
BH4	9.5-10	240	120
BH5	17-17.5	193	96.5
	19.5-20	212	106
BH6	6.5-8	123	61.5

Table:4.10 Classification of soil according to values of q_u(Terzaghi and Peck ,1996)

Consistency	**qu (kN/m^2)**
Very soft	0-25
Soft	25-50
Medium stiff	50-100
Stiff	100-200
Very stiff	200-400
Hard	> 400

The result of unconfined compression strength **(qu)** in study area range from 69-240 kPa, that's mean consistency of soil is medium in BH2 and range from stiff to very stiff in other boreholes.

c. Consolidation Test

Consolidation test was performed according to ASTM, for different depths of boreholes. The results of consolidation test summarized in Table: 4.10.

$$C_c = 0.2343 \left(\frac{LL\,\%}{100}\right) Gs \ldots\ldots(4\text{-}3)$$ (Nagaraj &Murty,1985)

$$C_r = 0.0463 \left(\frac{LL\,\%}{100}\right) Gs \ldots\ldots(4\text{-}4)$$ (Nagaraj &Murty,1985)

Where:

C_c = Compressibility index

C_r = Recompressibility index

Results of consolidation test are as shown below :

- Initial void ratio (e°/ the maximum value (0.748), and the minimum (0.526), The average of e°) (0.65) which represent a perfect case.
- Compressibility index (C_c) / The results of consolidation test, explain the compressibility index range from (0.103-0.152) in soil of dam site.
- Recompressibility index (C_r) / the results of Cr about (0.008-0.017) that's indicate the soils of dam site have low swelling rates.

Table: 4.10 illustrate Consolidation test parameter

BH NO.	Depth (m)	Consolidation test parameter			
		Initial void ratio (e°)	Compressibility index (C_c)	compressibility index (C_r)	Pre-consolidation (P_c) kPa
BH1	18-18.5	0.672	0.107	0.011	164
BH2	5-5.5	0.632	0.103	0.017	60
	8.5-9	0.526	0.131	0.017	66
BH3	5-5.5	0.609	0.113	0.009	101
BH4	9.5-10	0.748	0.152	0.012	155
BH5	17-17.5	0.598	0.115	0.008	173
	19.5-20	0.730	0.147	0.010	185
BH6	6.5-8	0.748	0.152	0.012	108

d. Permeability

The laboratory test of permeability coefficient (k) based on ASTM D2434.Table 4.11 illustrate classification of soil according to permeability coefficient (k).

Table: 4.11 Description of soil based on permeability coefficient (k) (Terzaghi and Peck ,1996)

Permeability coefficient (k) cm/s	Description of soil permeability
$>10^{-3}$	High
10^{-1} _ 10^{-3}	Medium
10^{-3} _ 10^{-5}	Low
10^{-5} _ 10^{-7}	Very low
$< 10^{-7}$	Impermeable

Maximum value of permeability coefficient (k) recorded in borehole 4. In general permeability coefficient (k) in dam site soil rang from (1.04×10^{-4} cm/s) at depth 15-20m (9.26×10^{-4} cm/s) at depth 10-15m. Therefore soil of dam site represent low permeability soil.

4.3.6 Assessment for cut-off width and location

Cut-off can be defined as wall of impermeable substance, which built under the dam in order to monitoring and reducing seepage and piping under dams toe (Bureau,1977). In Dewerige dam the cut off wall composed of concrete Fig.4.12.

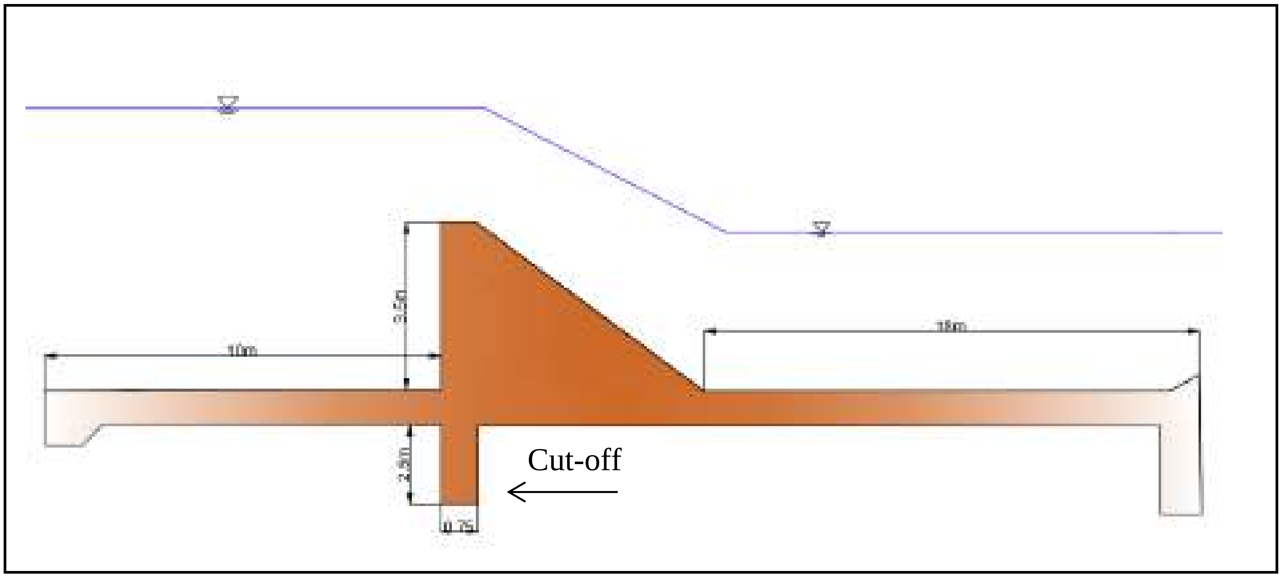

Fig. 4.18 Design of cut-off in Dewerige dam

a- Cut-off width

The perfect width of cutoff in design of small dams calculated by this equation (Bureau,1977):

$$w = h - d \quad \text{(4-5)}$$

where:
w= cutoff width.
h= water head in reservoir.
d= cut off trench depth.

When applied equation (4-5) to find the correct width of Dewerige dam

w = h - d

w =3.5m - 2.5m

w= 1 m

The correct width of cutoff is (1m), in spite of the design width is (0.75m).

b- Assessment for cut-off length

Vertical extent of cutoff should be ended on impermeable bed, To ensure seepage optimum control for example (Bureau,1977) :

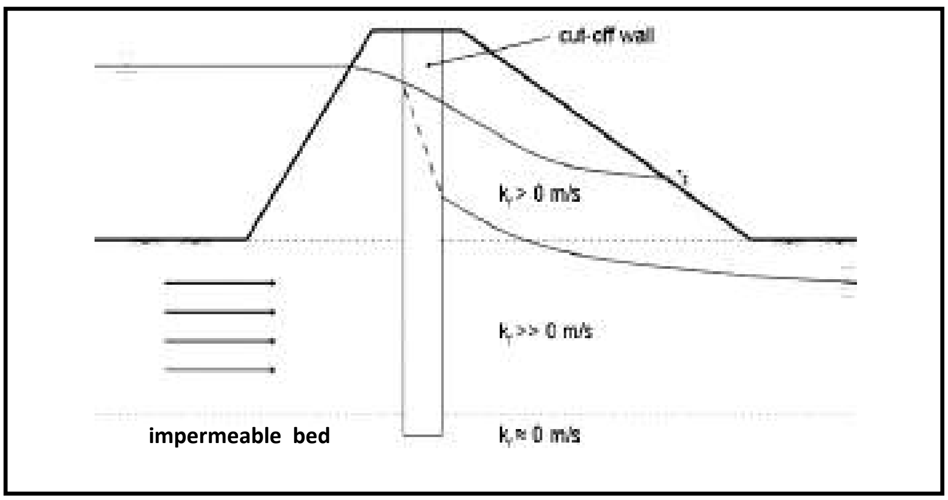

Fig. 4.19 Extent of cutoff through beds (Bureau,1977)

The Fig.4.13 shows the cutoff wall stops at impermeable bed, to limits and controls on length and velocity of the flow lines, which reduces seepage beneath the dam, Fig.4.14 explaine variation in permeability under Dewerige dam.

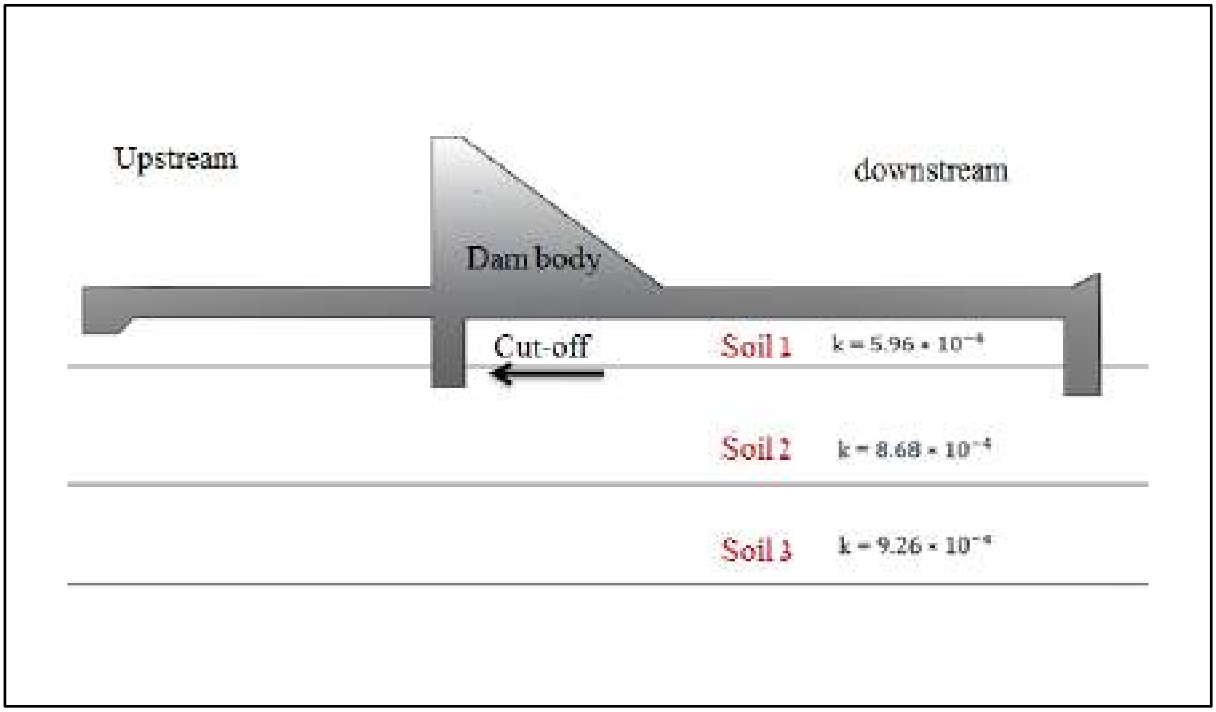

Fig. 4.20 Variation in permeability with depth in Dewerige dam

In case of Dewerige dam, the wall extended through soil1, and stopped at soil2, which had the higher permeability coefficient (k) compared by soil1. Therefore the cutoff wall could not control on flow lines in soil under the dam.

The summery of geotechnical investigation of dam site soils explained in details in Table: 4.12

4.3.7 Chemical Test

The result of chemical test shows that the gypsum content in soil are increase in shallow depth, above water table in granular soil Fig. 4.15. That's mean Dewerige river is the source of gypsum content in soil,

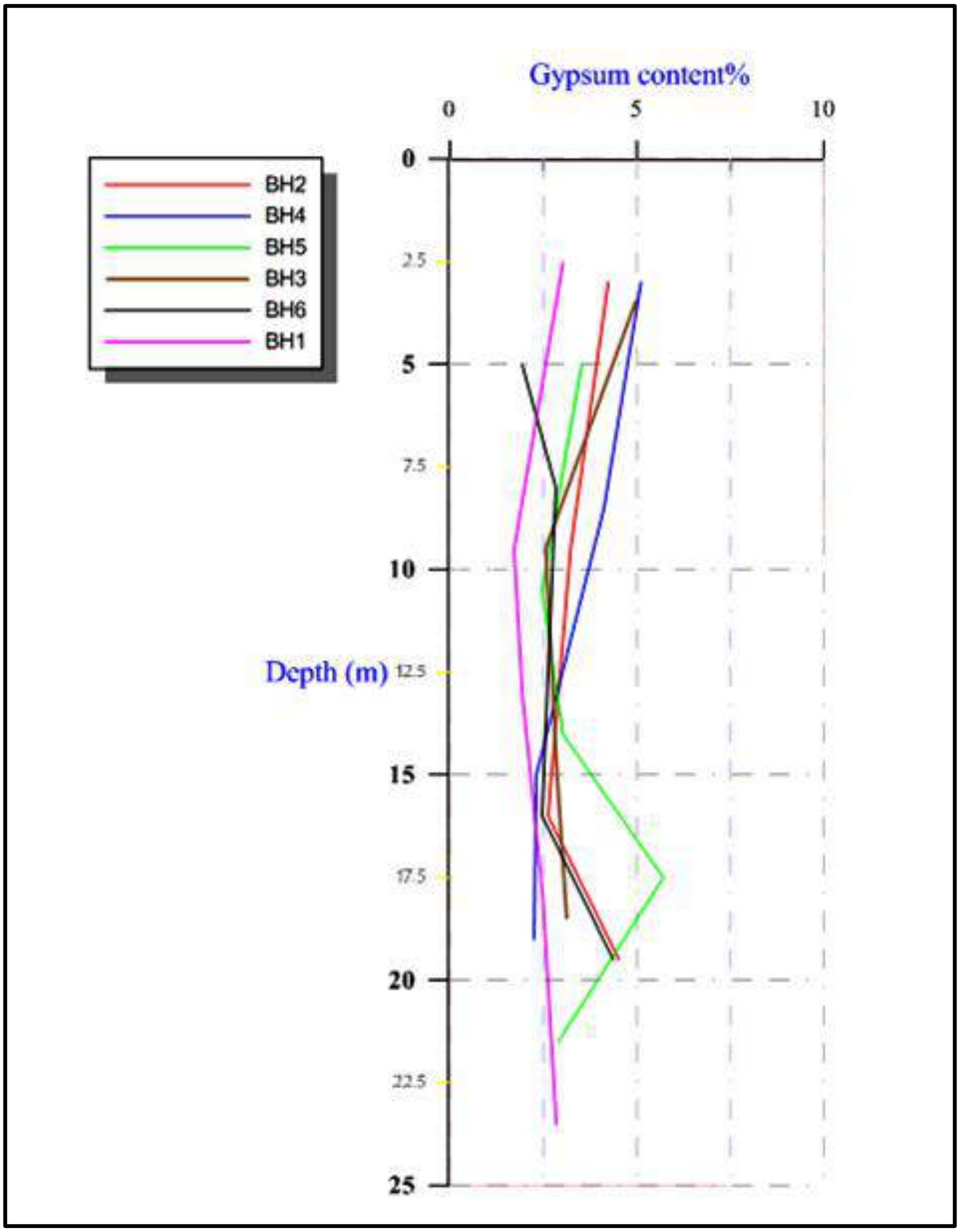

Fig. 4.21 Gypsum content in dam site

While the gypsum content under the water table increase in both of cohesive and granular soils. The maximum gypsum content is in BH5 at depth 17.5m about 5.72.

Table: 4.13 Final geotechnical assessment for critical zone (from ground surface to 3m depth)

BH NO.	ELEVATION A.S.L(m)	Soil Type	USCS	SAMPLE DEPTH(m)	DEPTH (m)	GYPSUM %	θ	C (kN/m^2)	N_{60}	Dr%	Pwp (kN/m^2)	σv (kN/m^2)	I_C	W.T	G_S	γ (kN/m^3)
BH1	+35	Cohesive	CL	0-1.5	30	3.05	-	162.5	-	-	0	29.6	2.1	11.5	2.67	19.78
		granular	SM	1.5-3		3.05	34.8	-	27	0.57	0	59.3	-			
BH2	+29.5	granular	ML	3	20	4.22	36.4	-	32	0.64	0	55.38	-	5	2.67	18.46
BH3	+29.2	Cohesive	CL	3	20.5	4.95	-	175	26	0.46	0	59.9	2.1	5	2.67	19.98
BH4	+23	Cohesive	CL	3	20	5.21	-	250	36.5	0.66		58.3	0.8	0.4	2.68	19.45
BH5	+33	granular	SM	3	25	3.54	33.5	-	22.5	0.52	0	60.1	-	10.5	22.6	20.06

CHAPTER FIVE

RESULTS OF THE STUDY

CHAPTER FIVE
RESULTS OF THE STUDY

5.1 Introduction :

In this chapter the results of the study are expose to show the main geotechnical problems in dam site. These problems are listed as the following:

I. Sulfate attacks.
II. Dispersive soil.
III. Siltation .
IV. Seepage modeling.

5.2 Results of sulfate attacks study

Based on the procedure which explained in chapter three, the results of external sulfate attacks divided the dam concrete body into three zones based on optical identification to the degree of attack, Fig. 5.1.

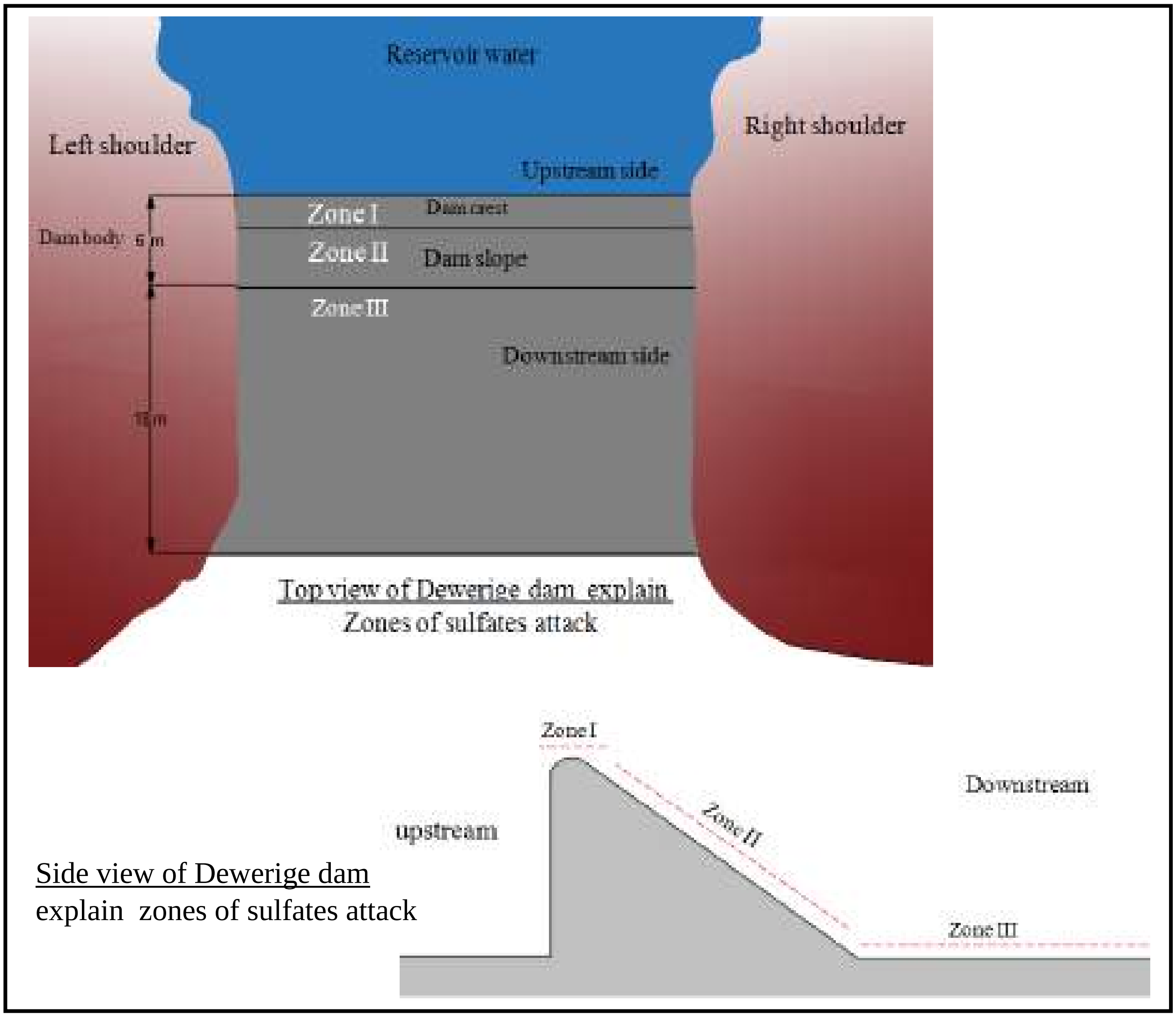

Fig.5.1 Sketch illustrate zones of sulfates attack

5.2.1 Zones of sulfate attacks in Dewerige dam

Sulfate attacks on concrete dam classified into three zones , as the following:

- Zone I: Represent the dam crest area, classified as negligible, Fig. 5.2.

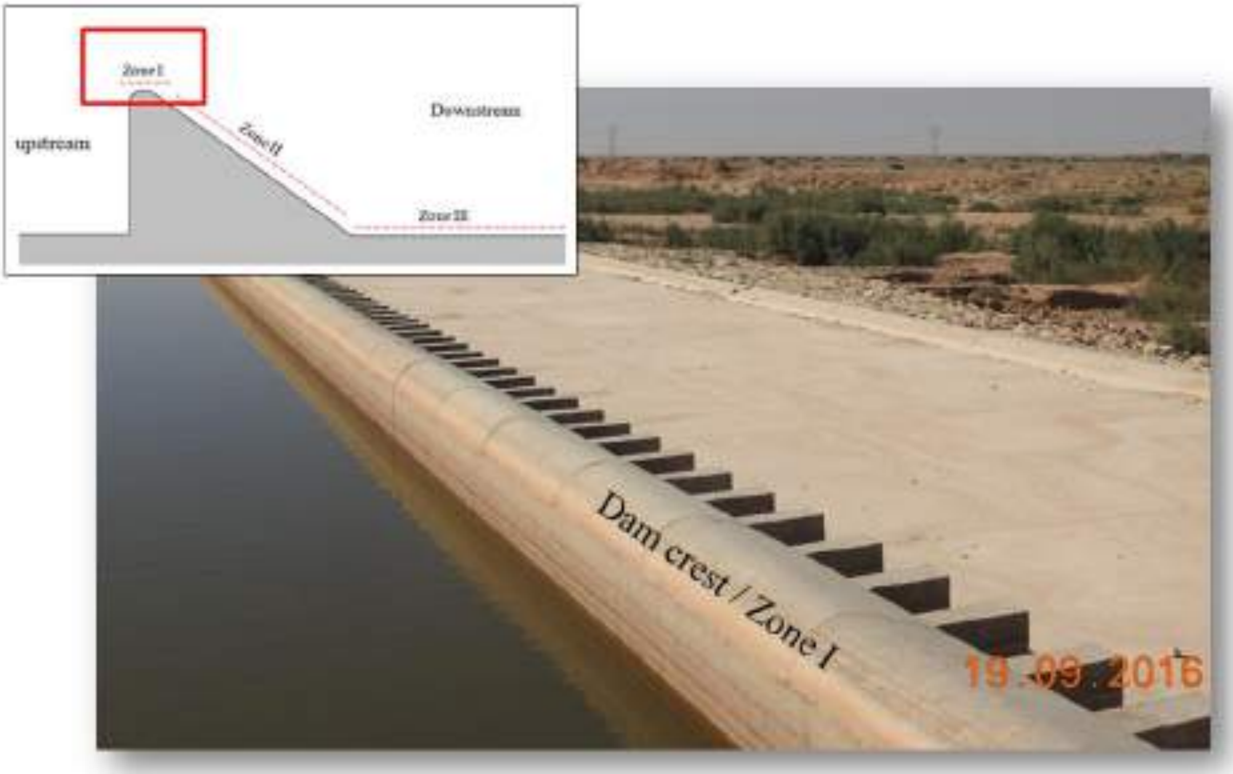

Fig.5.2 Sulfates attack in dam body, zone I

- Zone II : This area represented dam slope and where the external sulfate attacks is low to medium based on optical identification, Fig.5.3, 5.4.

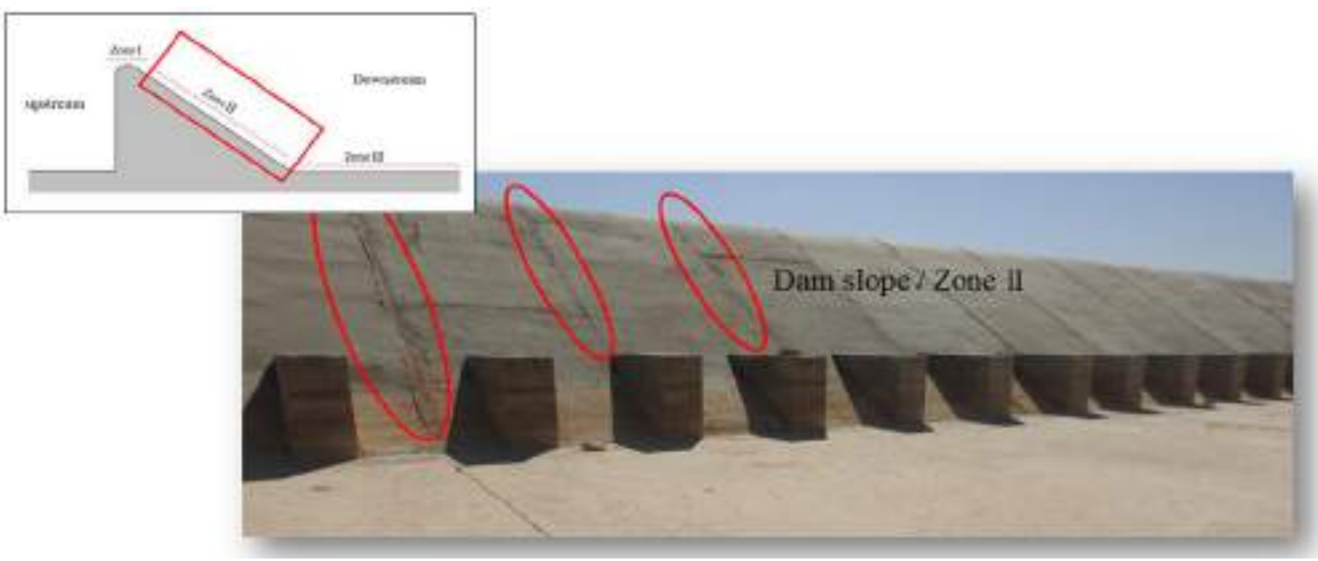

Fig.5.3 Sulfates attack in zone II

Fig.5.4 Effect of sulfates attack in dam slope, zone II

- Zone III : The higher intense attack in the dam body explained in this zone Fig. 5.5, 5.6, 5.7 and 5.8:

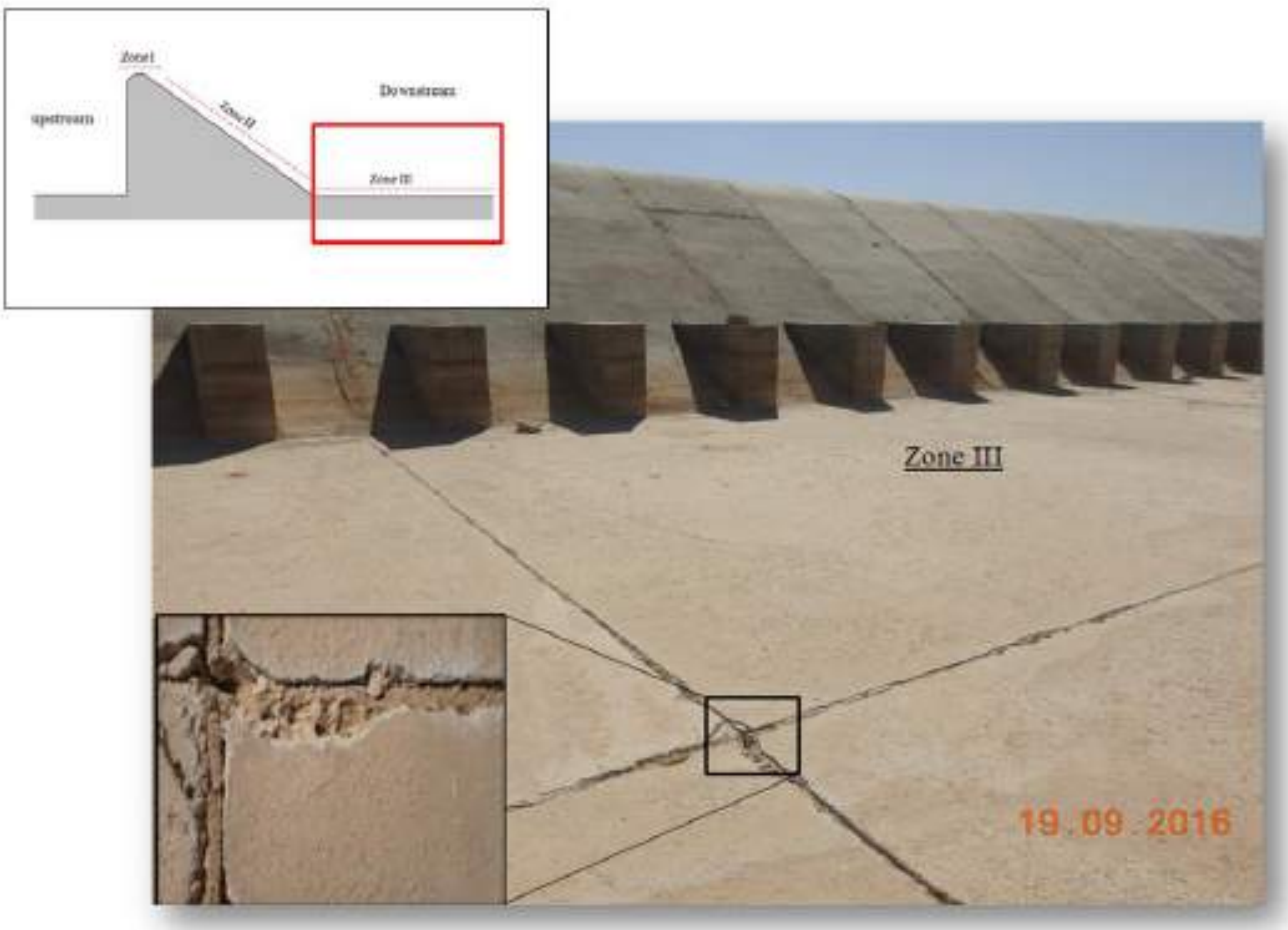

Fig.5.5 Crevices on concrete of dam body, zone III

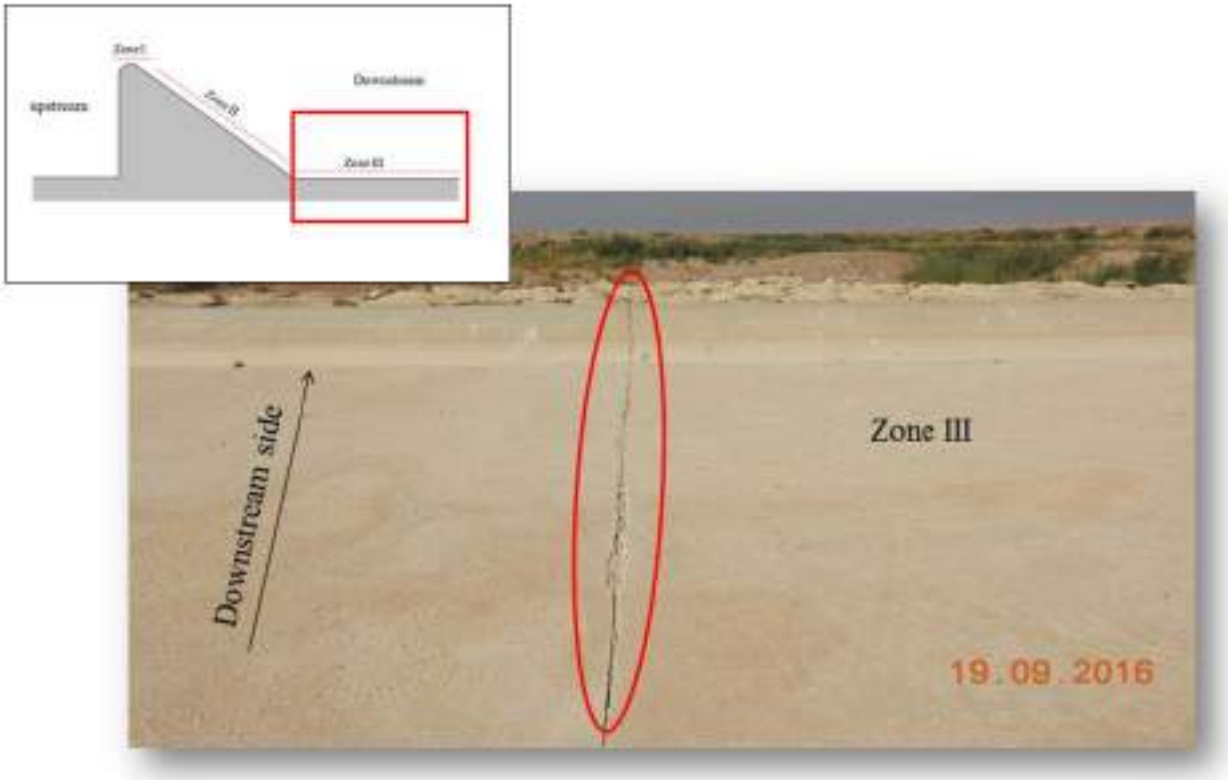

Fig.5.6 crevices in zone III

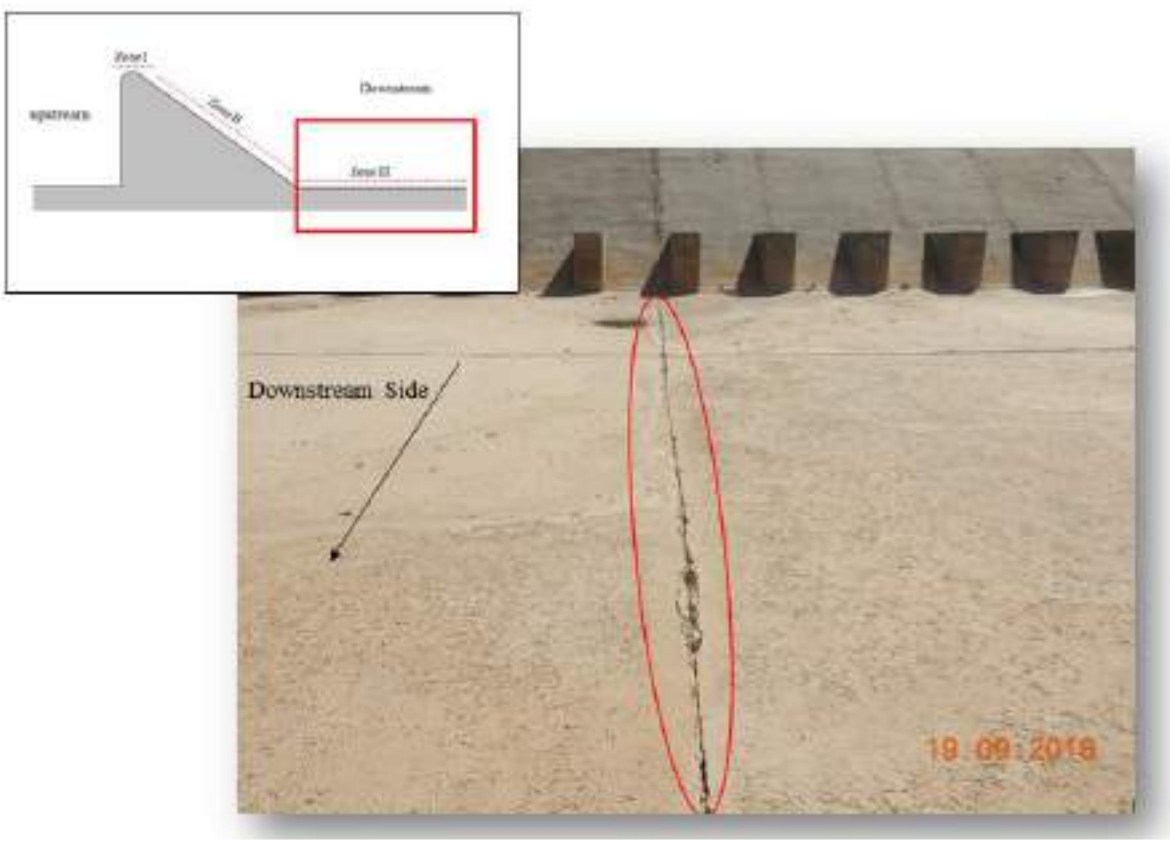

Fig.5.7 Impact of sulfates attack, zone III

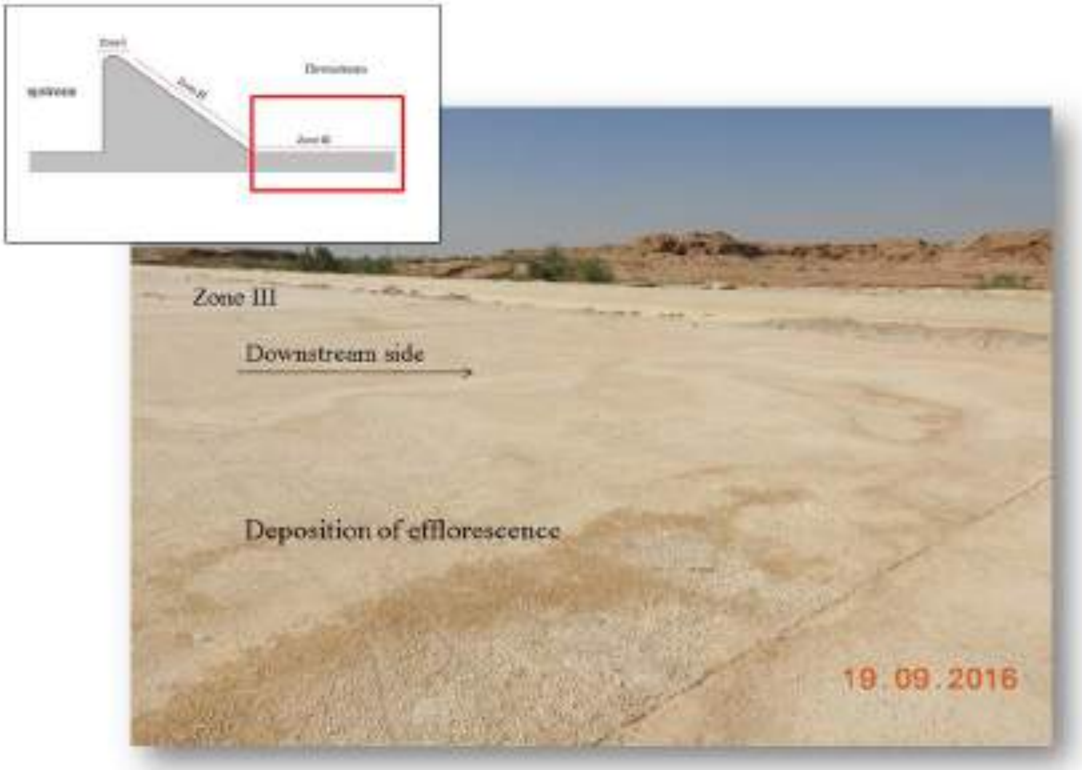

Fig. 5.8 Deposition of efflorescence on concrete as a result of sulfates attack

5.2.2 Assessment of sulfate in dam site soils

According to the results of geotechnical investigation report (Missan consultant engineering bureau, 2009), chemical tests which explained in chapter four, sulfate in foundation soil of Dewerige dam in about (3.33)% and concentrated in shallow depth. Therefore sulfate in foundation soil of Dewerige dam classifies as very sever, Table: 5.1.

Table : 5.1 Standard requirements of concrete foundation (Neville, 2004)

Classification of sulfates exposure	**Soluble sulfates(SO_4) in the soil %**	**Dissolved sulfates (SO_4)in the ground water(ppm)**	**Required Portland cement type**	**Maximum water-cement ratio**
Negligible	0.0 to 0.1	0 to 150	Any type	No requirement
Moderate	0.1 to 0.2	150 to 1500	Type II	0.50
Severe	0.2 to 2	1500 to 10.000	Type V	0.45
Very severe	over 2	over 10.000	Type V with pozzolan	0.45

5.3 Dispersive soil

The results of dispersive soil study of dam shoulders are discussed in the following:

5.3.1 Field survey

After surveyed dam site to determine dispersive soil Fig. 5.9 explained surveyed points in both shoulders. Field survey and high-resolution satellite imagery (bird eye) were used to study soil in study area and identify dispersion in more accurately. The following satellite imagery shown dispersive soil near the dam site, in shoulders of the dam, and its impact on engineering structures in study area, especially in right shoulder, Fig. 5.10, 5.11, 5.12, 5.13 and 5.14:

Fig.5.9 Surveyed points in dam shoulders by Google Earth

The detected area show highly and depth dispersive soil erodibility near the dam site, Fig.5.10.

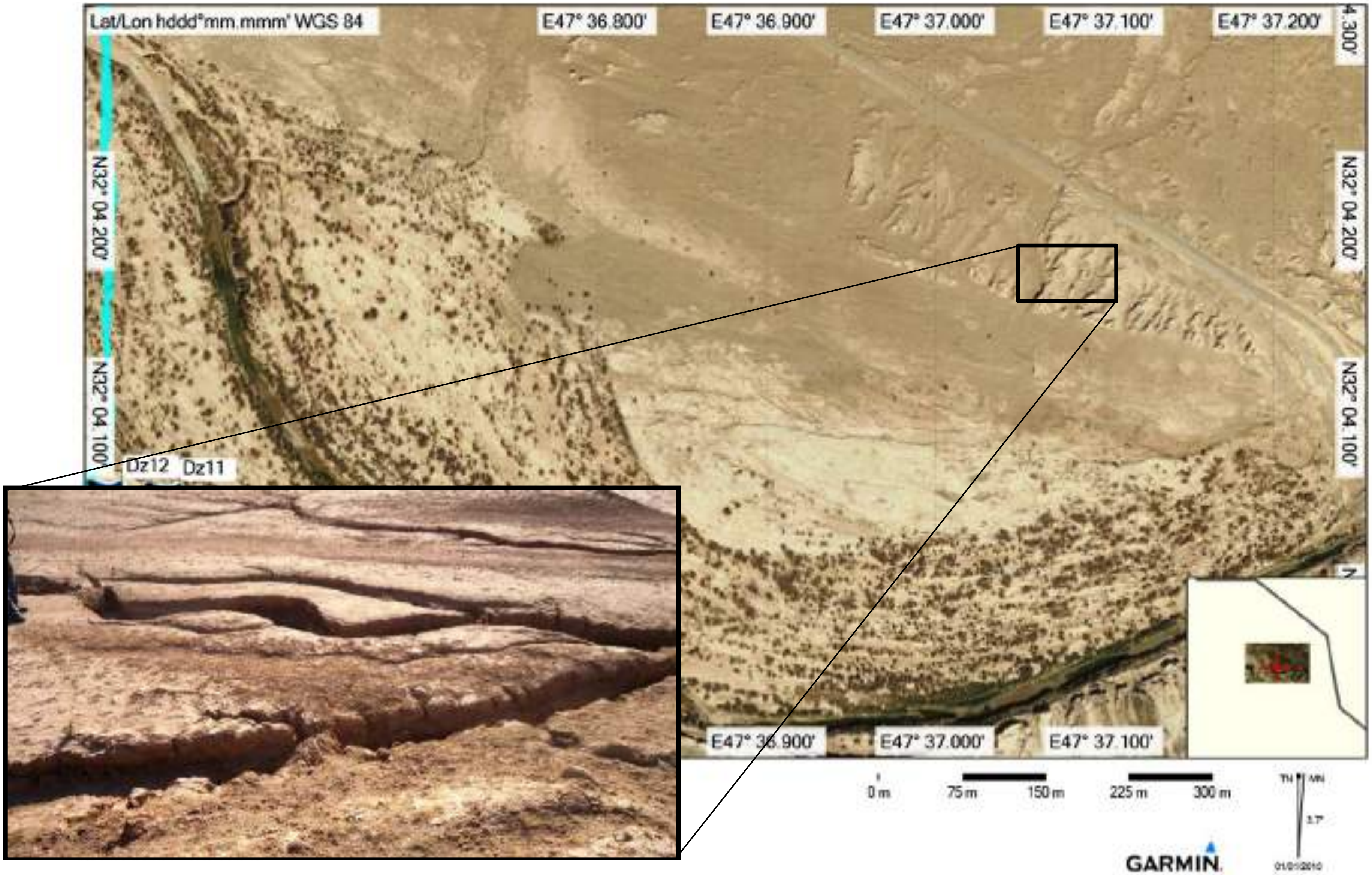

Fig. 5.10 satellite imagery explain the effect of dispersion in soil of dam site

The evidences of dispersive soil extend until more than 800m from dam site. That is indicate the soil of study area not suitable for backing the dam shoulders, Fig.5.11.

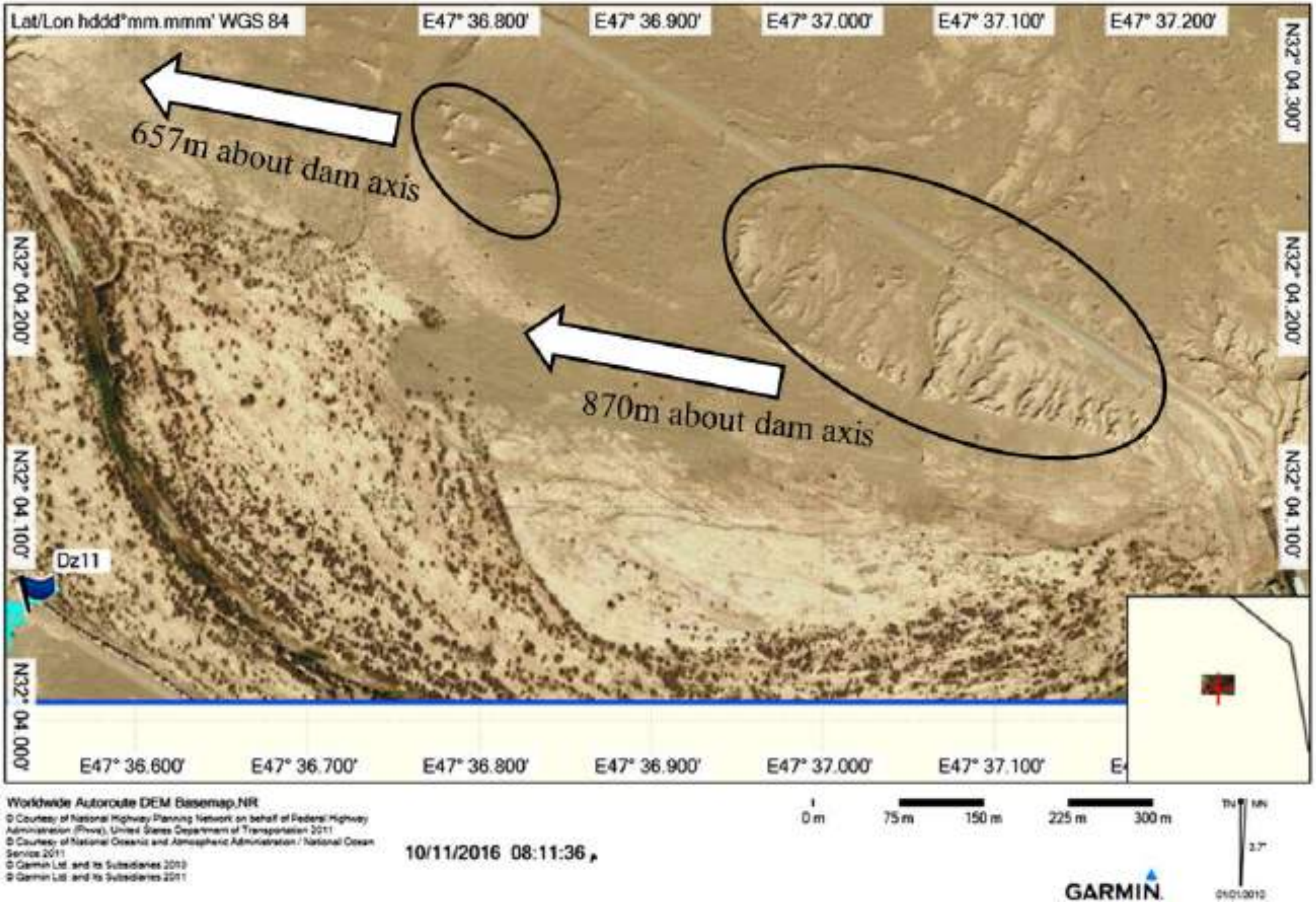

Fig. 5.11 satellite imagery shows influence of dispersive soil near dam

The evidences of dispersive soil in different positions in dam reservoir, Fig.5.12.

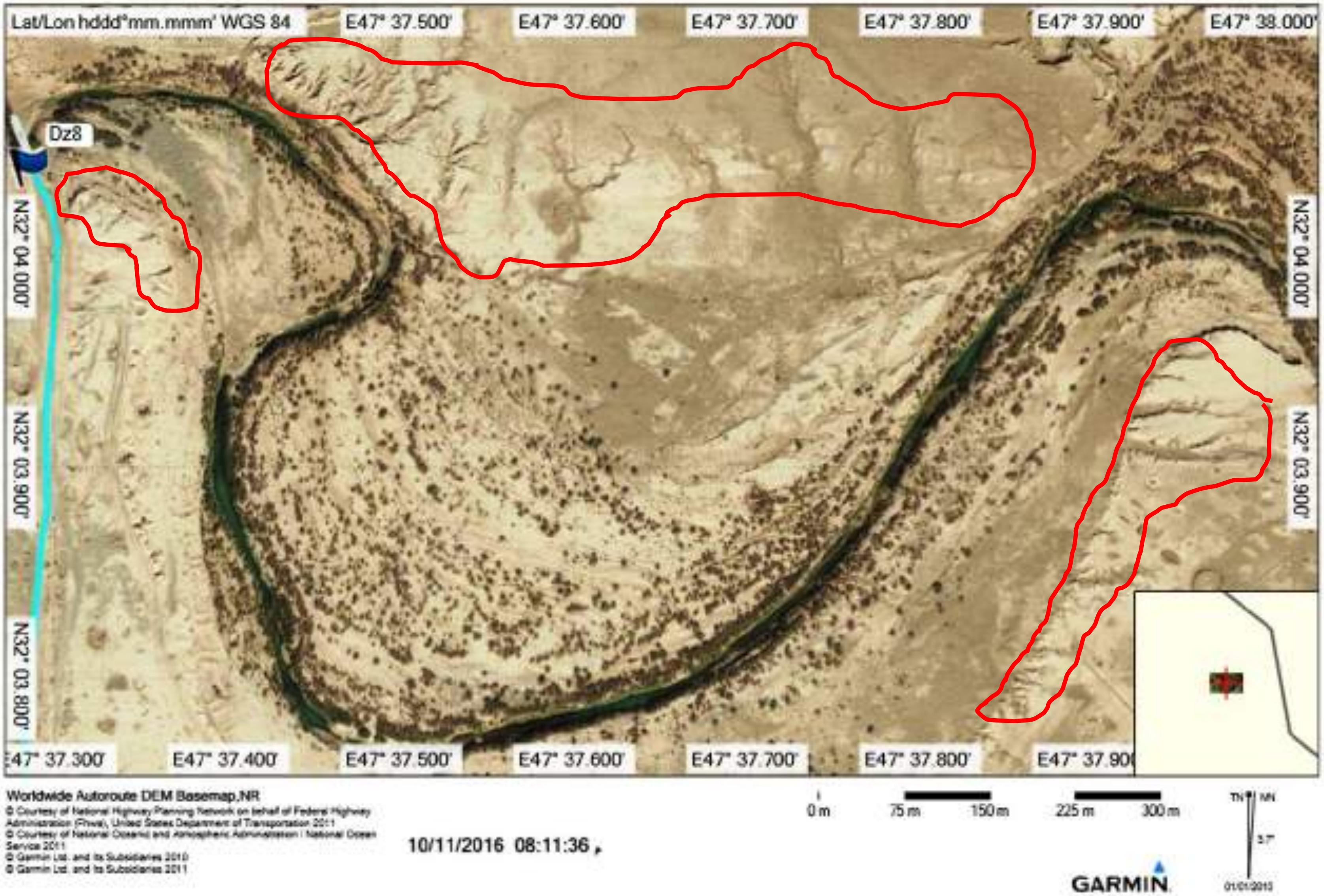

Fig. 5.12 satellite imagery shows influence of dispersive soil near dam site

Destruction of engineering structures by the action of dispersive soil in study area, Fig.5.13 and 5.14.

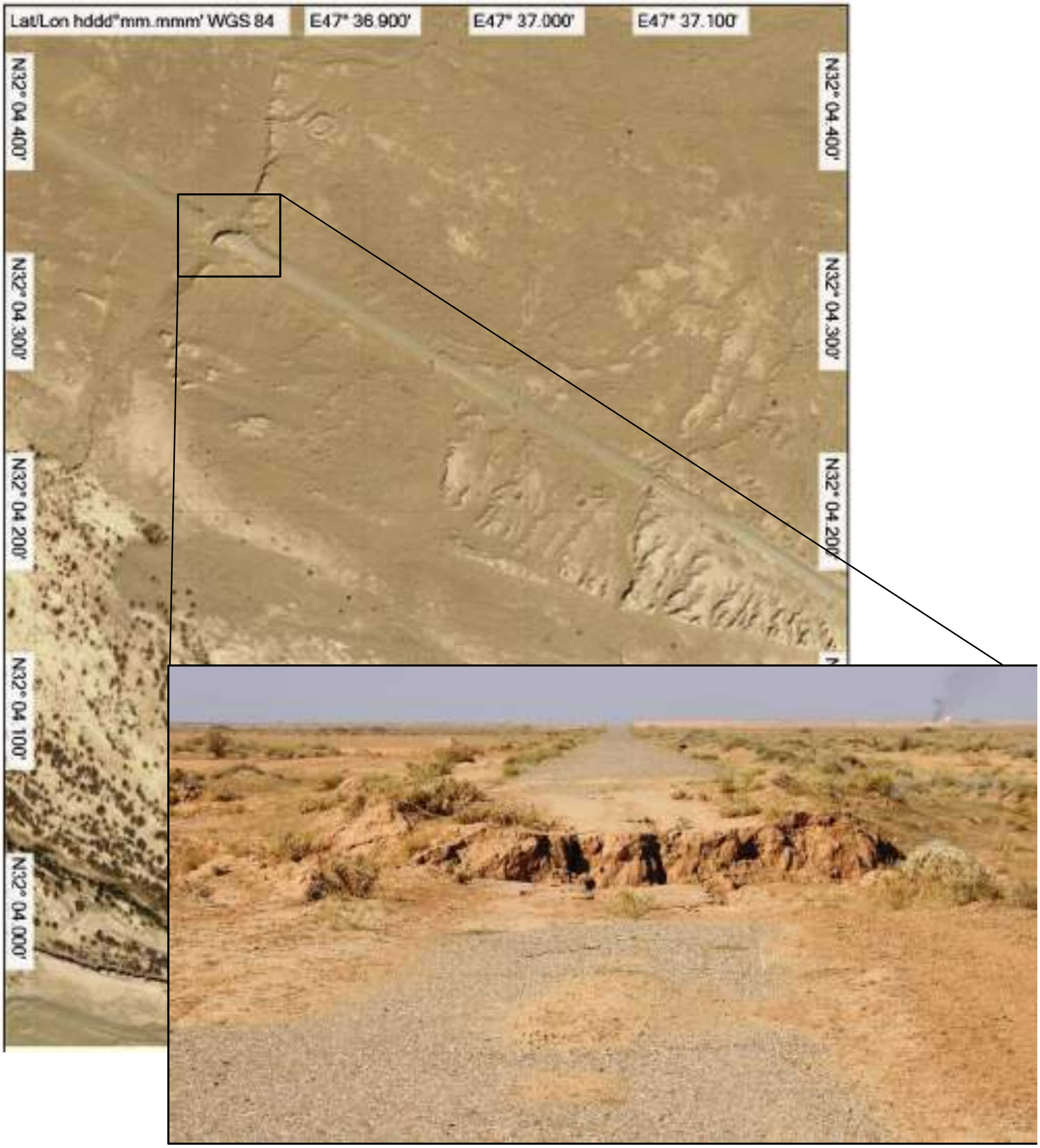

Fig. 5.13 Effect of the dispersive soil on external roads

Fig. 5.14 Dispersive soil destroyed engineering structure (abridge) in study area

5.3.2 Impact of dispersive soil on dam shoulders

Soil of dam shoulders eroded by influence of dispersion, and form grooves which develop to piping and threaten the safety and stability of Dewerige dam.

- Left shoulder / Fig. 5.15, 5.16 display dispersive soil in left shoulder:

Fig. 5.15 Dispersive soil in left shoulder

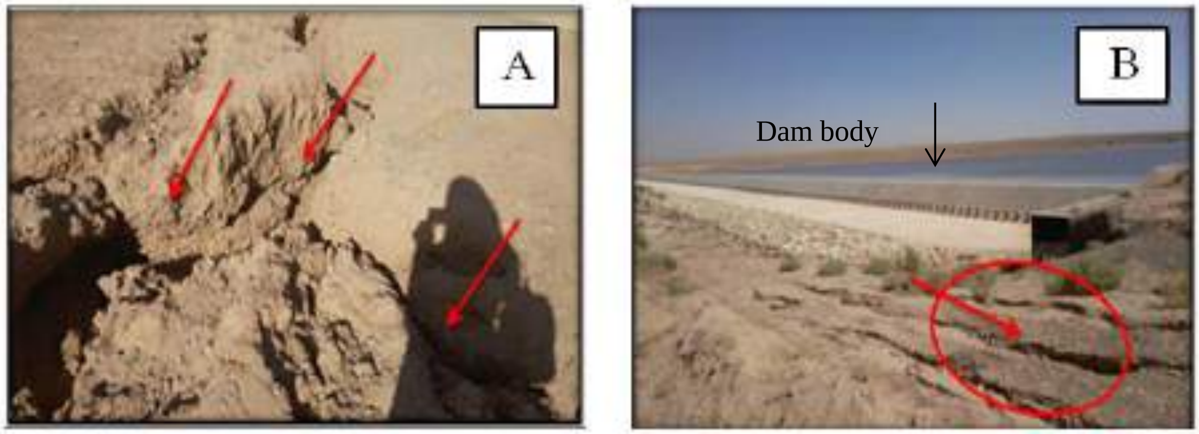

Fig. 5.16 (A & B) explain grooves and gullies dispersive soil in left shoulder

- Right shoulder / The impact of dispersive soil in the right shoulder explained in Fig. 5.17, 5.18 and 5.19

Fig. 5.17 Piping in soil of right shoulder

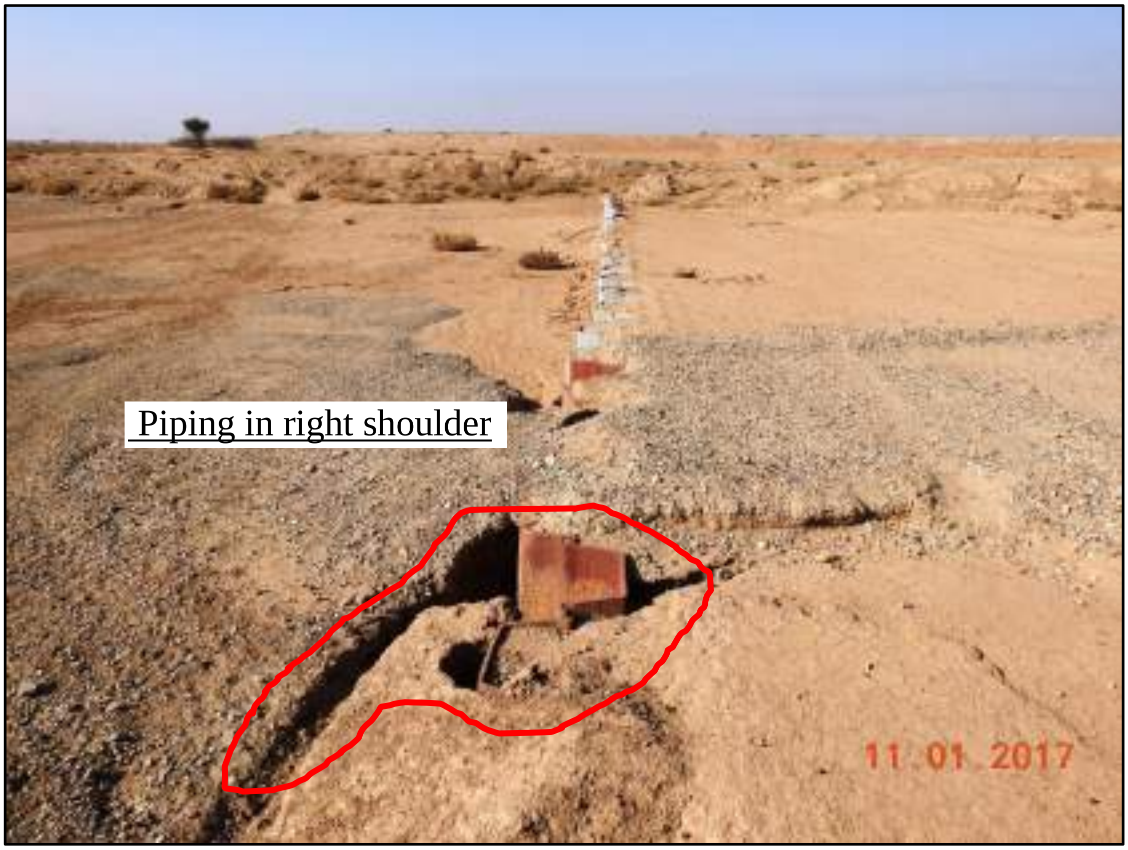

Fig. 5.18 Cavity & hole by the action of dispersion

Fig. 5.19 Gullies in dispersive soil

5.3.3 Dispersion test

The result of Emerson test indicate soil samples of dam shoulders classified as dispersive soil class 2, Fig. 5.20.

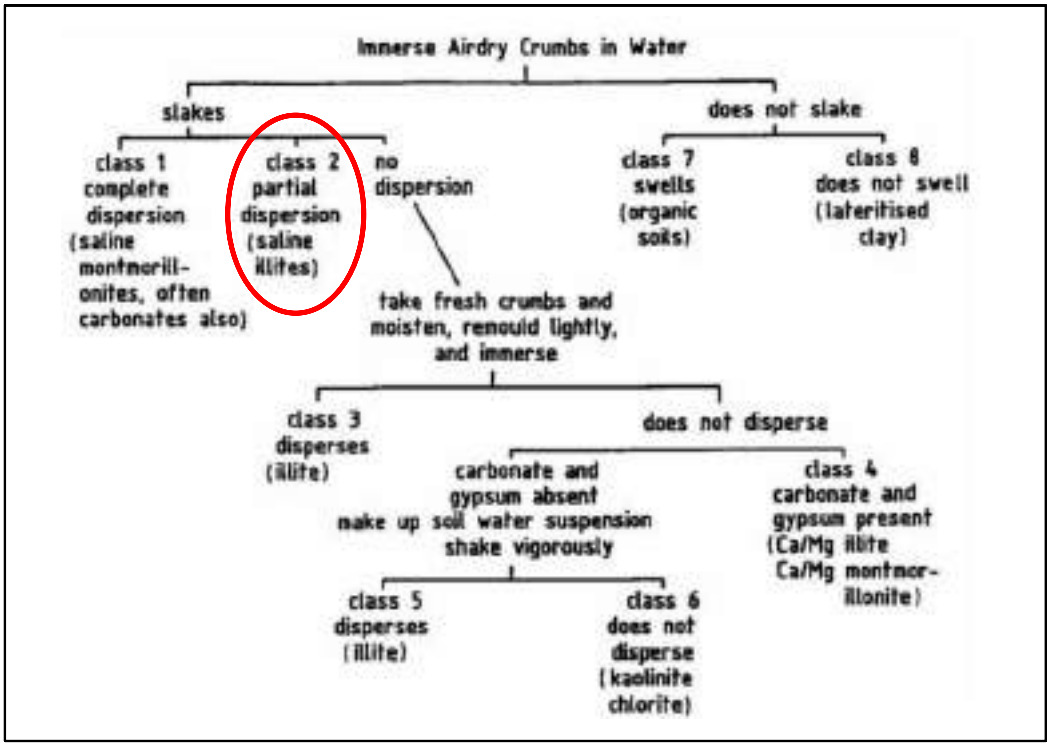

Fig. 5.20 Emerson class number (Ingles and Metcalf,1972)

5.3.4 Identify types of clay minerals in dispersive soil

Clay minerals in dispersive soil can be identify by location of these minerals on Casagrande plasticity chart Fig. 5.21

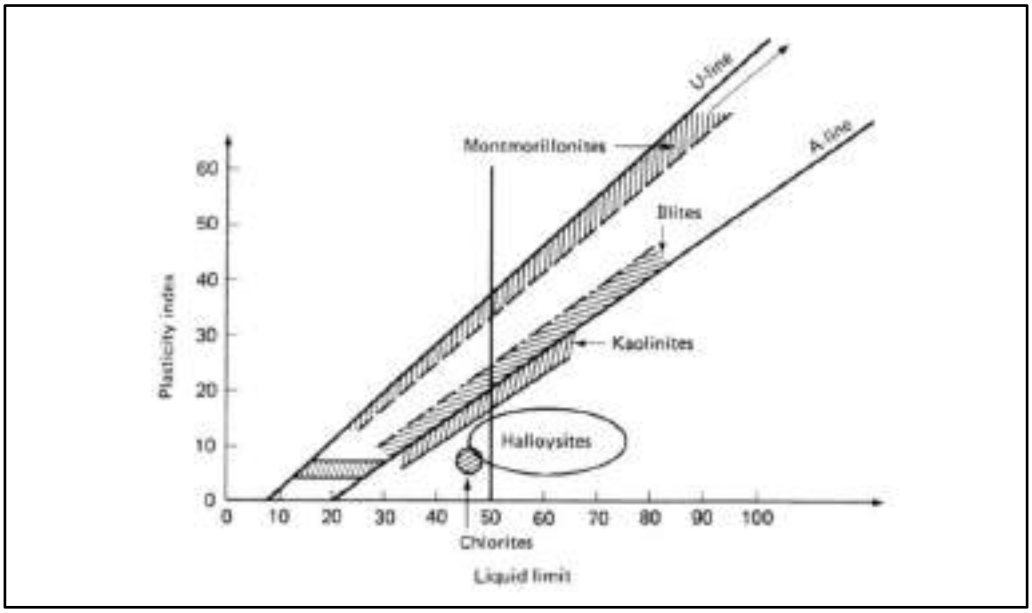

Fig. 5.21 Clay minerals on Casagrande plasticity chart (Holtz and Kovacs, 1981)

After using the results of Atterberg limits, especially soil samples from dam shoulders and representation in Casagrande plasticity chart to identify type of clay mineral in these soils Fig.(5.22 and 5.23).

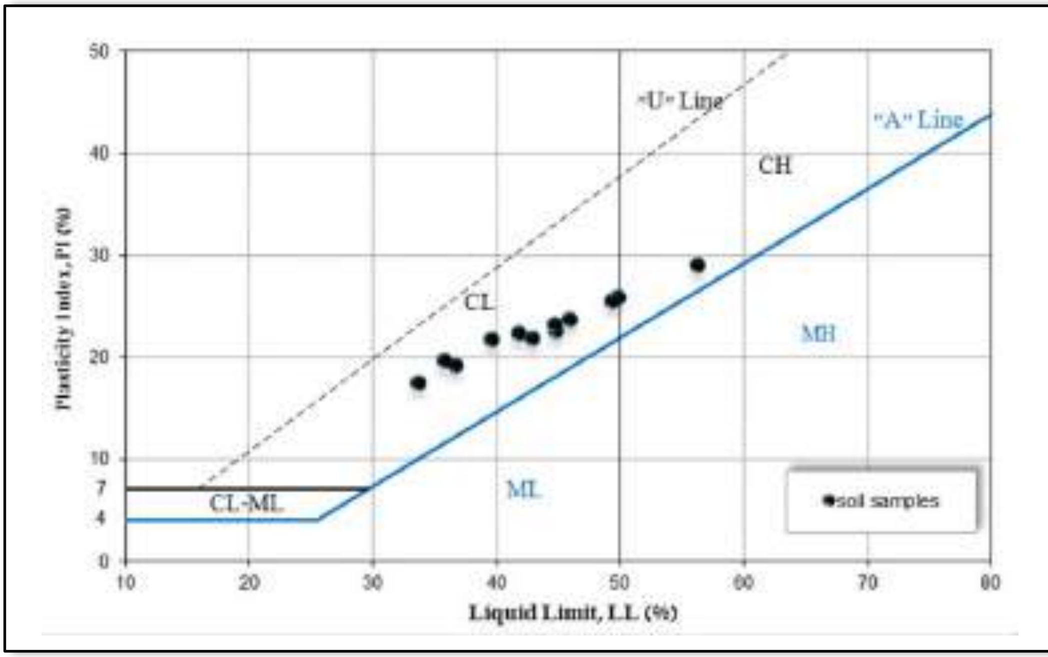

Fig. 5.22 Position of soil samples from left shoulder

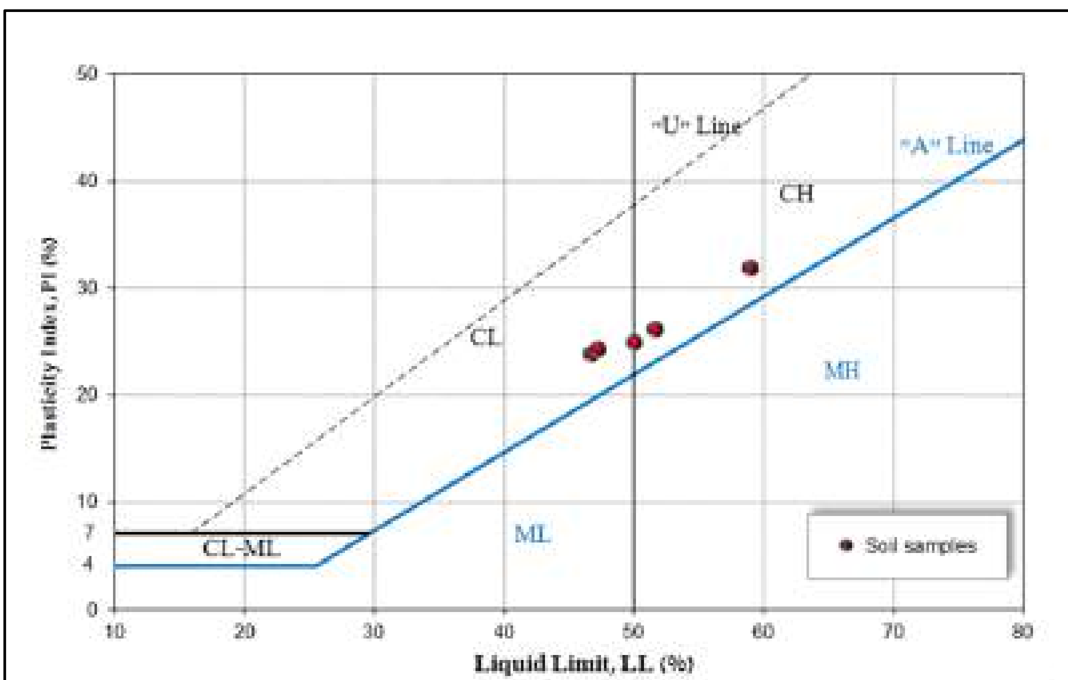

Fig. 5.23 Position of soil samples in Casagrande plasticity chart of right shoulder

Position of soil samples on plasticity chart proved that the type of clay mineral is Illite, also the field survey to dam site show effect of dispersive soil concentrated in right shoulder.

As a result of impact of dispersion on dam site, soil of dam shoulders classified according to intensity of dispersion in soil: zone I and zone II, when zone I represent dispersive soil with medium intensity, zone II represent dispersive soil with high intensity Fig.5.24.

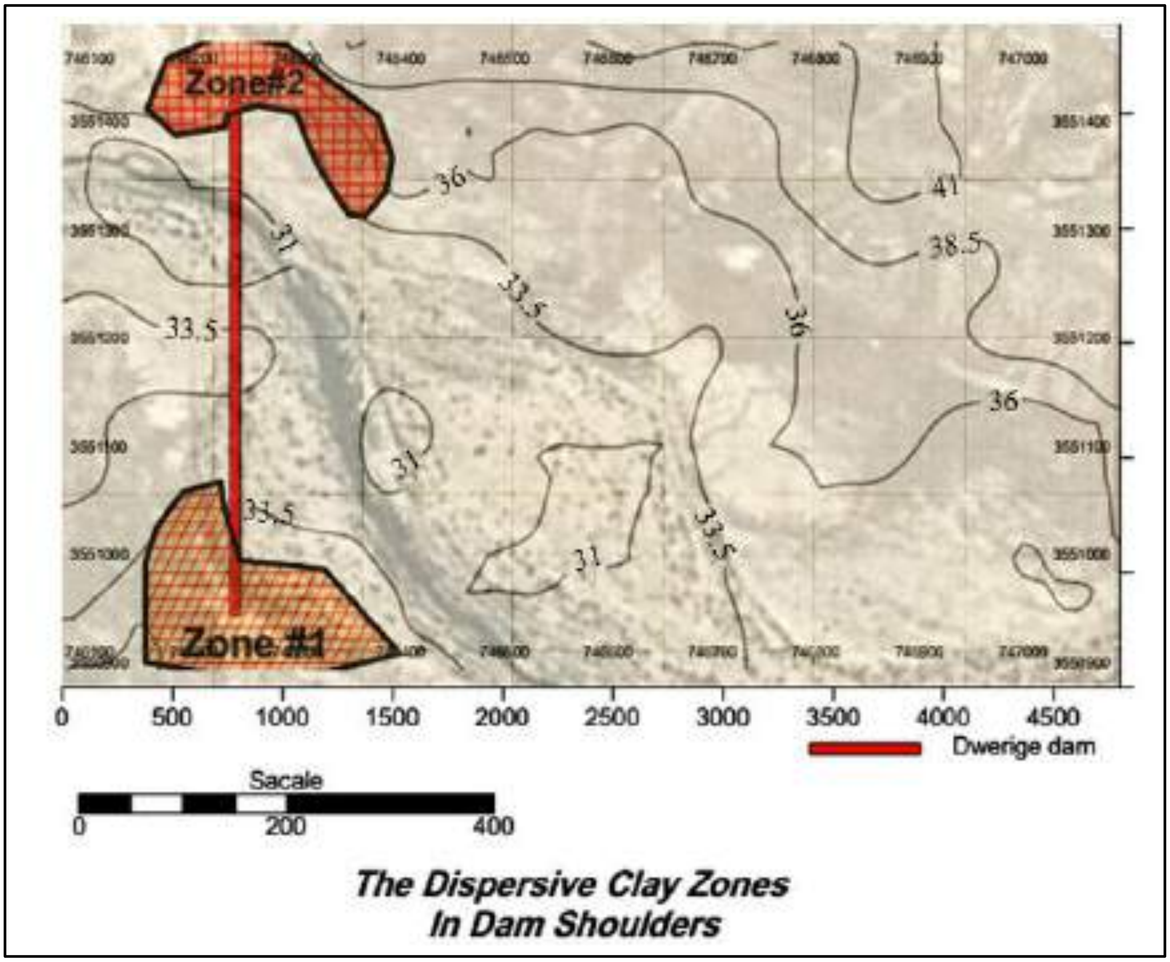

Fig. 5.24 Dispersive soil clay zones in dam shoulders

5.4 Results of microscopic study

Microscopic study explained the following results:

- Fabric of soil samples / fine sand : well sorted & subrounded particles, Fig.5.25 and 5.26.
- Mineralogy / particles consist mainly of : Quartz , Feldspar ,Chert fragments within Al-Mukdadiya formation . as illustrate in Fig. (5.27, 5.28) :

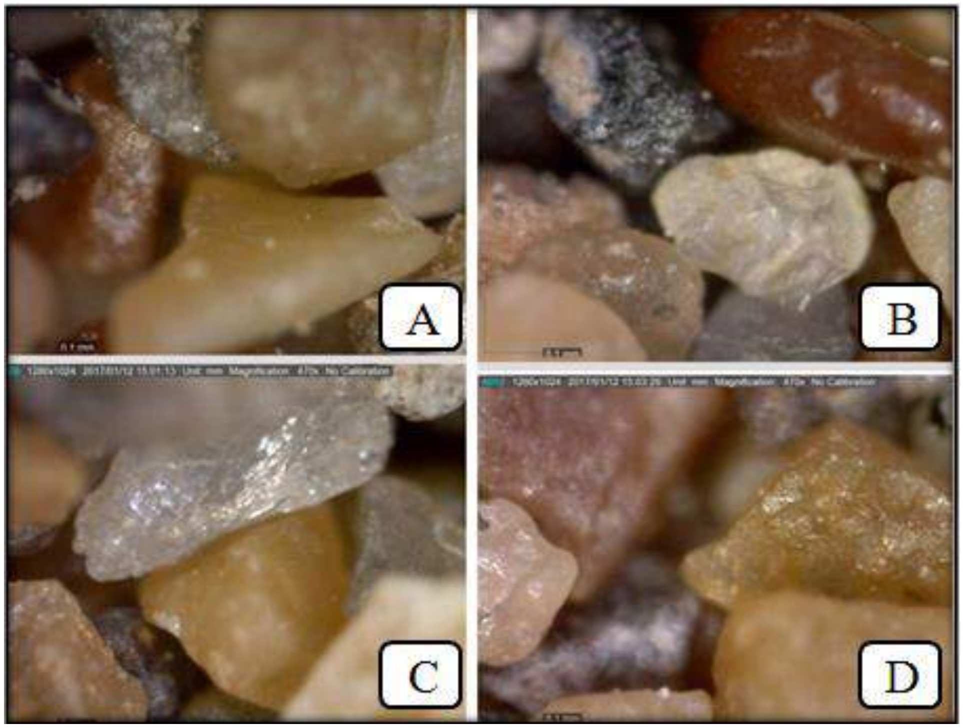

Fig. 5.25 Fabric of soil samples , sample (1)

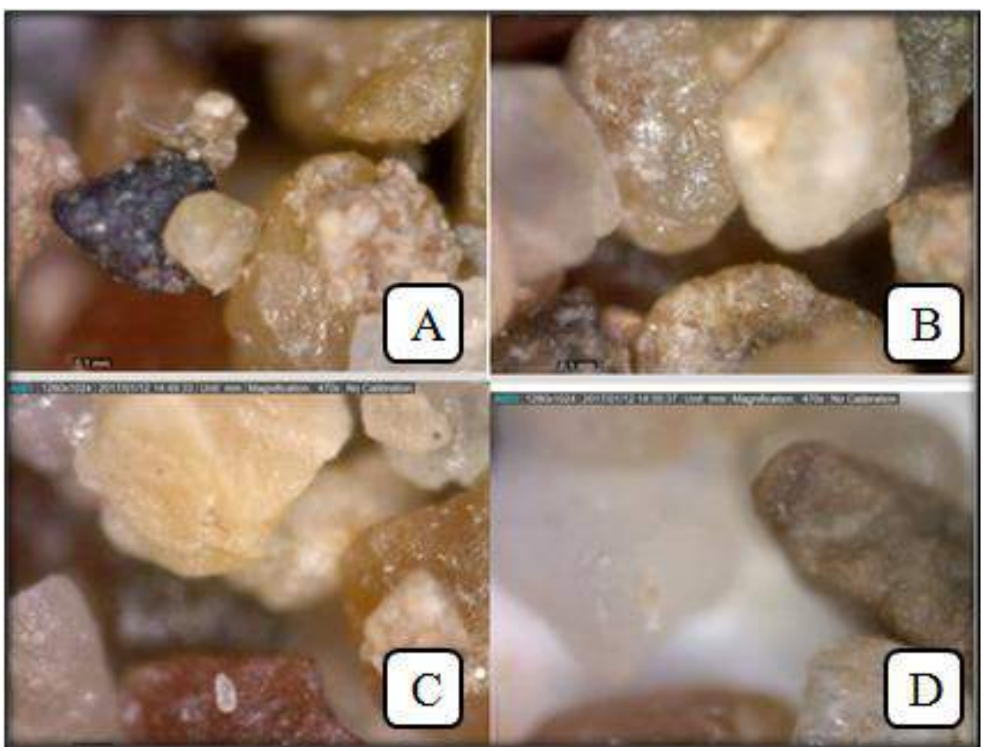

Fig. 5.26 Fabric of soil samples , sample (2)

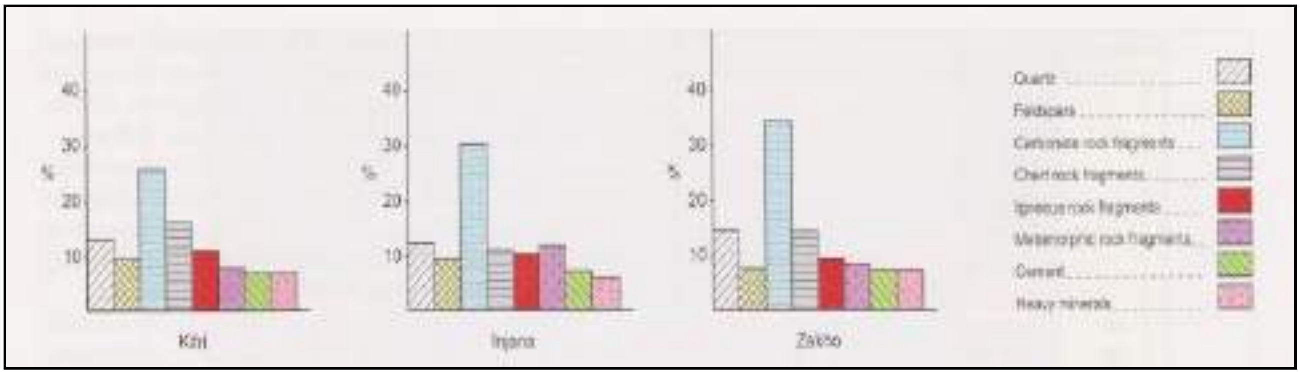

Fig. 5.27 Mineral composition of Al-Mukdadiya formation sandstone (after Ali & Khoshaba ,1981)

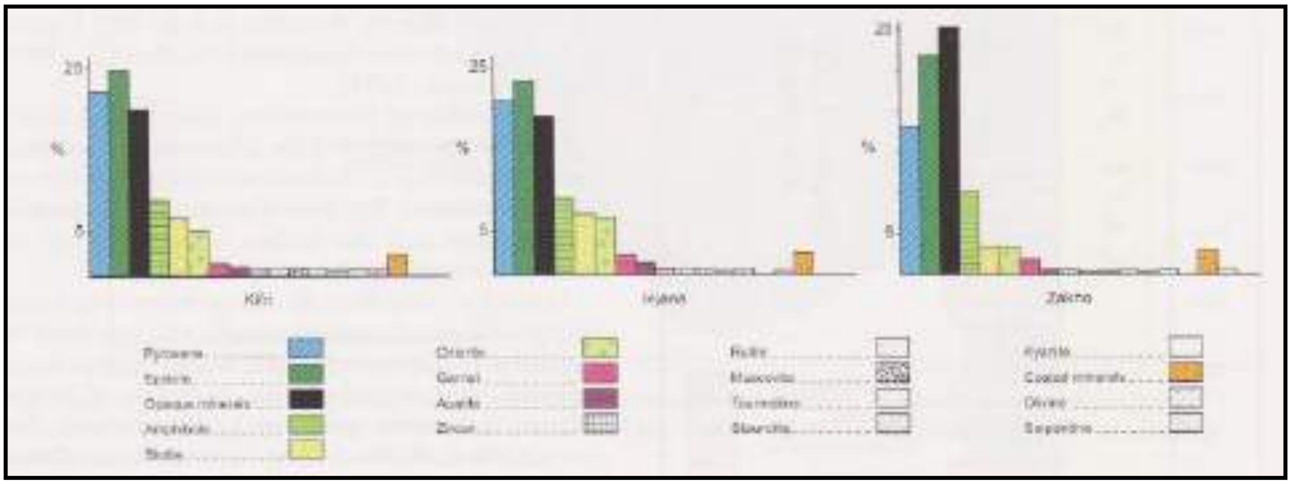

Fig. 5.28 Heavy mineral contain in of Al-Mukdadiya formation sandstone (after Ali & Khoshaba ,1981)

5.5 Siltation

the volume of siltation in Dewerige reservoir computed by technique explained in chapter three. The amount of siltation can explained as the following :

5.5.1 The initial elevation of the reservoir (base level), as Fig.(5.29).

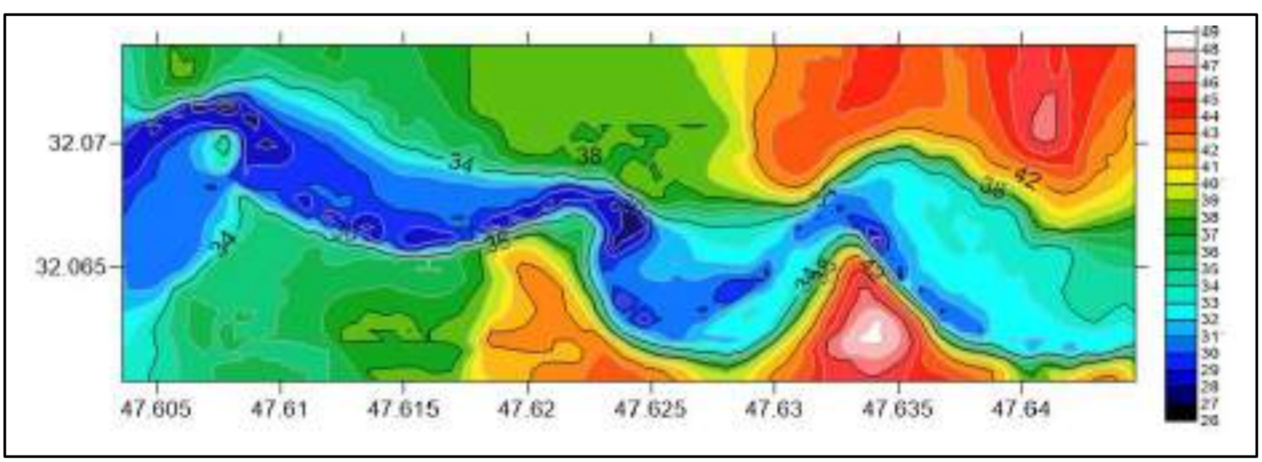

Fig. 5.29 Reservoir of Dewerige dam in initial elevation in (m)

5.5.2 Measuring the elevations of silt in the reservoir during dry season

Through a final surveying to the reservoir to measuring siltation thickness in reservoir, based on a benchmark (dam crest ,+32.5m) elevation. The elevation of the surveyed point was (+29 m), Fig. 5.30.

Fig. 5.30 Measuring siltation thickness

Siltation thickness in reservoir of Dewerige dam for first year calculated based on :

- I- Initial surveyed data (Ministry of water resourse /center of studies and engineering design ,2011).
- II- Results of field measurement and final survey to the silted surface during the draught period at 2017.

Measuring of siltation thickness / as explained :

Siltation thickness in upstream side = total dam height - measured height

= 3.50 - 2.23 =1.27m at measured points

That is indicate siltation level cover more than 36% of dam length in first year.

5.5.3 Estimate reservoir area

Area of reservoir have been calculated using Surfer software, as the following :

1- Determination of reservoir area by drawing polygon .
2- Calculate the area of this polygon .

Reservoir of Dewerige dam coloured in light green with area (1015426 m^2) as shown in Fig. 5.31.

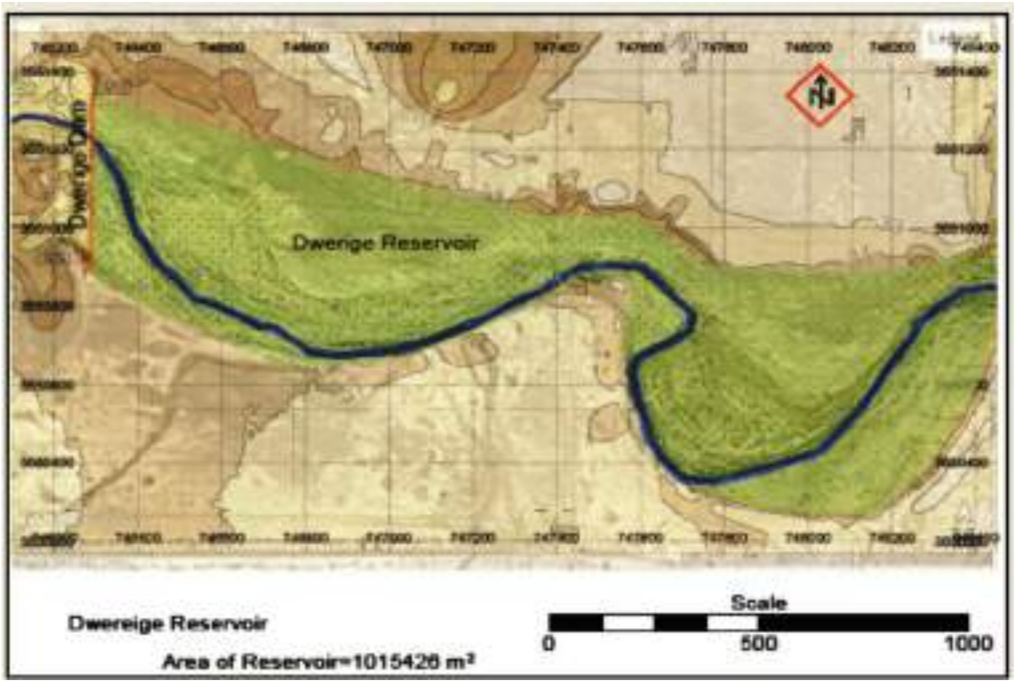

Fig. 5.31 Determination of reservoir area

5.5.4 Calculate elevations of silt sediment in reservoir

levels of siltation in dam reservoir shown in Fig.5.32 (measure in m) .

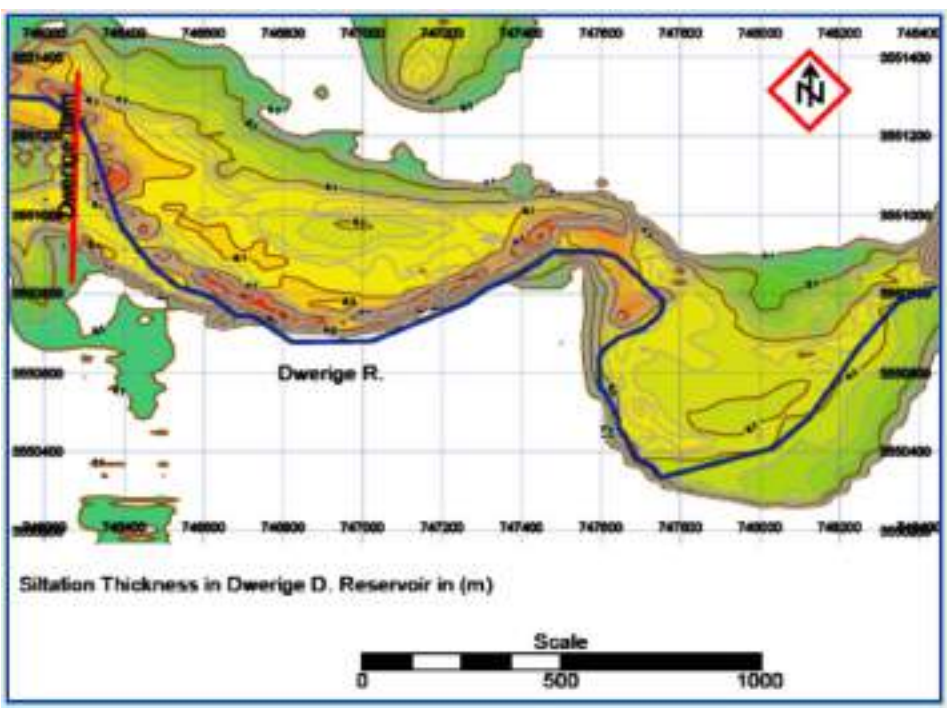

Fig. 5.32 Elevations of silt in dam reservoir

5.5.5 Estimate the total siltation volume in the reservoir

Siltation volume have been calculated by Surfer software by the volume command, which calculates the difference between two surfaces (2grids). Grid 1 represent initial elevation of reservoir and grid 2 represent siltation horizontal level. The difference between the two grids is siltation volume in Dewerige dam reservoir for 1st year = 285337 m^3.

Fig.5.33 explained siltation and initial elevation layers in reservoir.

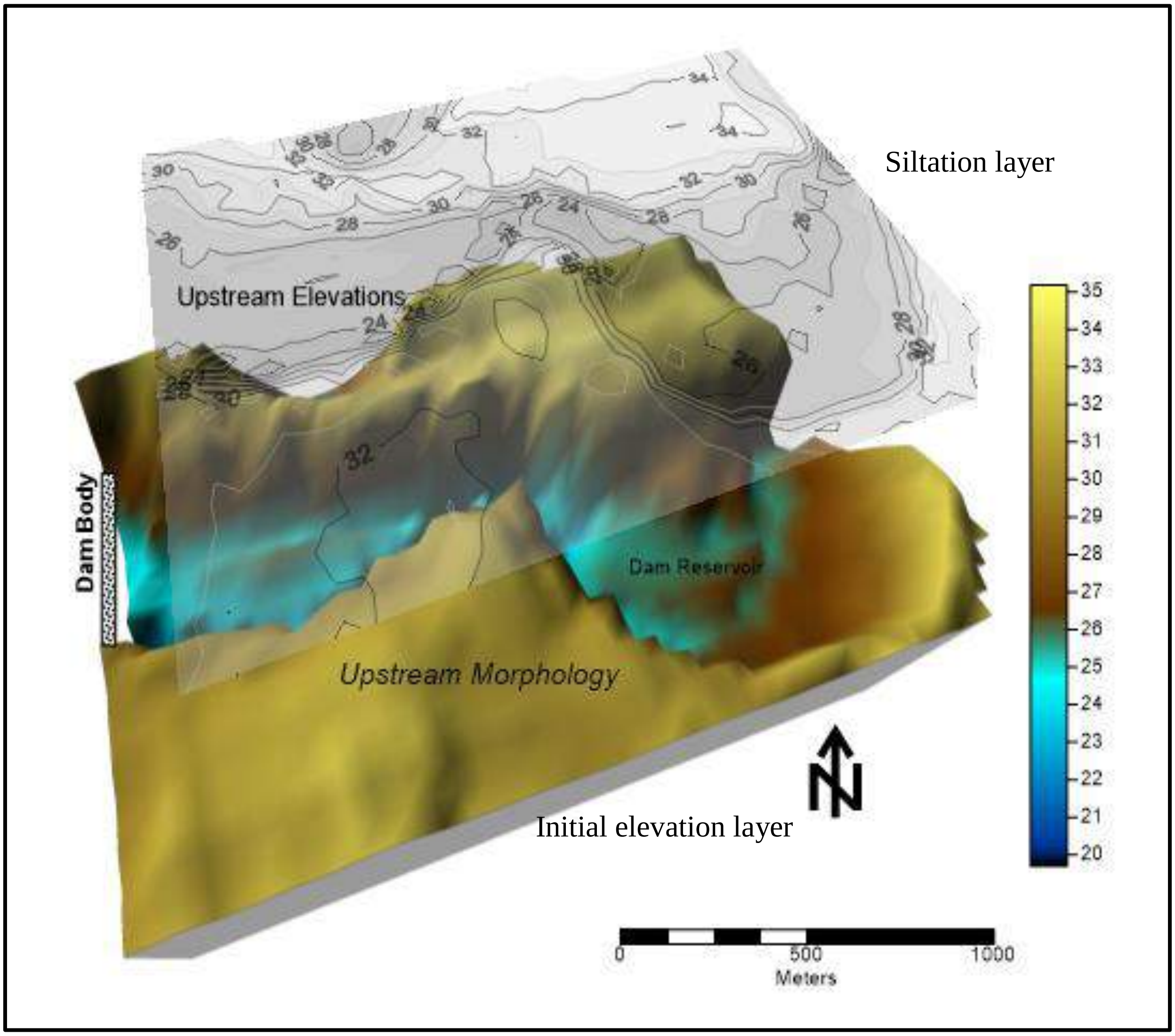

Fig. 5.33 Outputs of Surfer

5.5.6 Calculate rate of sediment, economic life time, and sediment yield in dam reservoir

siltation volume in the reservoir was compute the real economic life as explained in following equation and The results of siltation study are summarized in Table: 5.2

Rate of sediment (SR) = silt volume (SV) / age of reservoir (y) ....(5-1)

Economic life time (LE)= reservoir storage capacity(dead) / SR..........................(5-2)

Sediment yield (SY) = (SV) × dry bulk density (DBD)..(5-3)

Table :5.2 Summary of siltation study in Dewerige dam

Variables of Dewerige dam reservoir	
Sediment volume (m^3)	285337
Age of reservoir (y)	1y
Sediment rate (m^3/y)	285337
Reservoir storage capacity (m^3)	6886818
Designed life time (y)	50
Economic life time (y)	24
Dry bulk density (t .m^{-3})	1.62
Sediment yield ($t.y^{-1}$)	462245.94

As illustrated in Table (5.2) , the sediment volume in Dewerige dam reservoir is about 285337m^3, for the first year only, so the economic life time can be reduced from 50 years to 24 years, two times less than the designed. That's confirms there are gaps and errors in data which adopted during the design stage.

5.6 Seepage model

5.6.1 SEEP/W model

Simulation model (SEEP/W) dealt with seepage in foundation soil of Dewerige dam at flooding condition and analysis type steady-state, as explained in chapter three the following procedure, Fig.5.34:

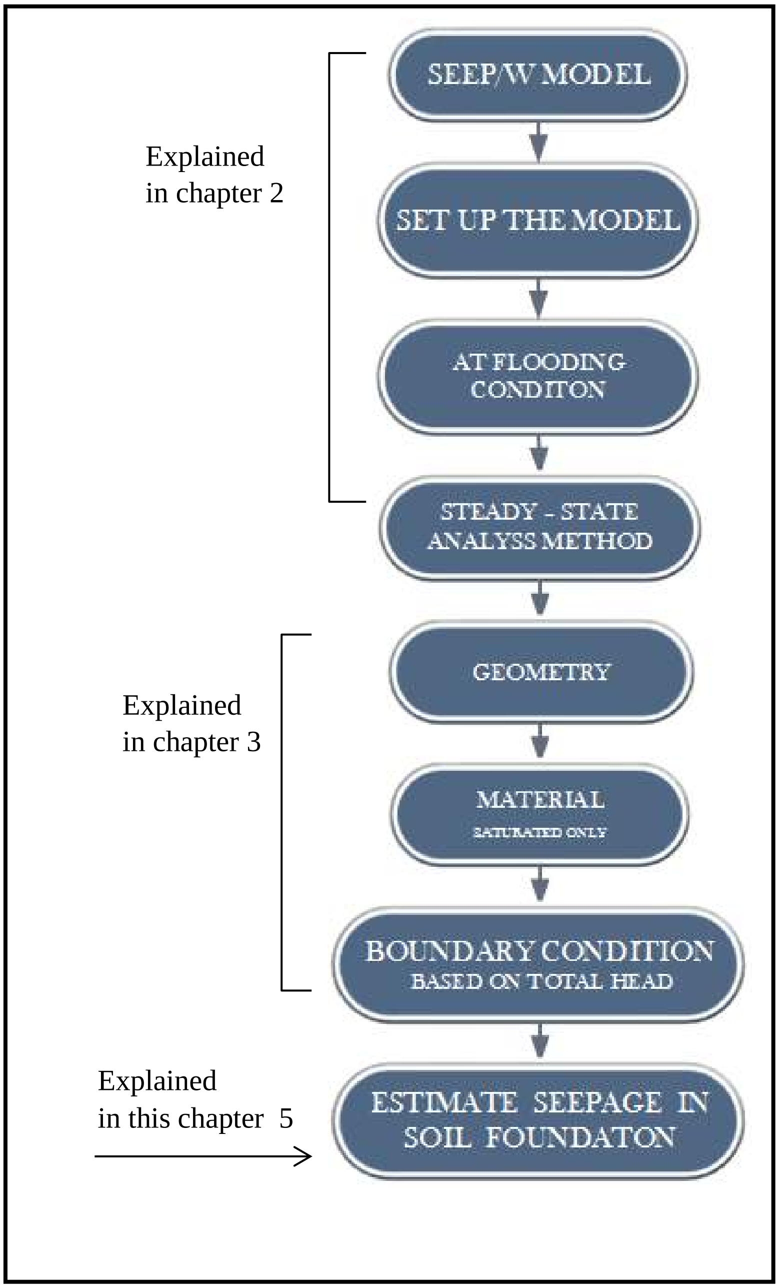

Fig. 5.34 Flow chart illustrate procedure of seepage modeling

5.6.2 The total head results :

Simulation model shows gradually decreasing in total head in upstream toward downstream , Fig. 5.35 and 5.36.

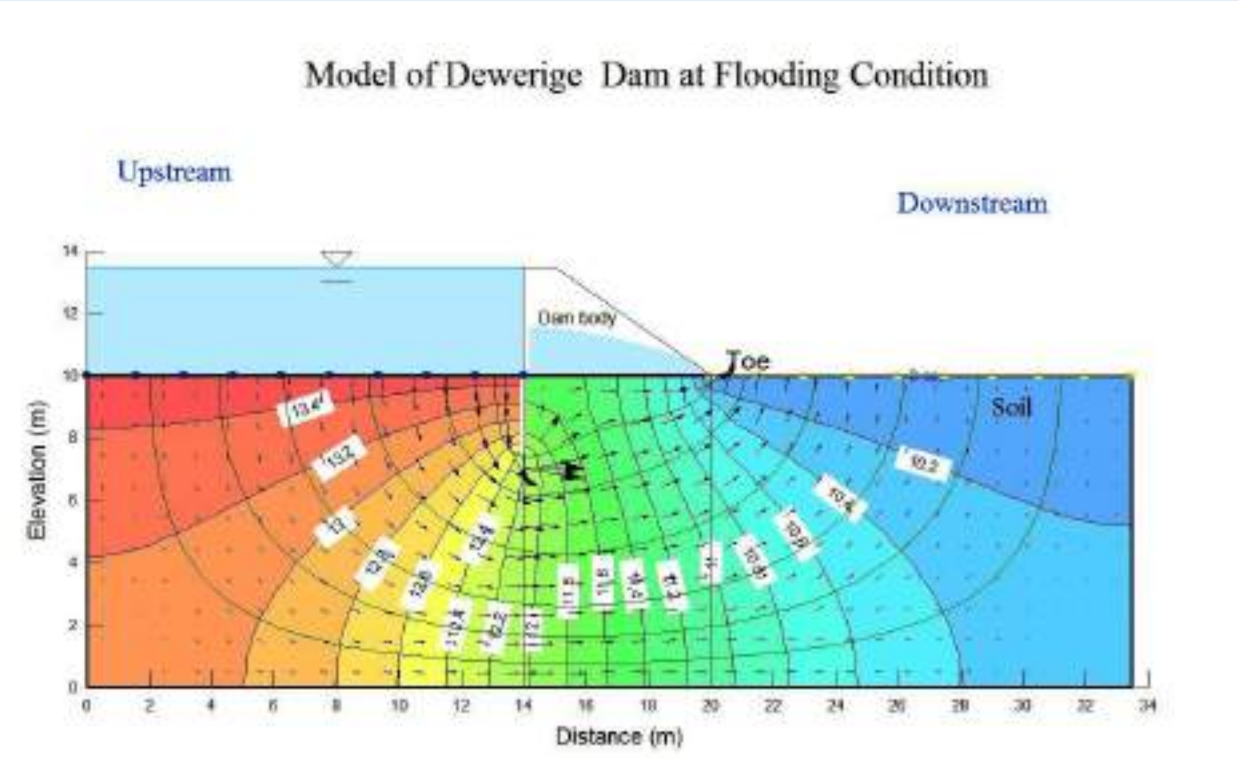

Fig. 5.35 Cross-section shows distribution of total head under the dam in (meters)

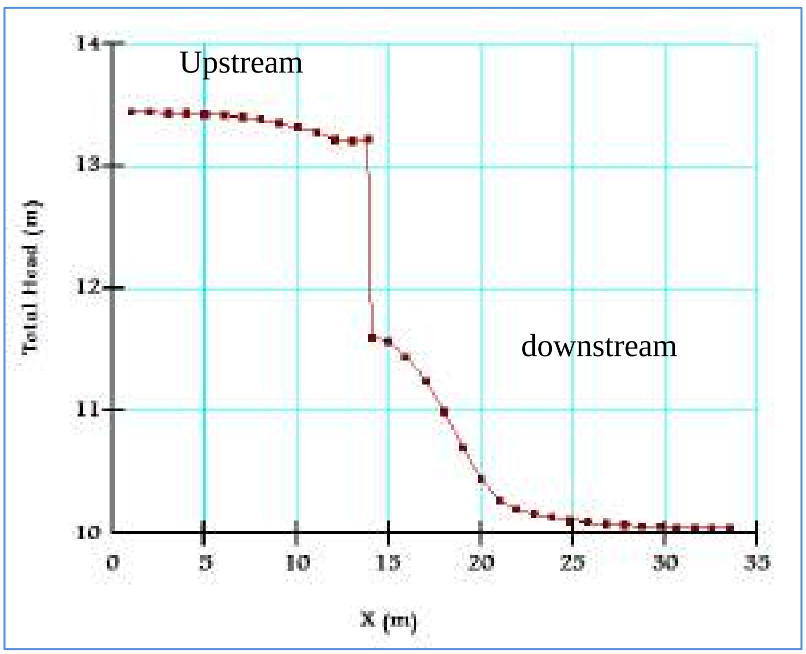

Fig. 5.36 Total head under the dam in X axis

5.6.3 The pressure head results :

Difference between upstream and downstream in pressure head, Fig. 5.37 and 5.38.

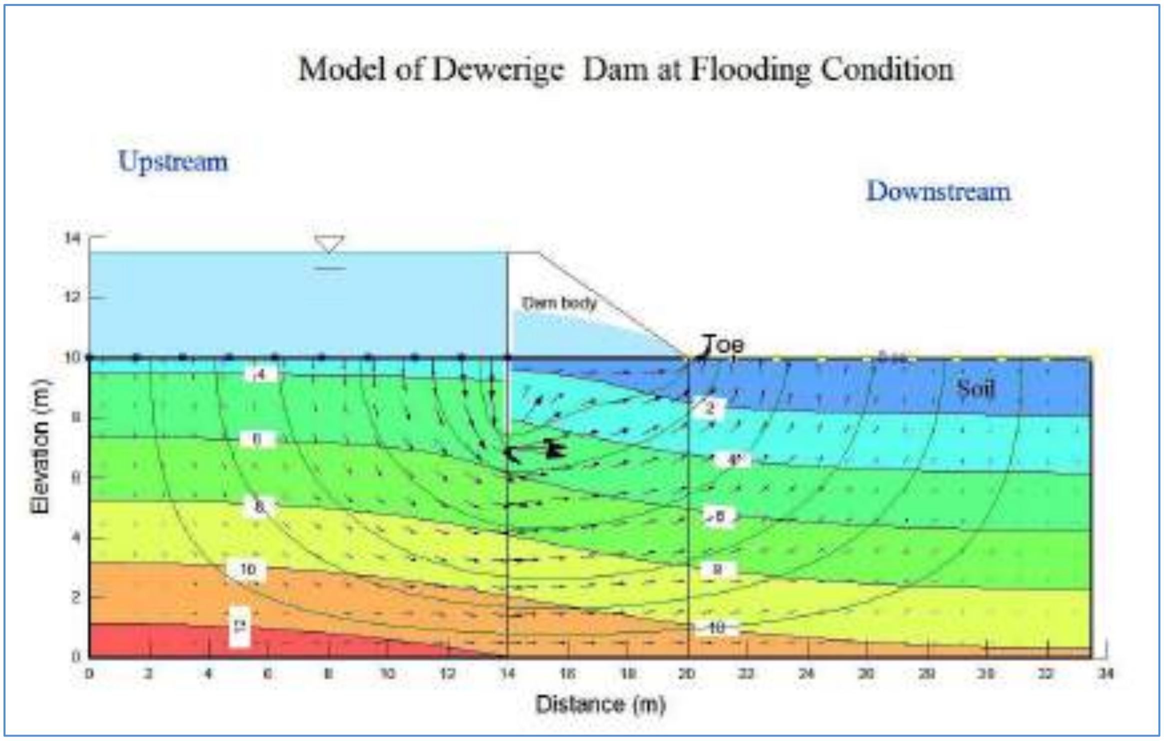

Fig. 5.37 Cross-section shows distribution of pressure head under the dam in (meters)

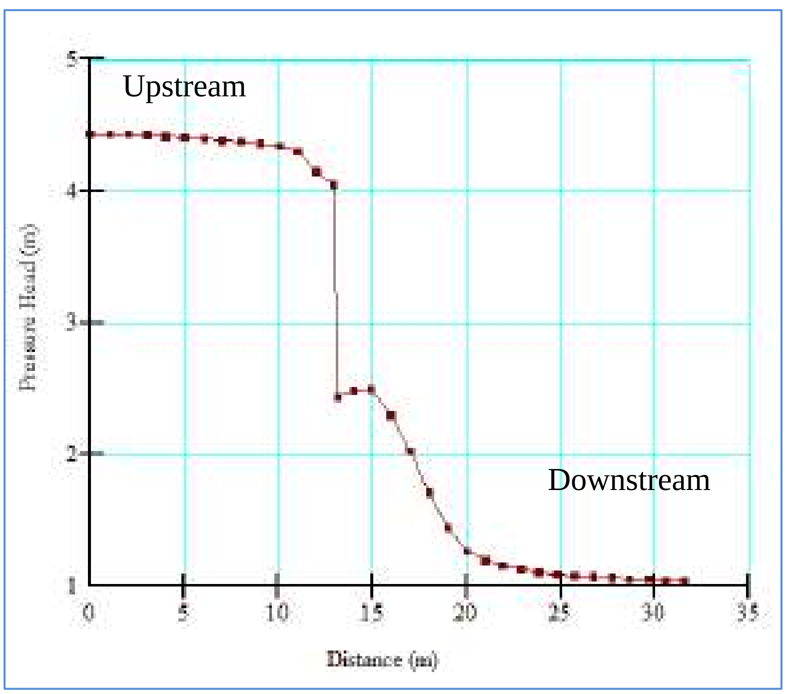

Fig. 5.38 pressure head in foundation soil (meters)

5.6.4 Pore-water pressure results (uplift pressure)

SEEP/W model explaine the difference in uplift pressure under dam body in the heel to toe. The difference in the pore pressure in the two sides is a serious problem because quicksand maybe happened on the downstream side because of the high pore water Fig. 5.39 , 5.40.

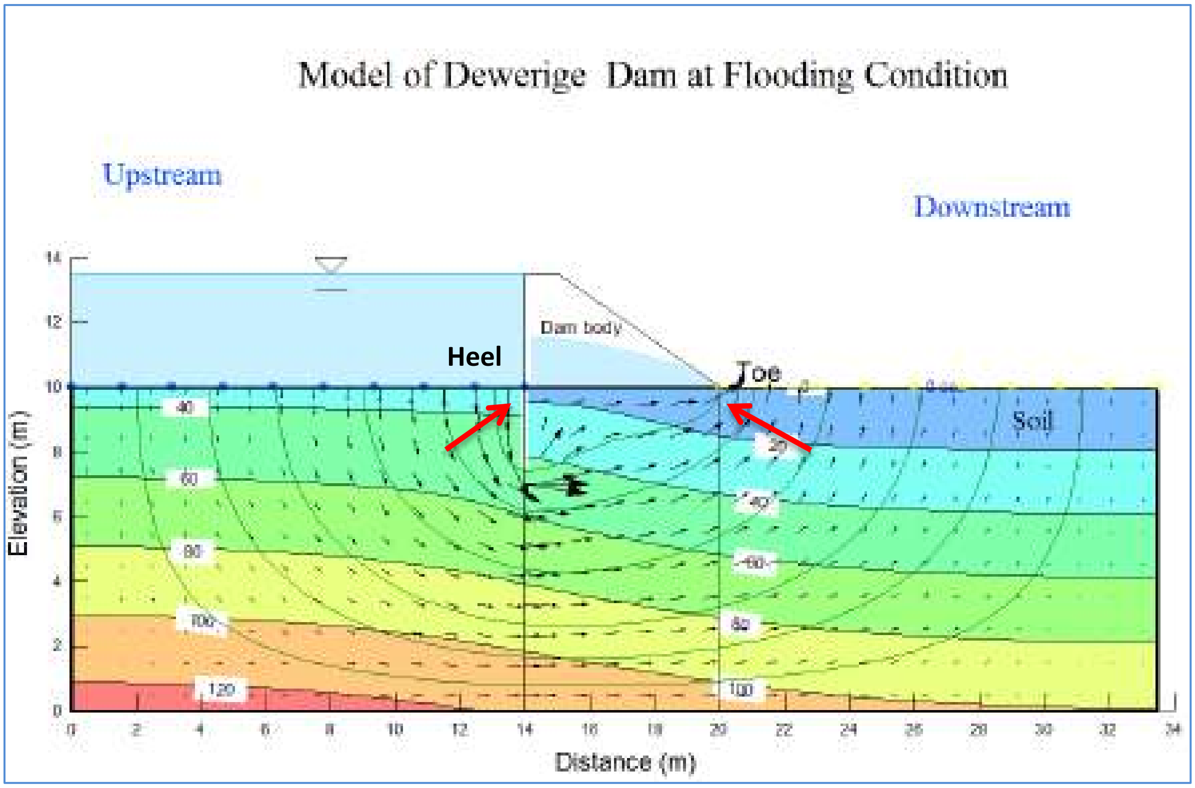

Fig. 5.39 Cross-section shows distribution of pore-water pressure under the dam in (kPa)

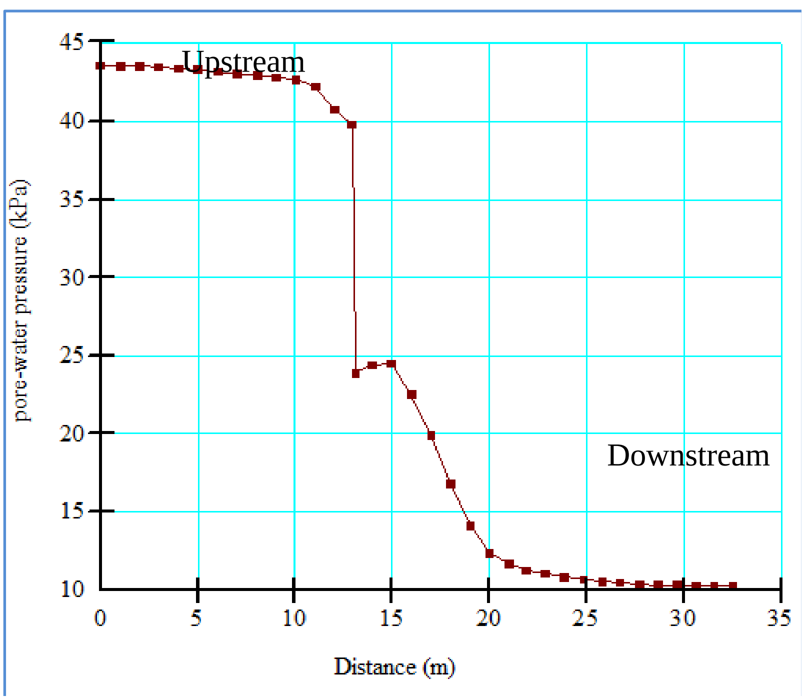

Fig. 5.40 pore-water pressure under the dam (kPa)

5.6.5 Seepage velocity results :

- Seepage velocity with depth / velocity of seepage within foundation soil in with depth concentrated under dam body is shown in Fig. 5.41, 5.42.

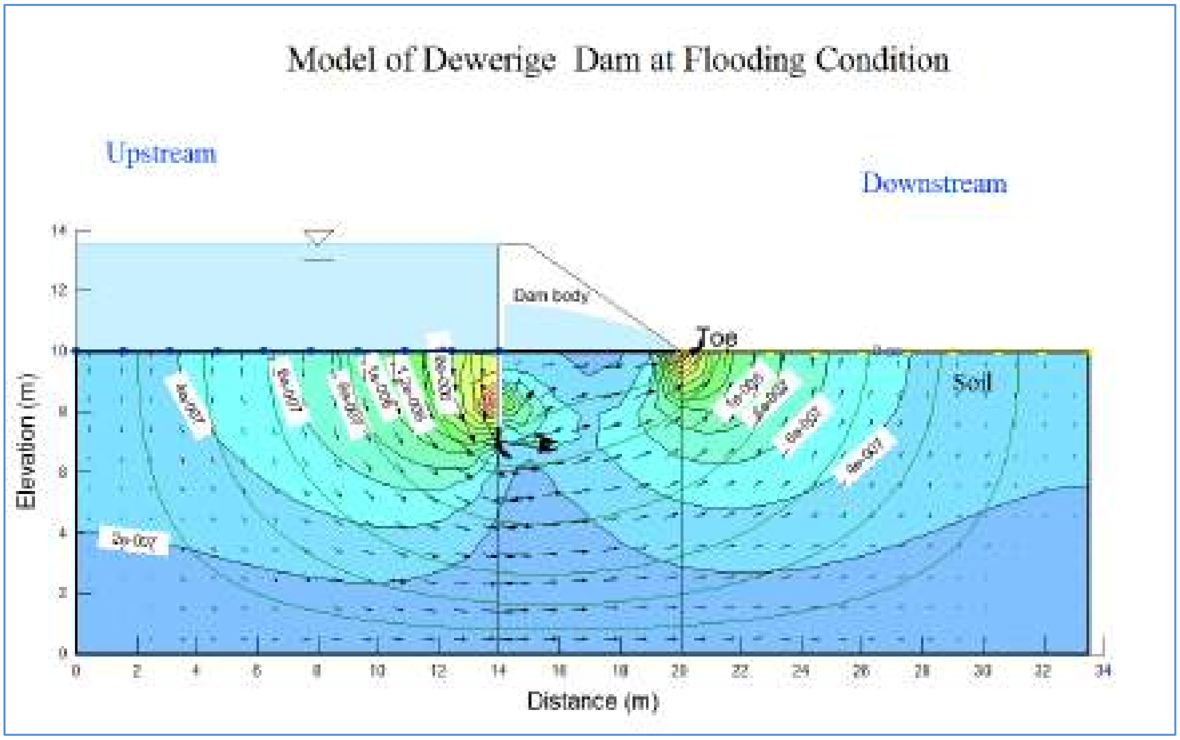

Fig. 5.41 Cross-section shows distribution of seepage velocity in Y-axis under the dam

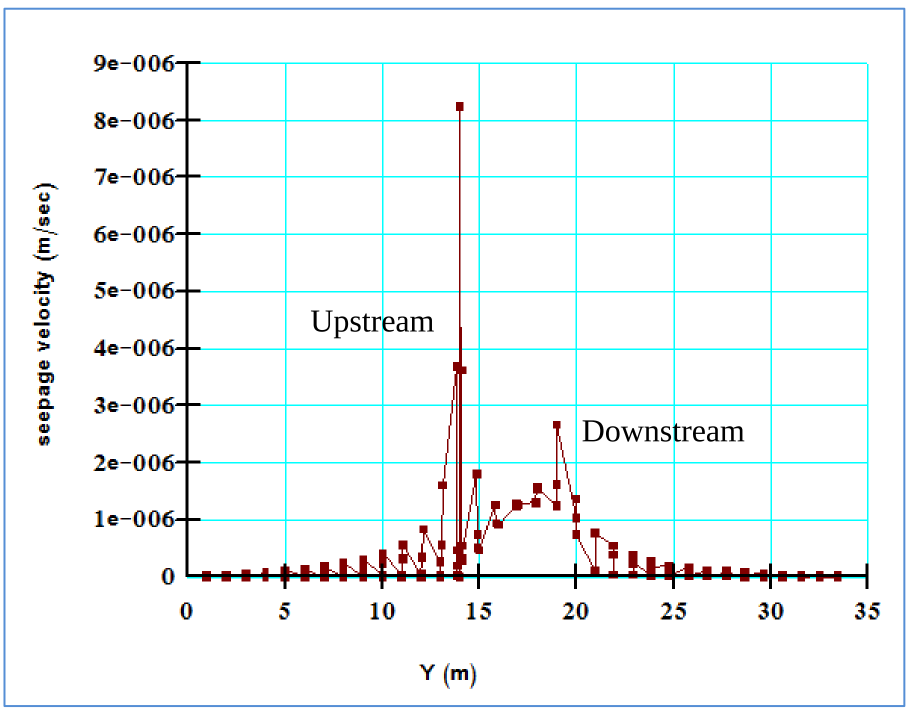

Fig. 5.42 Seepage velocity with depth

- Seepage velocity with distance / velocity of seepage in X-axis is very low and concentrated in heel, Fig. 5.43 , 5.44.

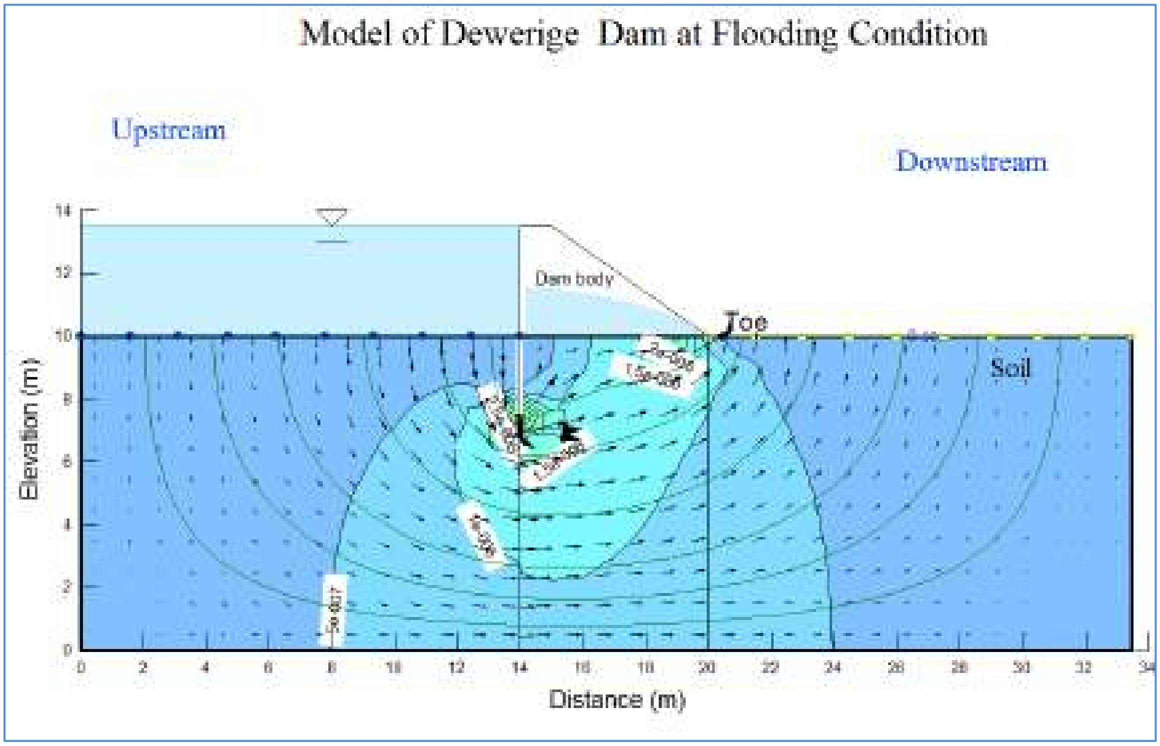

Fig. 5.43 Cross-section shows seepage velocity in X-axis

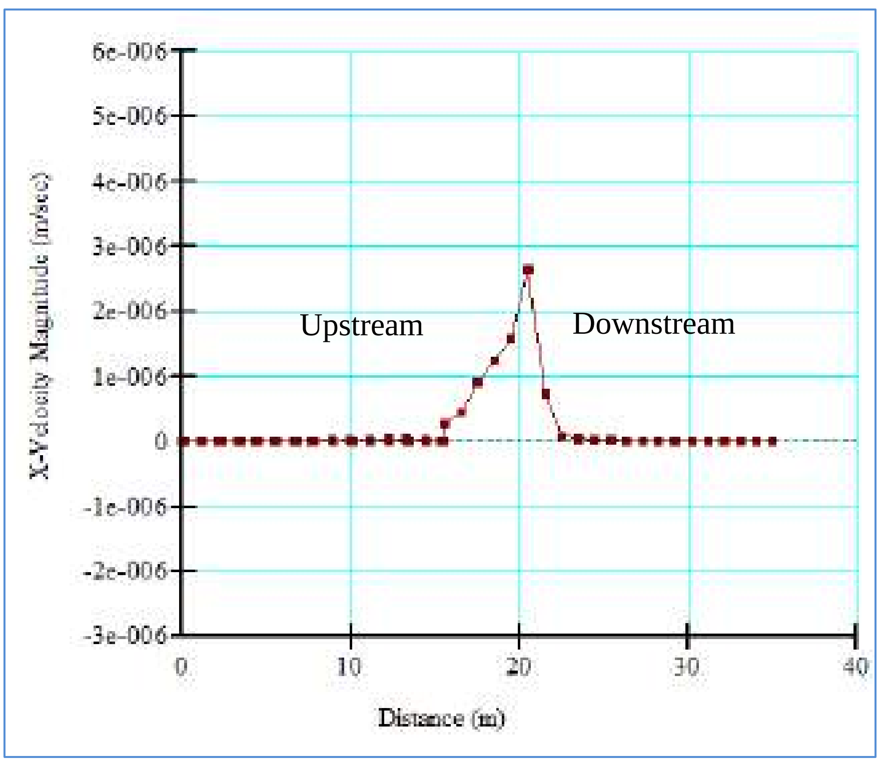

Fig. 5.44 Seepage velocity in X-axis

5.6.6 Hydraulic gradient result :

Fig. 5.45 , 5.46 illustrate hydraulic gradient in foundation soil between upstream and downstream with depth.

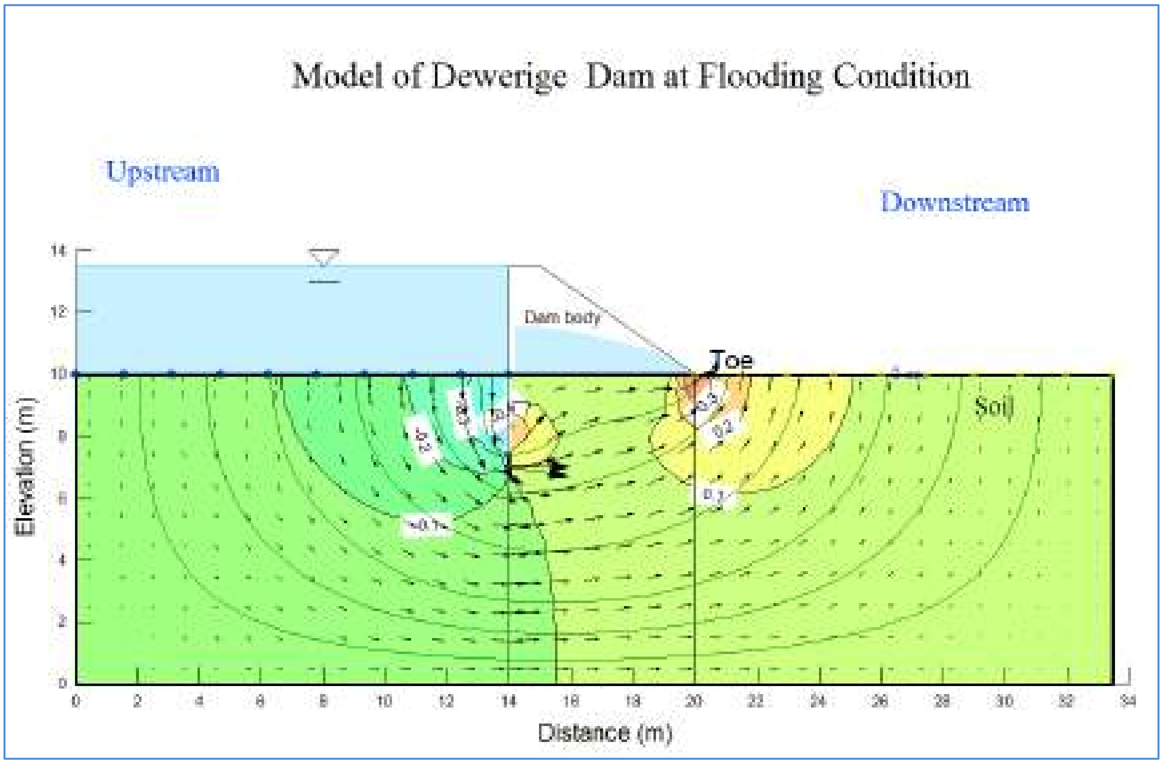

Fig. 5.45 Cross-section display hydraulic gradient in Y axis

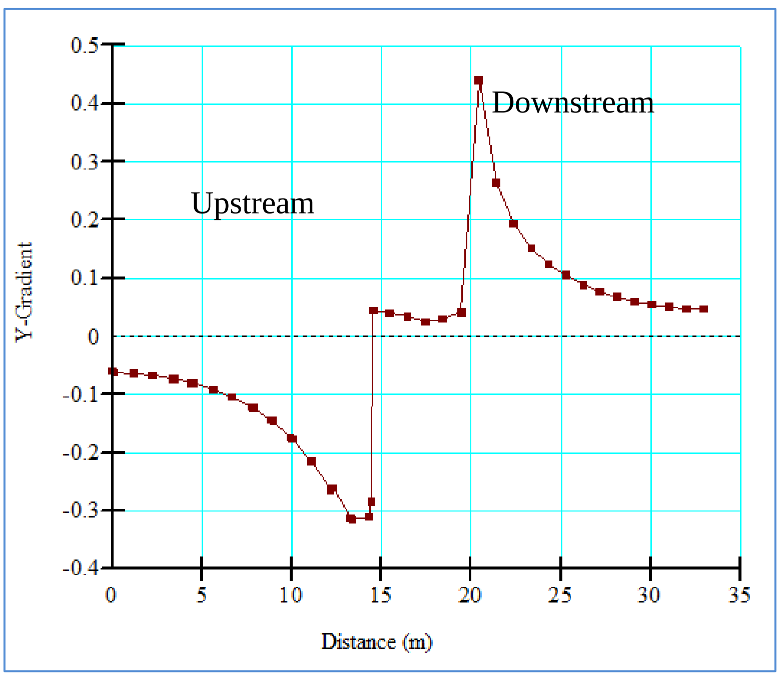

Fig. 5.46 Hydraulic gradient in Y-axis

The relationship between seepage velocity & hydraulic gradient shown in Darcy law:

$$v = i\,k \qquad (5\text{-}4)$$

where:

v= seepage velocity.
i= hydraulic gradient .
k= permeability.

Both of Fig. 5.47 , 5.48 illustrate the proportionality between (v and i).

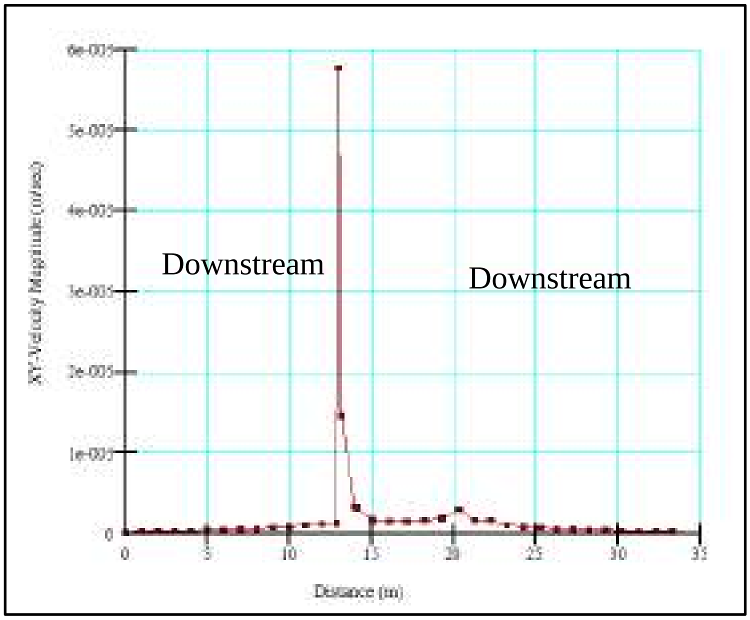

Fig.5.47 Seepage velocity under the dam in XY

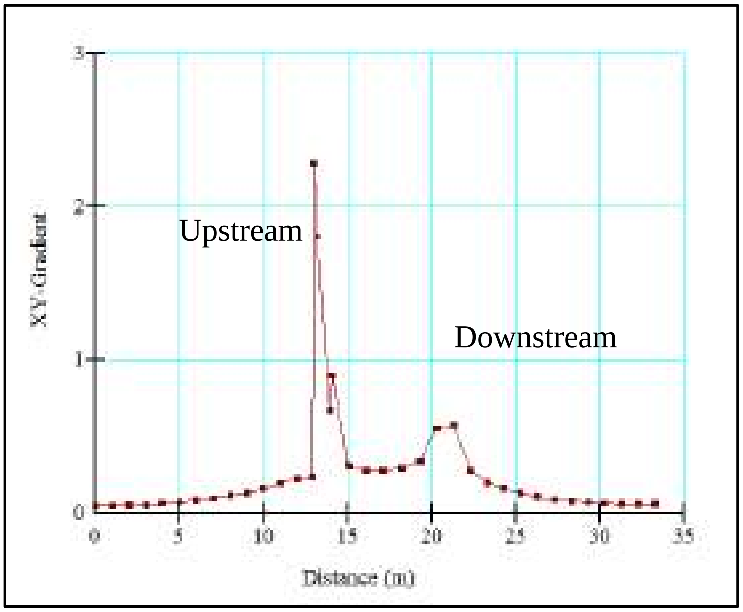

Fig.5.48 Hydraulic gradient under the dam XY

5.6.7 Summery of seepage simulation model

The results of SEEP/W model can be summarized based on hydraulic parameters which shown in Table (5.3).

Table: 5.3 summarized the outputs of simulation model

Hydraulic parameters	Min.	Depth	Max.	Depth
Total head	10 m	1m (upstream)	13.5 m	1m (downstream)
Pore-water pressure	0 kPa	0 m	129.06 kPa	10 m
Pressure head	0 m	0 m	13.15 m	10 m
X-velocity	5.9×10^{-11}	m	8.2×10^{-6}	At toe & cut-off
Y-velocity	3.7×10^{-9}	m	2.9×10^{-6}	At toe & cut-off
XY - Hydraulic gradient	0.004	2 m	1.2	At toe & cut-off

5.6.8 Calculation of piping safety factor under the dam

Hydraulic gradient as explained in Fig. (5.45, 5.46) concentrated under the dam at heel and toe.

To compute piping safety factor in downstream at toe :

1. Extraction hydraulic gradient at toe, Fig.5.49 (i_{exit}, hydraulic gradient = 0.45).

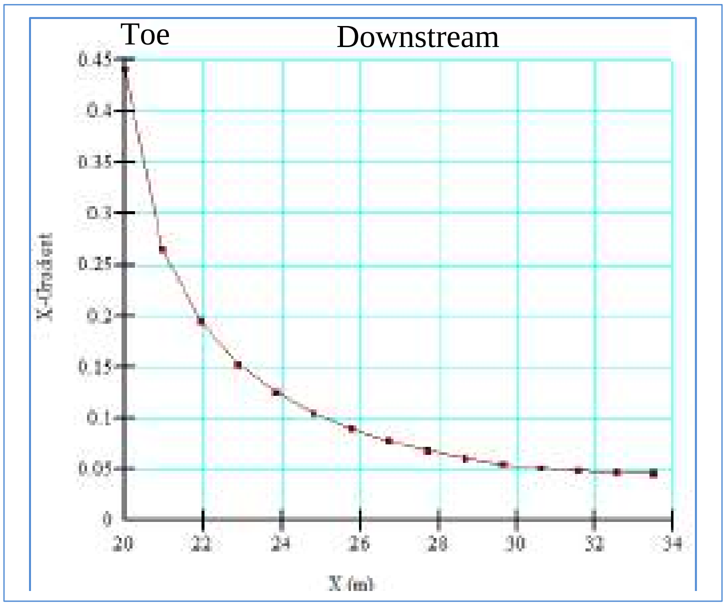

Fig.5.49 Hydraulic gradient at water exit (toe)

2. Calculation critical hydraulic gradient ($i_{critical}$) and piping safety factor by the following equations (Das and Sobhan,2013) :

Critical hydraulic gradient ($i_{critical}$) = $\frac{\gamma'}{\gamma w} = \frac{\gamma sat - \gamma w}{\gamma w}$ .... (5-5)

Hydraulic gradient (i_{exit}) have to be less than ($i_{critical}$), according to the result of simulation model in Table (5.3) hydraulic gradient under the dam range (0.005 – 1.2).

Critical hydraulic gradient ($i_{critical}$) $= \frac{\gamma sat - \gamma w}{\gamma w} = \frac{19.45 - 9.81}{9.81} = 0.98$

Piping safety factor (F_{Piping}) = $\frac{\text{i critical}}{\text{i exit}}$..(5-6)

$F_{\text{piping in soil}} = \frac{0.98}{00.45} = 2.1$

Since piping safety factor (2.1), Therefore the dam is relatively safe against piping problem in flooding condition.

CHAPTER SIX

Conclusions and Recommendations

CHAPTER SIX
Conclusions and Recommendations

6.1 - Conclusions of this study can be summarized as :

1. Soils of dam shoulder consist of dispersive soil class 2.
2. Based on (Emerson test 1967) dispersion degree in soil of dam shoulders classified as a moderate dispersive soil.
3. Concrete of dam body exposed to sulfates attack (as explained in chapter three and five) in down steam side, by the action of high salinity ratio in water of Dewerige dam.
4. The amount of siltation in the dam reservoir was similar to the initial calculations of siltation in 2009. Siltation decreasing the economic live time of the dam from 50year to 24 year for one year only, That is very dangerous and threatens completely bury to the reservoir in the next few years.

5. **Seepage modeling**
   - ✓ SEEP/W software which used to analyze seepage in foundation soil of Dewerige dam in 2D provide a good accuracy outputs compared with hand solutions, which make it a very important tool in geotechnical studies.
   - ✓ Hydraulic gradient and seepage velocity can be observed in maximum values under the dam body, especially in heel and toe, which produce internal erosion threaten stability of dam.
   - ✓ Dewerige dam is safety from piping problem, because of piping safety factor is 2.1, while piping safety factor have to 5 or more according to design studies of small dams.

6.2 – Recommendations

1 - **Sulfates attack** / It's a very necessary to use sulfates resistant coating to paint the surface of dam in zone III.

2- **Dispersive soil** / improve soil by using :

i. Soil stabilization by add gypsum or lime, to dam shoulders to support the dispersive soil. Since soil of dam shoulder is basic the gypsum will be used to increasing strength and supports soil stability.

ii. Soil stabilization by add organic material which increase bonding between soil particles and improve stability of soil (Davies et al ,2010).

iii. For more benefit organic material can be used with gypsum or lime with the same time.

3- **Siltation problem** /

a. Administration of watershed (erosion and deposition) in designing stage is a perfect way to decreasing accumulation of silt in reservoir.
b. Rehabilitation of storage capacity: through periodic maintenance for reservoir including : partially removal for siltation which depend upon reservoir topography, amount of water and the cost.
c. Maintenance of bottom outlet to avoid block out and Damage by the action of siltation velocity flow.
d. Using the removal sedimentation to improve agricultural land and used building.

4 - **Seepage problem**

a. **Using slurry trench** (consist of mixture of sand , gravel and slurry with width range (1-3) m and depth based on drilling method) to extend in foundation soil especially at maximum seepage velocity.
b. **Drilling wells** for relief pressure to controlling on hydraulic gradient at exit in foundation soil.

REFERENCES

References

Adwubi, A., Amegashie, B. K., Agyare, W. A., Tamene, L., Odai, S. N., Quansah, C., & Vlek, P. (2009). Assessing sediment inputs to small reservoirs in Upper East Region, Ghana. Lakes & Reservoirs: Research & Management, 14(4), 279-287.

Alahiane, N., El Mouden, A., Lhaj, A. A., & Boutaleb, S. (2014). Practical method proposed to estimate silting’s rate in small and hillside dams. Journal of water resource and protection, 6(10), 930.

Albergel, J., Pepin, Y., Nasri, S., & Boufaroua, M. (1998). Modeling small dams siltation with MUSLE. rain water harvesting and management of small reservoirs in arid and semi-arid areas. Proc LUTVDG/(TVVR-3222)/1-316/1999, Atelier hydromed de Lund, 29, 197-203.

Albergel, J., Pepin, Y., Nasri, S., & Boufaroua, M. (1998). Modeling small dams siltation with MUSLE. Rain water harvesting and management of small reservoirs in arid and semi-arid areas. Proc LUTVDG/(TVVR-3222)/1-316/1999, Atelier HYDROMED de Lund, 29, 197-203.

Ali, A. J., & Khoshaba, B. N. (1981). Heavy minerals study of L. Bakhtiari Formation. Jor. Geol. soc. Iraq, 14(1), 15-24.

Al-Kadhimi, T. K. H., Banfill, P. F. G., Millard, S. G., & Bungey, J. H. (1996). An accelerated carbonation procedure for studies on concrete. Advances in Cement Research, 8(30), 47-59.

Alwan, N. K. (2014). Estimating the volume of the runoff in Dewerige basin. Journal of geographic research Vol, 2(21).

Anonymous. (1999). Definition of geotechnical engineering, ground engineering Magazine, Vol. 32, No. 11, p. 39.

Aqrawi, A. A., Goff, J. C., Horbury, A. D., & Sadooni, F. N. (2010). The petroleum geology of Iraq. Scientific Press.

ASTM D 2166.(2001). Standard Test Method Unconfined Compressive Strength of Cohesive Soil Annual Book For Laboratory Testing: Vol.4 Part8.

ASTM D 2435-96(1996). Standard Test Method for One-Dimensional Consolidation Properties of Soils.

ASTM D 422.(2002). Standard Test Method for Partials size Analysis of Soils.USA.

ASTM D 4318.(2000). Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

ASTM D 854.(2002). Standard Test Method for Specific Gravity of Soil Solid by water.

Atkinson, K. E. (2008). An introduction to numerical analysis. John Wiley & Sons.

Ayyub, B. M. (1997). Uncertainty modeling and analysis in civil engineering. CRC Press.

Berney, O., Charman, J., Kostov, L., Minetti, L., Stoutesdijk, J., & Tricoli, D. (2001). Small dams and weirs in earth and gabion materials. AGL/MISC/32/2001, FAO, Rome, 1–172.

Bligh, W. G. (1915). Dams and Weirs: An Analytical and Practical Treatise on Gravity Dams and Weirs; Arch and Buttress Dams; Submerged Weirs; and Barrages. American Technical Society.

Bronick, C. J., & Lal, R. (2005). Soil structure and management: a review. Geoderma, 124(1), 3-22.

Bruk, S. (1985). Methods of Computing Sedimentation in Lakes and Reservoirs. IHP-II Project A. 2.6. 1. Unesco.

Buday, T., & Jassim, S. Z**.** (1987). The Regional geology of Iraq: Vol. 2. Tectonism, Magmatism and Metamorphism, Baghdad, 352.

BUREAU, O. R. (1977). Design of small dams. Washington. DC: Govt. Print. Off.

Burland, J.B. ,1996. Closing session discussions, proceedings of the first international conference on unsaturated soils conference, Paris, Vol. 3, p. 1562. (proceedings published by A.A. Balkema; Editors, E.E, Alonso and P. Delage).

Chanson, H., & James, D. P. (1999, January). Siltation of Australian reservoirs: some observations and dam safety implications. In Proceedings of the 28th International Association of Hydrological Sciences Congress, Session B (Vol. 5).

Das, B. M., & Sobhan, K. (2013). Principles of geotechnical engineering. cengage Learning.

Davies, S., & Lacey, A. (2009). Identifying dispersive soils. Western Australia, department of agriculture and food.

Duncan, J. M. (2000). Factors of safety and reliability in geotechnical engineering. Journal of geotechnical and geoenvironmental engineering, 126(4), 307-316.

Emerson, W. W. (1967). A classification of soil aggregates based on their coherence in water. soil research, 5(1), 47-57.

Fell, R., MacGregor, P., Stapledon, D., & Bell, G. (2005). Geotechnical engineering of dams. CRC Press.

Gandhi, G. N. Geotechnical aspect of dam safety and foundation problems.

GEBHARDT, K., & Van Havern, B. P. (1986). William L. Jackson. In drainage basin sediment delivery: proceedings of a symposium held in Albuquerque, New Mexico, USA, 4-8 August, 1986 (No. 159, p. 413). International Association of Hydrological Sciences.

Geologic Hazards and Environmental Impacts (No. 2008-1241). Geological Survey (US).

Goldstein, S. (1936). A note on the measurement of total head and static pressure in a turbulent stream. Proc. R. Soc. Lond. A, 155(886), 570-575.

Hardie, M. A., Doyle, R. B., Cotching, W. E., Duckett, T., & Zund, P. (2009). Dispersive Soils and their Management, Technical Reference Manual.

Hinchberger, S., Weck, J., & Newson, T. (2010). Mechanical and hydraulic characterization of plastic concrete for seepage cut-off walls. Canadian Geotechnical Journal, 47(4), 461-471.

Holtz, R. D., & Kovacs, W. D. (1981). An introduction to geotechnical engineering (No. Monograph).

Ingles, O. G., & Metcalf, J. B. (1972). Soil stabilization principles and practice (Vol. 11, No. Textbook).

Iraqi Meteorical Organization (I.M.O), climatological section, climatological Atlas of Iraq, 2003, Baghdad , p.12,29.

Jassim, S. Z., & Goff, J. C**.** (Eds.). (2006). Geology of Iraq. DOLIN, sro, distributed by Geological Society of London.

Kareem, A. H. A. (2010). Analysis of the construction behaviour of western desert Horan dam H-2. Journal of Iraqi Desert Studies Vol, 2(2).

Kay, M. (2007). Practical hydraulics. CRC Press.

Khan, M. J., Khan, G. D., Ullah, O., & Khan, M. Z. (2007). Sediment load assessment of small embankment dams in southern regions of NWFP [Pakistan]. Sarhad Journal of Agriculture (Pakistan).

Khan, M. S., Gul, M. A., & Aziz, M. (2012). Geological aspects of seepage problem and its management at Khanpur dam project, Pakistan. Journal of Himalayan Earth Sciences, 45(1), 77-81.Kirkuk/north Iraq. Journal of Pure Science (7)21.

Kraatz, D. B., & Mahajan, I. K. (1982). Small hydraulic structures (Vol. 1). Food & Agriculture Org.

Krahn, **J.** (2004). Seepage modeling with SEEP/W: An engineering methodology. GEO-SLOPE International Ltd. Calgary, Alberta, Canada.

Krahn, **J.** (2007). Stress-deformation modeling with SIGMA/W 2007: An Engineering Methodology. GEO-SLOPE International Ltd., Calgary, Alta.

Ljungblad, M., & Bäckström, J. (2016). Safety Evaluation of the Zhaoli Tailings Dam: A seepage, deformation and stability analysis with GeoStudio.

Marchand, J., Odler, I., & Skalny, J. P. (2003). Sulfate attack on concrete. CRC Press.

Ministry of water resource, center of studies and engineering design,2009.

Missan consultant engineering bureau, 2009. Geotechnical investigation report for Dewerige dam site.

Morgenstern, N.R. 2000. Common ground, invited paper, conference proceedings, GeoEng2000, Melbourne, Australia.

Mustansiriya University, Engineering college 2007 . Planning Report of KHASA CHAI dam.

Nagaraj, T. S., & Murthy, B. S. (1985). Prediction of the preconsolidation pressure and recompression index of soils.

Nasser, A. S. 2014 . Evaluation of storage for Dewerige weir and creation a 3D model using Gis. Journal if Al- Taqani , Vol. 27 , No. 4.

Neville, A. (2004). The confused world of sulfate attack on concrete. cement and concrete research, 34(8), 1275-1296.

Noori, B., & Ismaeel, K. S. (2011). Evaluation of seepage and stability of Duhok dam. Al-Rafadain Engineering Journal, 19(1).

Ouyang, C., Nanni, A., & Chang, W. F**.** (1988). Internal and external sources of sulfate ions in Portland cement mortar: two types of chemical attack. Cement and Concrete Research, 18(5), 699-709.

Pollock, D. W. (1988). Semianalytical computation of path lines for finite-difference models. Groundwater, 26(6), 743-750.

Richards, K. S., & Reddy, K. R. (2007). Critical appraisal of piping phenomena in earth dams. Bulletin of engineering geology and the environment, 66(4), 381-402.

Rickard, C., Day, R., & Purseglove, J. (2003). River Weirs–Good Practice Guide Guide-Section A. Unpublished report for Environment Agency.

Rogers, J. D. (2006). Subsurface exploration using the standard penetration test and the cone penetrometer test. Environmental & Engineering Geoscience, 12(2), 161-179.

Sheraed, J. L., Dunnigan, L. P., & Decker, R. S. (1976). Identification and nature of dispersive soils. Journal of Geotechnical and Geoenvironmental Engineering, 102(Proc. Paper# 12052).

Skempton, A. W. (1953). The colloidal activity of clays. Selected papers on soil mechanics, 106-118.

Swenty, B. J. (1989). Engineering Analysis of Dams. Department of Natural Resources, Division of Geology and Land Survey.

Swenty, G. J., & Westphal, J. (1989). Basin lag as a function of rainfall.

Taylor, H. F. (1997). Cement chemistry. Thomas Telford.

Terzaghi, K., Peck, R. B., & Mesri, G. (1996). Soil mechanics in engineering practice. John Wiley & Sons.

The Republic of Iraq, Ministry of Irrigation, the general commission of dams and reservoirs, geotechnical report of Dewerige dam,2009.

The Republic of Iraq, Ministry of water resources, center of studies and engineering designs, dams department,2009. hydrologic study for Al-Shahabi, Al-Teeb ,Al-Dewerige dams.

The Republic of Iraq, Ministry of water resources, center of studies and engineering designs, dams department, Khasa Chai dam,2007.

Tigray, E.(2006). Small-scale reservoir sedimentation rate analysis for a reliable estimation of irrigation schemes economic lifetime (A case study of Adigudom area, Tigray, northern Ethiopia).

Tomlinson, S. S., & Vaid, Y. P. (2000). Seepage forces and confining pressure effects on piping erosion. Canadian Geotechnical Journal, 37(1), 1-13.

Valentin, C., Poesen, J., & Li, Y. (2005). Gully erosion: impacts, factors and control. Catena, 63(2), 132-153.

Wahlstrom, E. (2012). Dams, dam foundations, and reservoir sites (Vol. 6). Elsevier.

Whitaker, S. (1986). Flow in porous media I: A theoretical derivation of Darcy's law. Transport in porous media, 1(1), 3-25.

Wood, P. J., & Armitage, P. D. (1997). Biological effects of fine sediment in the lotic environment. Environmental management, 21(2), 203-217.

الخلاصـــــــــــة :

تناولت الدراسة الحالية المشاكل الجيوتنيكية والهايدرولوجية في مشروع سد الدويريج . تم اختيار الموضوع لأهمية المشروع كون السد هو الأول من مجموعة سدود من المؤمل انجازها في المنطقة لحمايتها من الفيضان وتطوير برنامج حصاد المياه إضافة الى الاستخدامات الأخرى. إضافة الى كون السد قد انجز قبل سنة من بدء الدراسة وبالتالي من الممكن مقارنة الحسابات التصميمية للسد مع الواقع الفعلي لبعض اهم المشاكل الجيوتكنيكية فيه.

استخدمت الصور الفضائية والمسوحات الحقلية لرسم الخارطة الجيولوجية الهندسية للموقع وبمقياس 1:50000 حيث تم تحديد اهم أنواع التربة في المنطقة. كما ان التقارير السابقة عن السد وعن جيولوجية المنطقة والفحوصات الموقعية للتربة قد تم تحليلها لمعرفة وتقييم المواصفات الجيوتكنيكية لتربة الموقع.

لتسهيل دراسة المشاكل الجيوتكنيكية فقد قمنا بتصنيفها ضمن مجموعتين:

المجموعة الاولى تضمنت المشاكل الجيوتكنيكية المؤثرة على كفاءة المشروع وتشمل : مشكلة رواسب السلت في خزان السد و مشكلة التاكل في تربة اكتاف السد.

المجموعة الثانية تضمنت المشاكل الجيوتكنيكية التي تؤثر على استقرارية جسم السد وتشمل:

تأثير الكبريتات على الهيكل الكونكريتي للسد و التسرب وتأثيره على مشكلة التعرية للتربة اسفل السد وحساب معامل الأمان الفعلي للسد ضد مشكلة رفع قاعدة السد.

بالنسبة لحساب كمية الترسبات في خزان السد تم اعتماد طريقة مباشرة اعتمدت على حساب المنسوب الاولي لخزان السد باستخدام معلومات المسح الأرضي للخزان قبل التشغيل. اما منسوب السلت فقد تم قياسه موقعيا في موسم الجفاف وبالتالي تم حساب الحجم الفعلي للسلت في السنة الأولى للشغيل الخزان إضافة الى العمر الاقتصادي المتوقع للسد وتم مقارنته مع الحسابات التصميمية للمشروع.

يمثل التاكل للتربة الطينية الغنية بالسلت والحاوية على الصوديوم واحد من اخطر المشاكل المؤثرة على المشاريع الهندسية عموما ومشاريع السدود خصوصا نتيجة لتسببها بتكون الفجوات و إزالة التربة الساندة للمنشأ. أظهرت الصور الفضائية للقمر الصناعي الأوربي Birds Eye وجود المشكلة في المناطق المحيطة بالسد وتأثيرها على الطرقات والسداد في المنطقة. تم اجراء مسح موقعي لمنطقة السد وتبين وجود هذه المشكلة في الموقع. تم اخذ 20 نموذج من تربة المنطقة بواقع عشرة نماذج من الكتف الأيمن وعشرة من منطقة الكتف الايسر للسد. استخدم تحليل ايمرسون Emerson لتحديد رتبة التاكل للمعادن الطيني ودرجة تأثرها بالتاكل. رسمت النتائج على خارطة أظهرت شدة التأكل في كل منطقة من اكتاف السد وتم اقتراح عدة طرق لمعالجة المشكلة.

استقرارية جسم السد تمثل واحدة من أخطر المشاكل التي يجب ان يتم متابعتها خلال او بعد العمر التشغيلي للسد لان أي مشكلة ولو بسيطة يمكن ان تؤثر على سلامة الأشخاص والمنشآت.

وفي هذا المجال درس تأثير الكبريتات على الجسم الكونكريتي للسد من خلال مسح المنشأ موقعيا وتم تقسيمه الى ثلاثة انطقة من حيث تأثير الكبريتات. تبين بان النطاق III والواقع في اسفل السد هو الموقع الأكثر تأثرا نتيجة لزيادة نسبة الكبريتات الموجودة في المياه نتيجة التبخر. تم اقتراح المعالجات المطلوبة لحل المشكلة.

كما تم بناء الموديل الرقمي باستخدام برنامج SEEP/w لحساب تأثير تعرية التربة اسفل قاعدة السد نتيجة تسرب الماء اسفل جسم السد إضافة الى حساب معامل الأمان الفعلي لقاعدة السد ضد تأثير ضغط المياه. من الموديل الناتج تم دراسة فرق ارتفاع المياه امام وخلف السد وسرعة تسرب المياه ومساراتها إضافة الى ضغط الماء المسامي في التربة امام و خلف السد. ايضاً تم تحديد اخطر منطقة لتعرية التربة اسفل قاعدة السد و اقتراح المعالجات لها. كما تم حساب معامل الأمان لجسم السد والذي اظهر ان جسم السد مستقر نسبيا.

دراســـة جيوتكنيكية وهيدرولوجية لمشروع سد الدويريج في محافظة ميسان/ جنوب العراق

رسالة مقدمة الى
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كجزء من متطلبات نيل درجة الماجستير
في الجيولوجيا الهندسية

من قبل
زهراء رسول فاخر السوداني
بكالوريوس / علوم جيولوجيا / 2008

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