



# Design a protection Dam for Wadium Allakhma in Wallyat Sur

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: Damage caused in the past times and left by rain which led to floods of water and affected human life. On the other hand the occurrence of scarcity of water after periods of rain, which led to the provision of quick solutions to avoid recurrence, such as constricted protection dam. In general dam is an engineering constriction that is built above a wadi or a low place, with the aim of reserving water. They are usually classified according to their forms, the materials used in their construction and the goals for which they were built. There are 2 types of dams that are determined in Oman according to the needs of the area to be applied which is: protection dam and Recharge Dams. The main objectives of this study are to conduct a feasibility study of design a protection dam for this area with most economically advantageous engineering solution protecting from flood in wadi um allakhma in wallyat SUR. to achieve this goal we will use many important method that's help as to provide a design for this dam like: using geological and hydrological data by analyzing rain and wadi station to run models and find the final design. In general by the initial data of this wadi, the total area of the catchment almost 400 km<sup>2</sup> which the possibility of saving up to 25-30 million m<sup>2</sup>

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## Introduction

The Sultanate of Oman located in arid and semi-arid area which have long dry periods for many years. However, it occasionally exposed to high rain events due to deep depressions and cyclones in summer and winter seasons. The number of cyclones hits the Sultanate increased during the last 20 years and the recurrence period between cyclones almost range between 3 to 6 years. Cyclones and high rain events causes flash floods which results in large losses in infrastructure services like roads, electric lines and other facilities, results in inundation of residential areas and results also in loss of life.

The highest recorded flood events hits the Sultanate was Gonu cyclone in 2007 which was categorized as level five cyclone and the data analysis done for the cyclone results in concluding that it has a return period of 500 year. The other high cyclone event hits the Sultanate was Phet cyclone in 2010 which categorized as level three cyclones and the return period of that cyclone is about 100 year.

The dam is a barrier that limits the water behind it for the purpose of storing large amounts of water and making use of it mainly for irrigation and generating electricity. Each dam has gates that allow it to remove excess water from the lake in the flood season. The dam is also very important for preventing flood waters from destroying and flooding agricultural land and villages near the riverbed. Geological and climatic factors are the best advantages for dam types.

The best location for dam construction is the narrow valley location where geology is suitable as a dam and the area in front of the dam is capable of storing large quantities of water. They are several points need to study before reached to design which are : area study , choice type of dam , geological study , topographic study , hydrological study , run module (HEC-RAS , HEC-HMS) , soil investigation and final design .



## Type of dam

The main objective of this study is to select and determine the type of dam in the overall environmental and economic aspects, which is important, to changes the amount of cost and the desired goal. This study was carried out in Al Amarat, specifically in the Al Mahj area located on the western side of the city center. Which caused many floods across the state and also had a direct impact on infrastructure and human relic? The team led by Eng. Said Al-HABSI led to visits to the area and to determine the level of damage caused by the first and second hurricanes in order to produce positive results, the most important of which is to work on setting up a dam for the area and determining its type in the following ways: study the hydrologic area and calculate the level of water passing through the main wadi . Analysis data of the water balance project prepared by the Ministry of Municipalities and Water Resources in 2013 and determining the amount of deficit and abundance of the region through a number of important points such as: Calculation the percentage of evaporation, quantity of water stored, quantity of discharge in the region,

The percentage of feed by the aflaj and neighboring farms in that period, calculation of agricultural consumption. After these analyzes, they prepare a questionnaire for the people of the region to know the water needs in order to find solutions at the environmental and agricultural level and the needs of the residents (Alhabsi, 2010). After these analyzes, they was achieved as following: Damaged and protected dam at the same time for the following reasons:

The results of the survey showed that the people have a deficit in water, both agricultural and domestic

- The percentage of rainfall and water flows directly to the sea without interest for the population of this water.
- Hydrological calculation of the region gives indications of stronger floods and more impact on the region in the future
- The area bears rocks of the type of sedimentary stone known as direct leakage of water and non-storage.

Finally, the results of the study decided the work of an integrated system of dams for the area, including reservoir storage and protection to solve all previous problems.



**Figure 1.** damage cause by floods

### **HEC-RAS, HEC-HMS Models**

(Al-Zahrani, M, 2016) The purpose of this study is to analyze and calculate the percentage of water in the region until the flood occurs by using different models which are HEC-RAS and HEC-HMS. were used to determine and calculate the quantities of water and to know how to determine the overall design , The area of Hafr al-Batin is the highest receiving area of rainfall and wadi flow in Saudi Arabia because it is located on three main channels in wadi, Which makes the region at the highest level of water and has a direct impact on the area located below this wadi and specifically on the downstream, in this study there are used method of collecting data from the stations of this wadi by taking the amounts of precipitation and water quantity and use HEC-RAS and HEC-HMS in the introduction of these data and exit with some important results which help them to designing the channels to reach the dam lake which simulate the flood in the city, summarized the results of programs as follows: The average depth of the flow of water within the city along the channels are : 3.02 , 3.26 , 3.46, 3.76 , 4.04 and 4.34 , which means the amount of highest water 4 meters Which gives an initial perception of the depths of the channels.

Return Period	Peak Discharge (m <sup>3</sup> /s)	Precipitation (mm)	Total Loss (mm)	Total Excess (mm)	Direct runoff (mm)	Discharge (mm)
Qmaf	11	18	14.24	3.76	3.65	3.65
5 - yr	28	26	17.47	8.53	8.33	8.33
10 - yr	54	36	20.27	15.73	15.40	15.40
20 - yr	81	45	22.08	22.92	22.48	22.48
50 - yr	121	58	23.98	34.02	33.42	33.42
100 - yr	150	67	24.98	42.02	41.31	41.31
200 - yr	182	77	25.87	51.13	50.30	50.30

Figure 2. HEC-RAS and HEC-HMS result

## Research Methodology

A combination of qualitative and quantitative approaches were used as shown in figure 1.3. The qualitative method includes interviews with 5 experts from MRMWR and analysis by constant method. The quantitative approach includes Design dam (Geological and topographic survey, Hydrological and soil investigation and Calculation and final design)

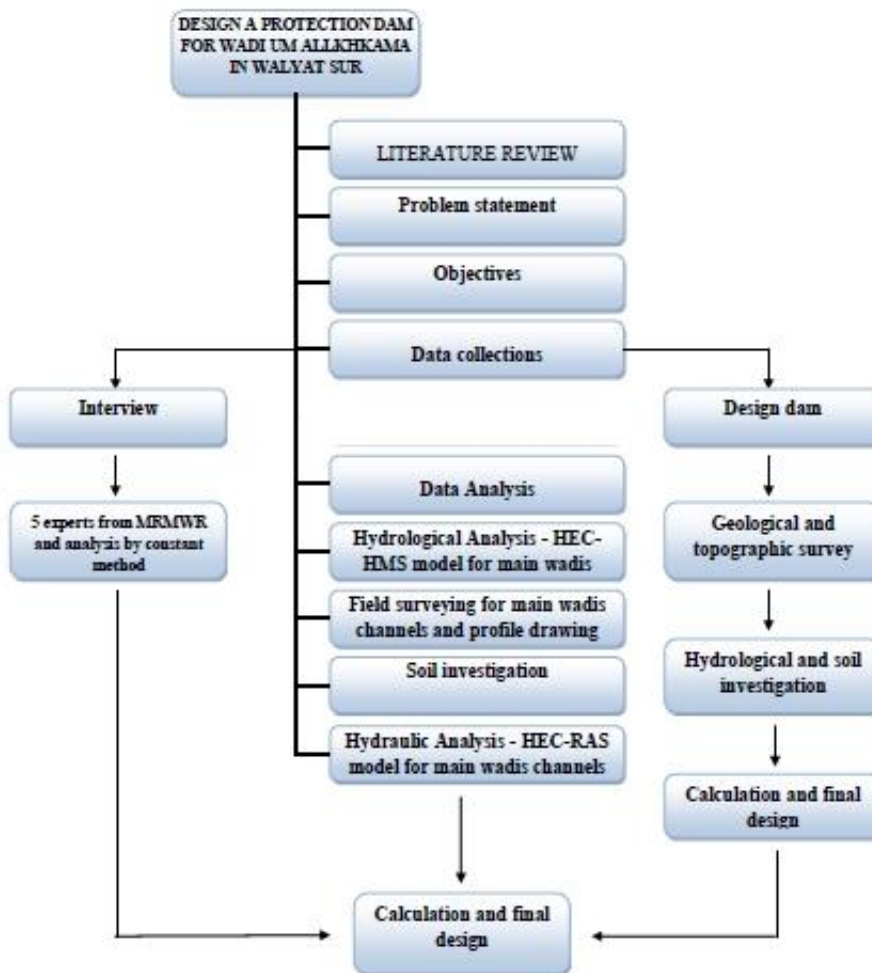


Figure 3. Research design

## Qualitative data analysis

Result is very important part in any project and studies which explain and finds the main calculation for all parts in methodology which are: soil investigation, hydraulic study, geological study, topographic survey, rainfall and runoff for the channel, etc... also analysis the data of interview by using qualitative method for 5 experts in ministry of regional municipalities and water resource. This chapter includes also the discussion part which discuss the result of the study and the main change in all parts and finally gets the final design of the dam with including the main impact and cost estimate of the dam.

**Question 1:** They are many important criteria should take for selected dam site for example: the geological structure of area, topographic, amount of water, soil investigation and nature of the site.

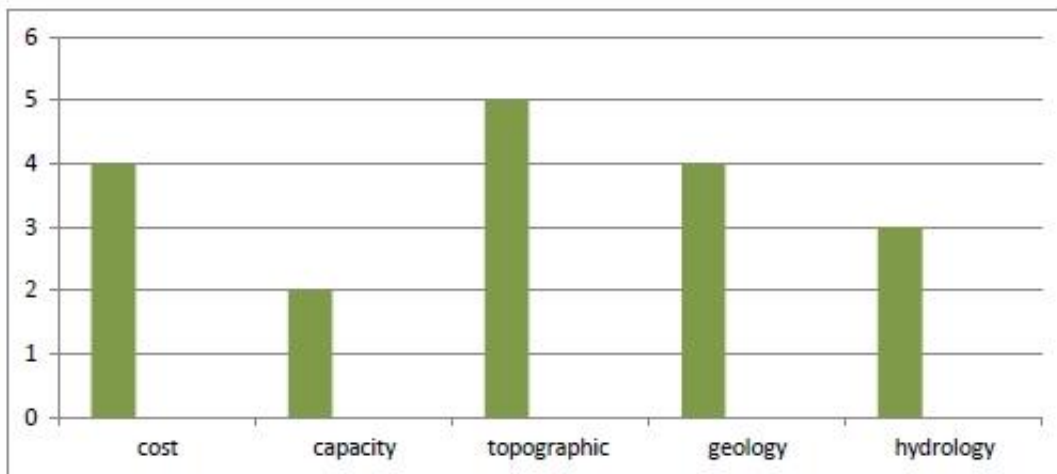


Figure 4. Question 1

**Question 2:** the important step for designing dam are:

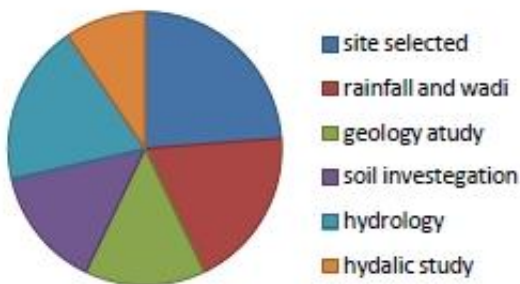
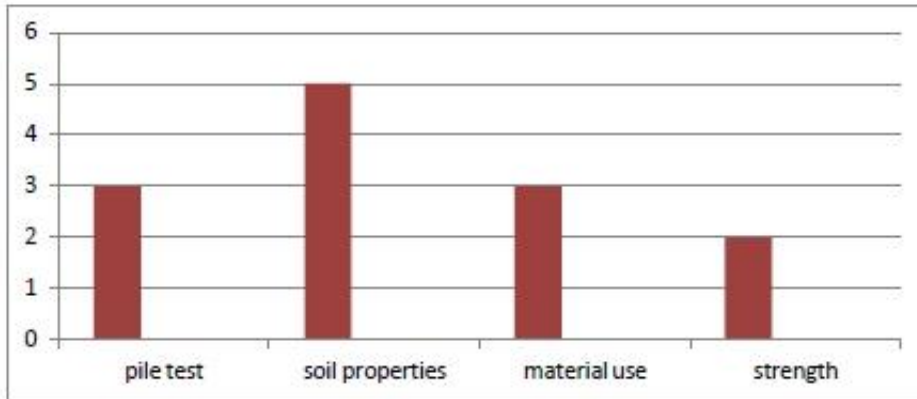


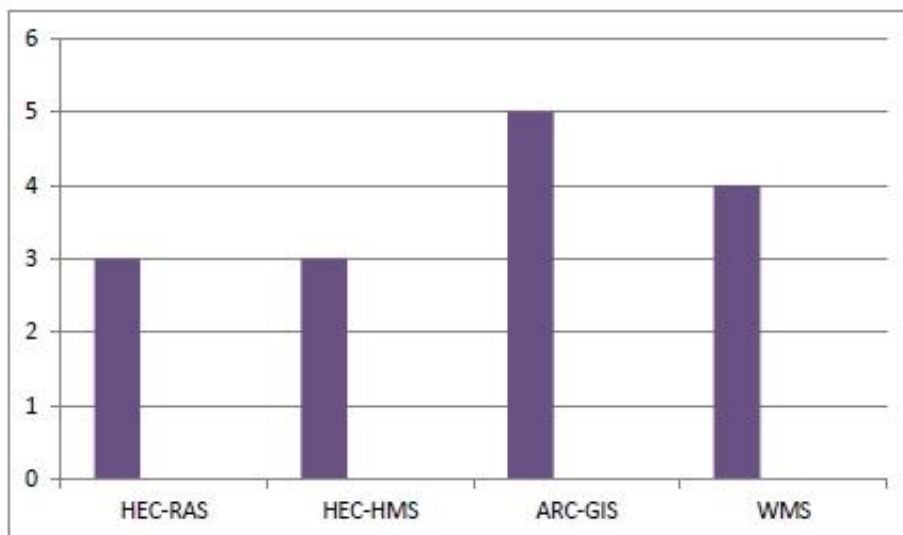
Figure 5. Question 2

**Question 3:** Geotechnical investigation is very important for any construction which gives us the description and property of soil and chemical properties to can select the material for foundation and the additive for the soil.



**Figure 6.** Question 3

**Question 4:** They are many muddling was using and every years was come new one, fro example of this software: HEC-RAS, HEC-HMS, and ARC-GIS.



**Figure 7.** Question 4

No of Q	Answers
Q1	Storage capacity, cost, topographic survey, environmental issue, geology, hydrology
Q2	Site selected, rainfall and wadi data analysis , geology study, soil investigation, hydrology study, hydraulic study,
Q3	Soil properties, design for foundation, structure of soil, material use
Q4	HEC-RAS, HEC-HMS, ARC-GIS, WMS

**Table 1.** summarize answer of interview

## Rainfall data

The catchments area of Wadi Rafsah is a typical Omani wadi. It extends over some 738 km<sup>2</sup> at the sea. The catchment is surrounded from all sides by rather high mountain chains. To the West the mountains raise more than 2000 m.a.s.l. (Jabal Khadar) and almost 1000m (m.a.s.l) to the east at Jabal Khamis. To the south, the catchment area limit is much less marked; the top of the hills does

not exceed some hundreds.

As shown on table below, the analysis data by using semi-log methods for all stations available in wallyat sue especially in wadi rafsah that's to find the maximum rainfall and discharge of the wai in different return periods. It is clear that the coastal area was noticeably more affected by the precipitations. Nevertheless the cumulated rainfall recorded at Tawah 3 station during Gonu exceeded 160 mm. Such order of magnitude was confirmed by the nearby Jalan Bani Bu Hassan station records: 159.4 mm for Gonu Event a first Rainfall - Runoff model was then built on Wadi Hilm catchment area (using rainfall recorded at Sur). According to our experience gained on other studies in the region, the catchment area physical parameters were rapidly calibrated. According to the MRMWR monitoring department, Gonu event provided a total flow volume of some 66 Mm<sup>3</sup> at the Wadi Gauge Hilm near Qalhat. The model computed a volume of some 68 Mm<sup>3</sup> for the same event. Our calibration could then be considered as satisfactory. The calibrated parameters used on Wadi Hilm model were then applied to Wadi Rafsah catchment area, with the adequate rainfall distribution. A total volume of some 120 Mm<sup>3</sup> was then computed at the outlet of the Wadi Rafsah catchment area for Gonu event, with a peak discharge of some 1 800 m<sup>3</sup>/s (at Fulajj dam). The final result after analysis data for amount of rainfall in different return perioda as follow: (Almaqali, 2016).

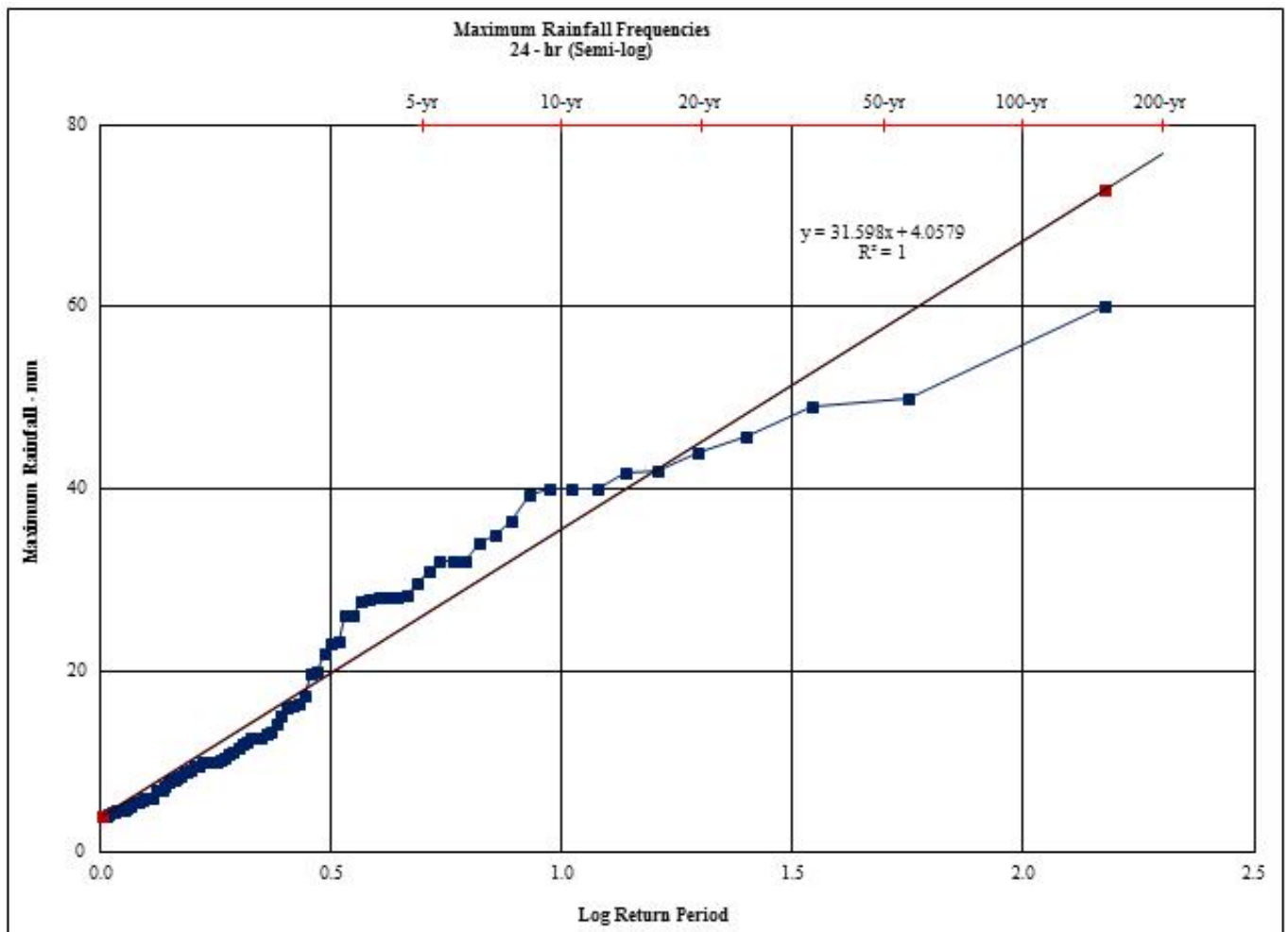


Figure 8. frequency of rainfall intensity probation by semi log method

## Wadi data

Wadi station is very important to find the maximum flow of water that's happened in this wadi and



flood peak frequency in different return periods; by analyzing the data of wadi by using POT analysis from 1980 to 2018 we find it in table below:

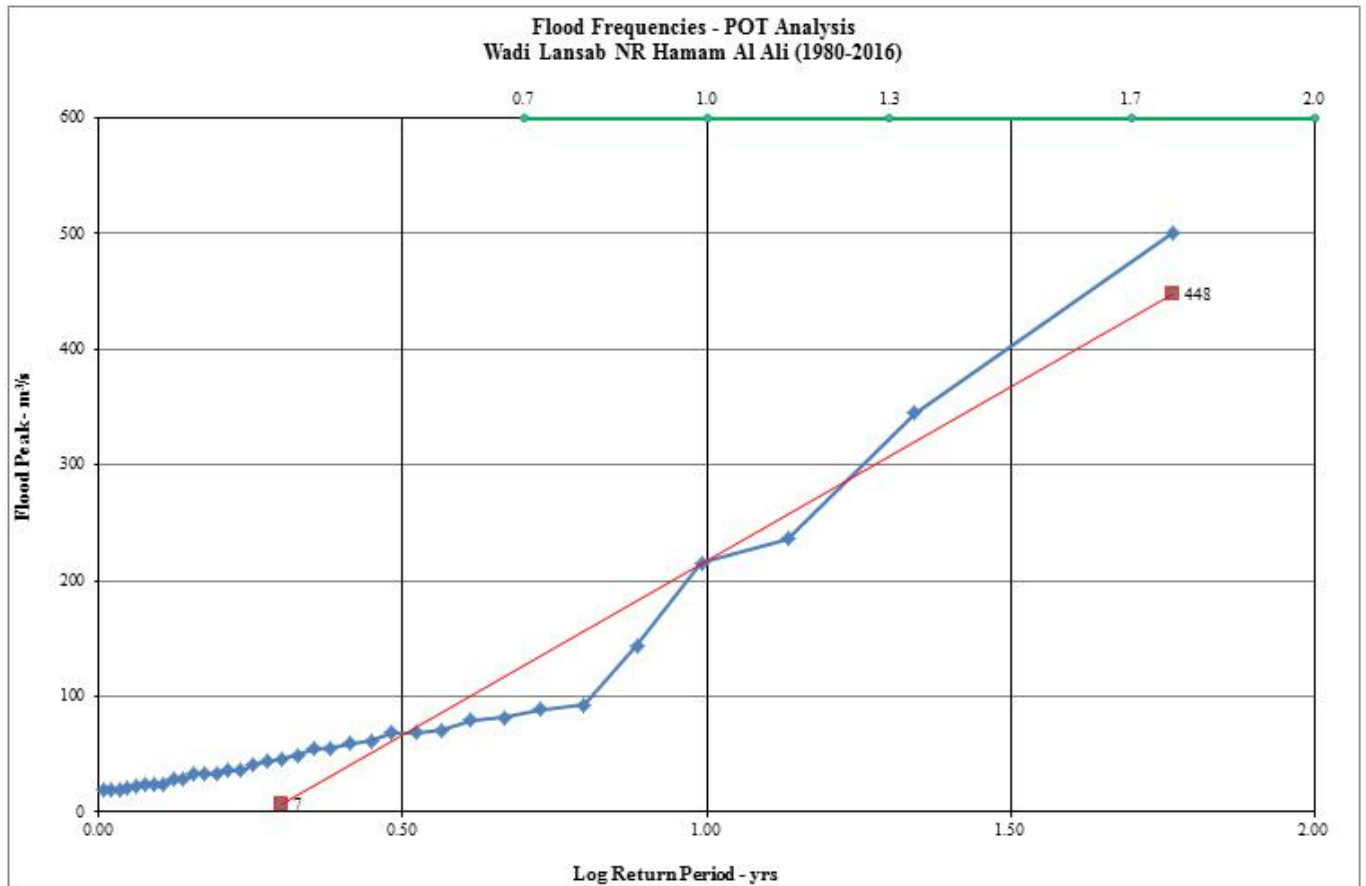
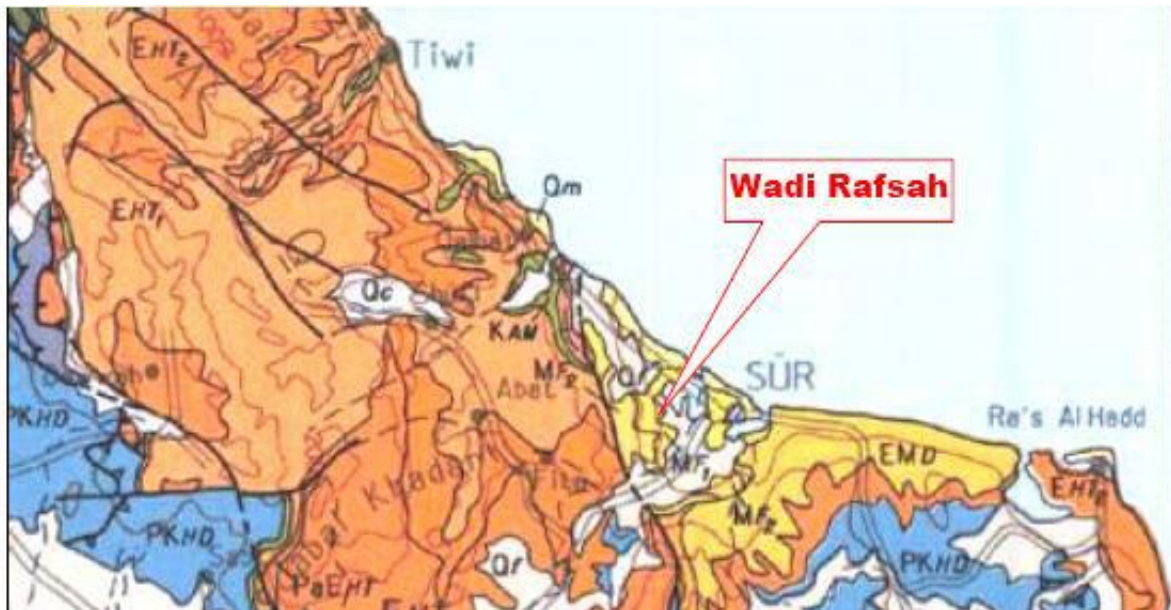


Figure 9. frequency of wadi intensity probation by semi log method

### General geological catchment of the area

The catchment of Wadi Rafsah covers the Hajar Ash Sharqi consisting mainly of Tertiary Formations (Figure 1.9 ) forming the Abat Through





**Figure 10.** geological structure of wadi Rafsah

The Tertiary Formations unconformable overly the Hawasina nappes which are only Represented in the catchment area by outcrops of red radiolarian chert of the Wahra Formation (JkwaC), and purple sandstone and shale of the Mar bat Formation Jmb (, Located east of Gharayafah and Rafsah ).

The tertiary sequence begins with the Late Paleocene - Early Eocene Jafnayn Formation (Ejf), 400 to 600 m thick, consisting of black hard limestone outcropping north of Fita and west of Abat (Figure 11). To the south, the Jafnayn Formation passes laterally to the Abat Formation (Eab) of same age and same thickness, consisting of medium hard white marly limestone and soft marl. (VENOOD, K, 2018).

The overlying formation is the Middle Eocene Seeb Formation (Ese) which only the lower member 300 m thick outcrops north of Tahwah, consisting of hard limestone. To the SE, this formation passes laterally to the Middle-Late Eocene Musawa Formation), 1100 m thick, consisting of beige to greenish soft marl, marly limestone and medium hard limestone.

## Soil investigation:

Geotechnical investigations were conducted during the feasibility stage. A total of fifteen (15) Boreholes were realized together with 17 trial pits in order to investigate the upper layer. The object of the investigation campaign was to determine:

1. Nature and characteristics, including the in-situ permeability, of alluvium overburden in the wadi bed;
2. Location of bedrock;
3. Extent of the limestone formation that are observed in the left bank;
4. Extent of weathered marls formations observed in both banks;
5. Location, orientation, extent and nature of joints, bedding planes and faults, if any, present at the dam site

The following tables gather the geotechnical investigations, laboratory and on field testing carried out to assess the geotechnical conditions of the site with result of all layer.

The specific data of trial pits as follow:



TP NO	EASTING	NORTHING	LEVEL (mamsl.)	Depth (m)
TWH_TP_01	729860	2479152	235.15	3
TWH_TP_02	729829.719	2479400.814	232.39	4
TWH_TP_03	730165.766	2479252.119	227.66	1.2
TWH_TP_04	729840.566	2479923.763	249.54	3
TWH_TP_05	729824.27	2479834.702	245.92	3.1
TWH_TP_06	729591.245	2479720.664	243.60	0.9
TWH_TP_07	729599.338	2479557.334	233.55	2.2
TWH_TP_08	729364.818	2479732.463	235.45	1.8
TWH_TP_09	729412.264	2479620.469	239.39	1.5
TWH_TP_10	729342.779	2480033.051	252.81	1.6
TWH_TP_11	729372.896	2479431.517	240.66	2
TWH_TP_12	729164.649	2479383.351	238.57	1.7
TWH_TP_13	728829.45	2479760.944	242.64	2.7
TWH_TP_14	728739.343	2480019.397	243.62	1.2
TWH_TP_15- Mosq	728360.185	2480024.254	257.31	2.2
TWH_TP_16	728734.724	2479512.817	245.30	2.3
TWH_TP_17	730061.199	2479520.664	237.05	1.1

Figure 11. description of trail pits

### Hydrological Analysis Result

The wadi UM ALLKHKMAM was divided into 3 sub basin in the upstream area which is A1, A2, A3, which this channel connected directly to the reservoir of the dam, by using the analysis data of rain and wadi gauge station also we find the curve number of wadi UM ALLKHMA which used as a input in watershed module system (WMS) to find many important result such as: maximum of stream slope, maximum length of stream, basin area and flow distance of every channels. As show in table below:



Basin name Physical parameters	Area A1	Area A2	Area A3
UTM E	٧٤٥٣٥٥	٧٤٥٩٢٥	٧٤٦٤٦٦
UTM N	٢٤٨٥٦٧٥	٢٤٨٦٦٢٣	٢٤٨٧٥٩٨
Basin Area (Km <sup>2</sup> )	٤٥,٥٢	٨٢,١٣	٦,٠٣
Maximum Stream length (km)	١٩,٧١	٢٢,٩٢	٥,٥٩
Highest Elevation (m)	١٣٥٠	١٤٠٠	750
Station Elevation (m)	61	59	50
Perimeter (km)	64.16	71.24	21.59
Maximum Flow distance (km)	7.98	21.71	24.63
Maximum Stream Slope (m/m)	0.0093	0.0424	0.0412

Figure 12. Sub basin physical characters for wadi UM ALLKHKMA

The most critical point of the input data is the curve number which is depended to the two important things for the two important things which are: soil classification and land use. Soil classification was divided in 4 groups which depend to the porosity of the soil type (mention it in Appendix A). as we shown in figure below (kkk), the porosity was increase in group A and very low in D , all this description was in appendix A, the land use is depended to the uses of the area for every basin like ( residential, commercial and industrial area ) , so by using the group and land use for every basin we find the curve number of all basin (attach in appendix A) , the final curve number was fined for every basin are : for basin A 82, basin B 83 and 85 for basin 3.

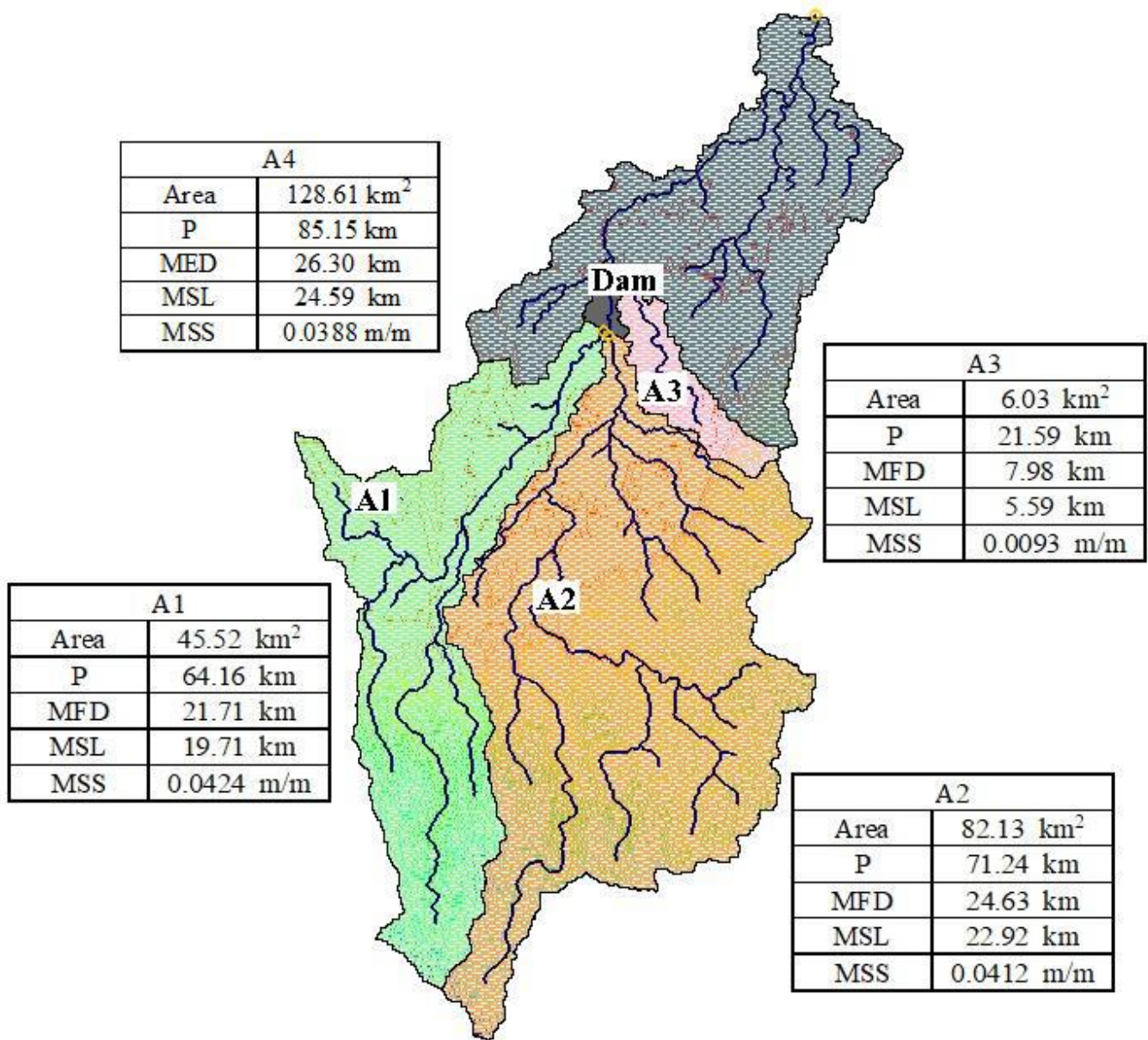


Figure 13. Sub basin Shape of UM ALLKHKMA catchment

Finally in this case it's time to use HEC-HMS module which is to find the flood peak frequency for every basin by using all available data was analysis before for different return periods up to 200 year. The final hydrology result for every basin (rainfall and runoff) was show below:



Wadi Name	Catchment Area (km <sup>2</sup> )	Return Period - yrs						
		<u>Q<sub>maf</sub>*</u>	5	10	20	50	100	200
		Flood Peak Frequencies - m <sup>3</sup> /s						
A 1	٤٥,٥٢	11	28	54	81	121	150	182
A 2	٨٢,١٣	24	64	125	186	278	345	420
A 3	٦,٠٣	2	8	10	14	22	27	32
A1&A2 (A3)	128.61	34	89	174	260	390	483	588

Figure 14. Flood peak frequency for sub basin

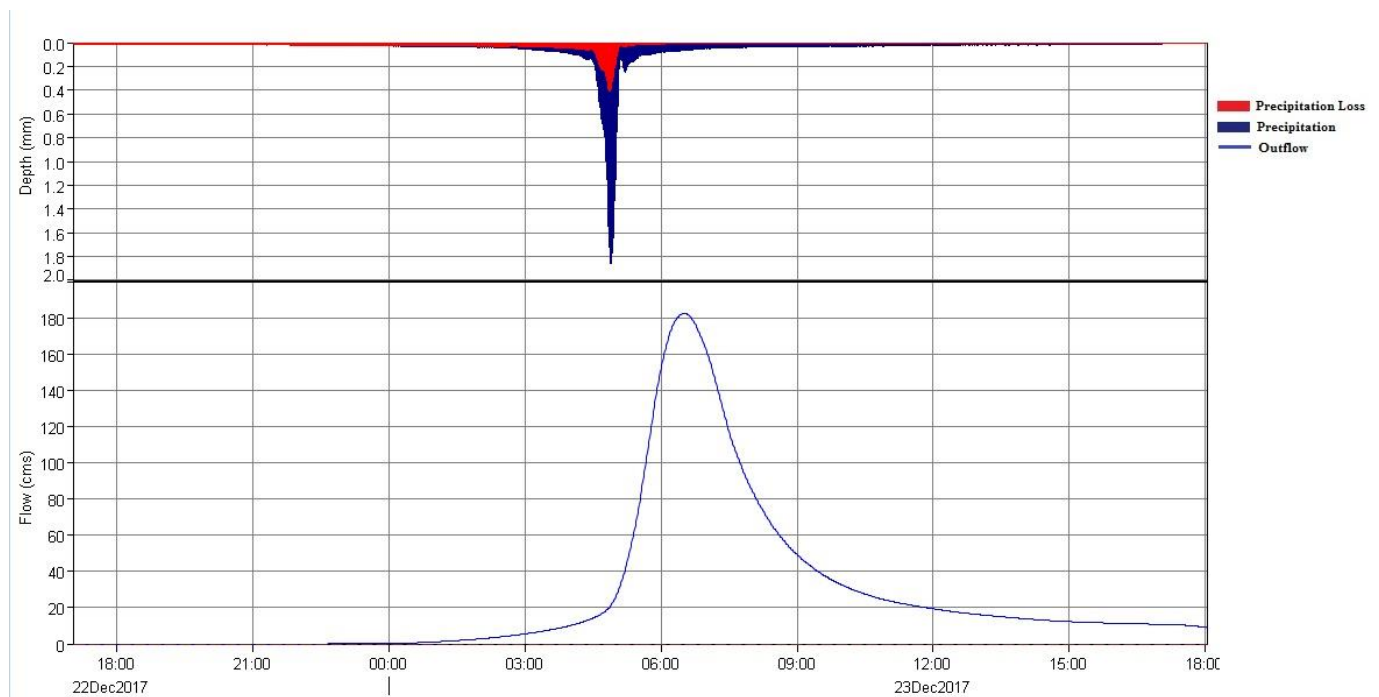


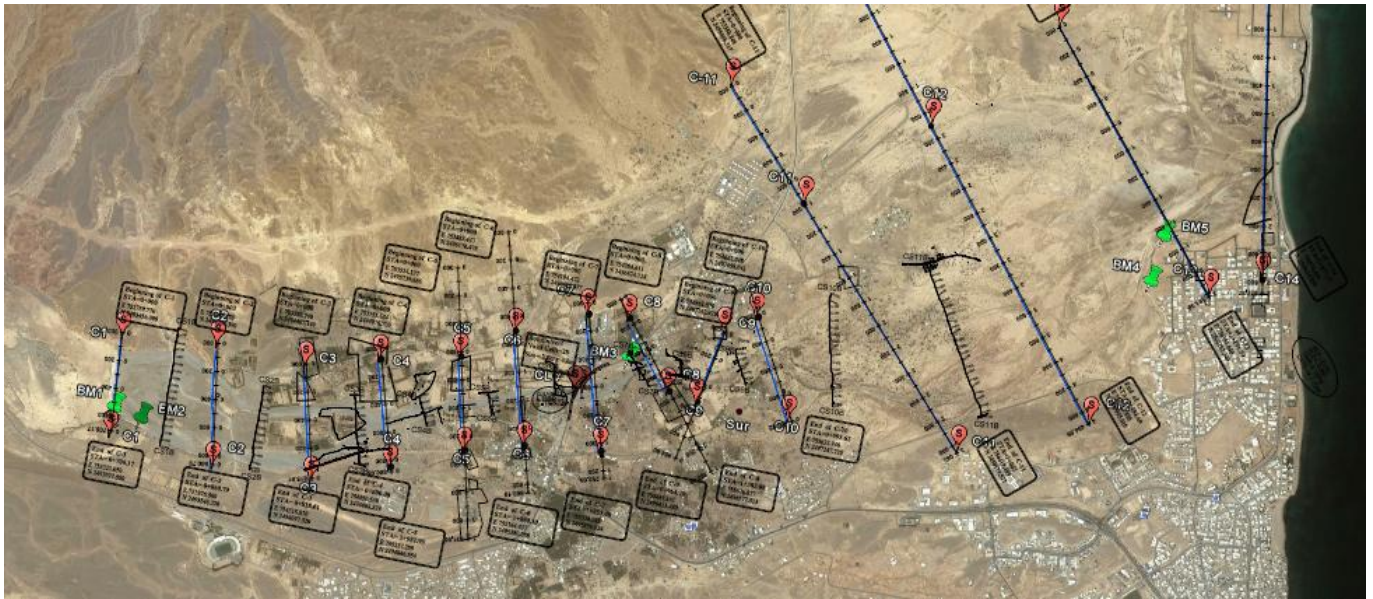
Figure 15. Rainfall and runoff for 100 return periods in basin A

### Topographic Survey result

The result of topographic survey it's very important for calculate the flow of water and also used as a input in HEC-RAS module, from filed survey we output with 3 main result which is: elevation of channel, distance and slope with sketch as mentions before. They are 3 sub channel connect o the main channel of wadi UM ALLKHKAMA so the survey include 3 cross sections for every sub channel except A3 only 2. Which is the total line will be 8 lines. For this part of project should connect all topographic point by the bench mark which is more accurate, for that they are 2 BM that's connection to the survey which is near the location of the wadi from NSA BM. For that's the starting point from BM of NSA and by DGPS and cross sections method we going through all



change in the sub basin channels as show in the figure below:



**Figure 16.** Cross section line for all wadi

The result of the survey as follow:

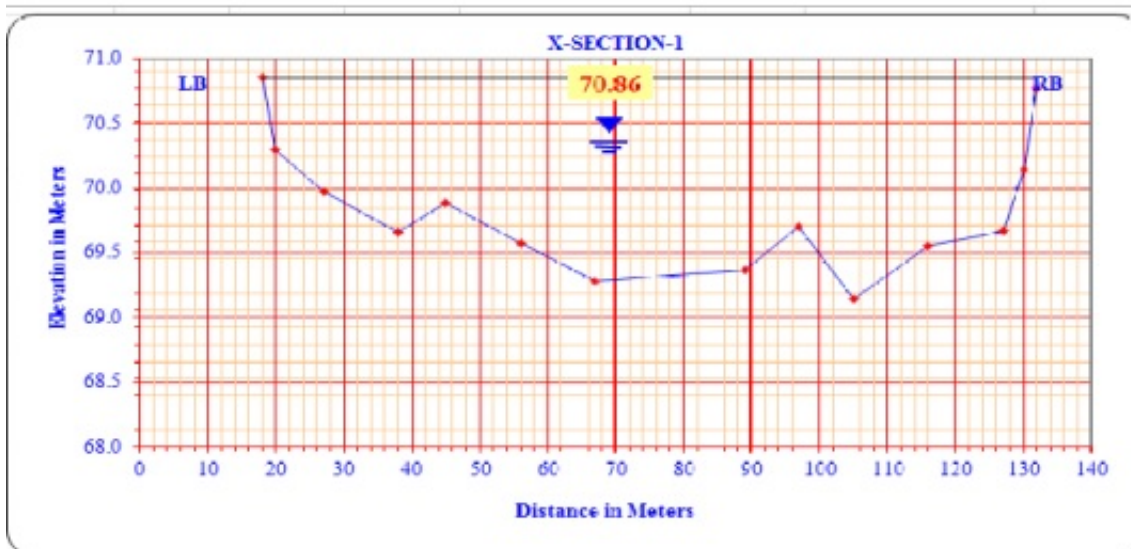
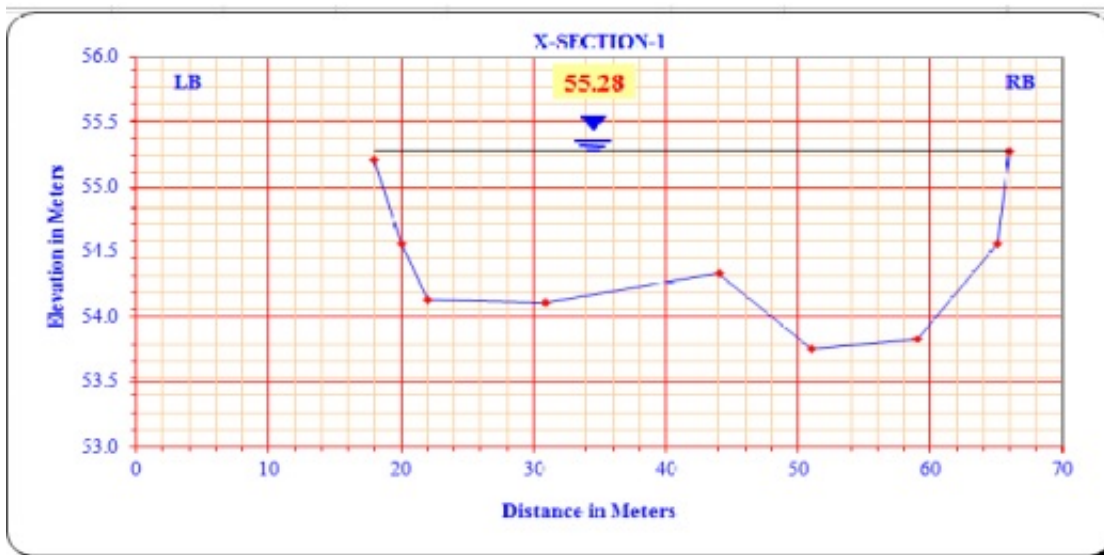
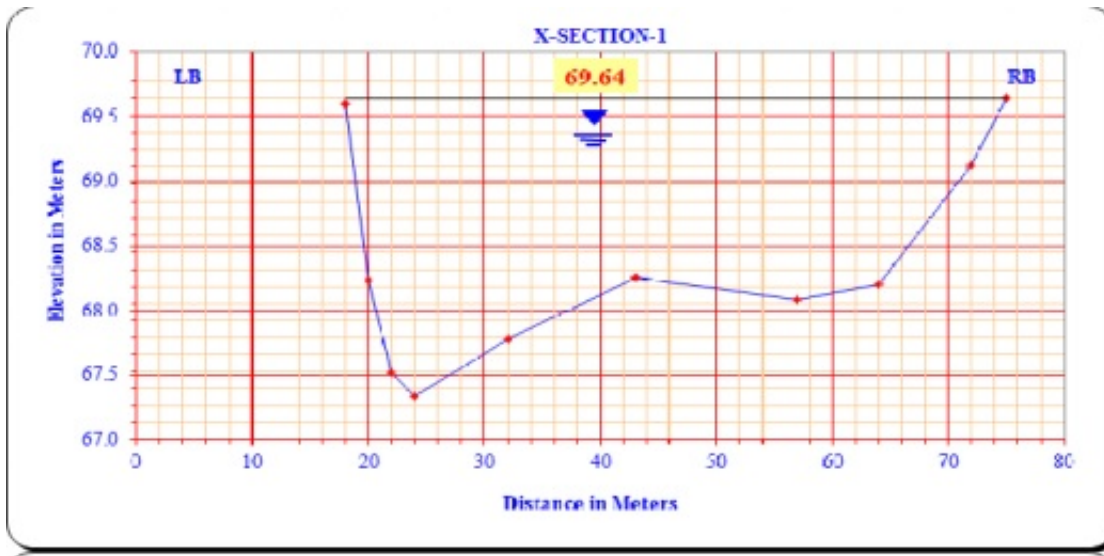


Figure 17.

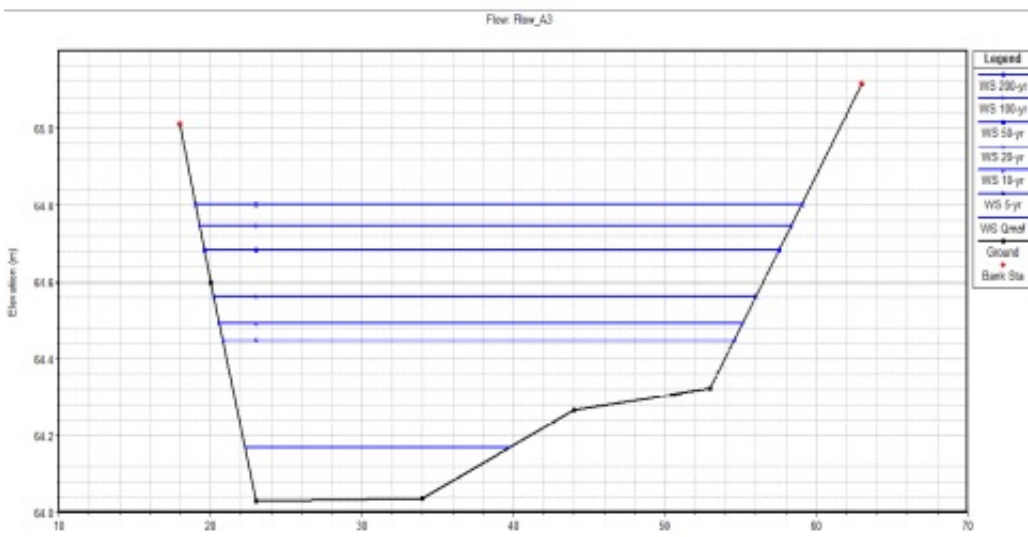
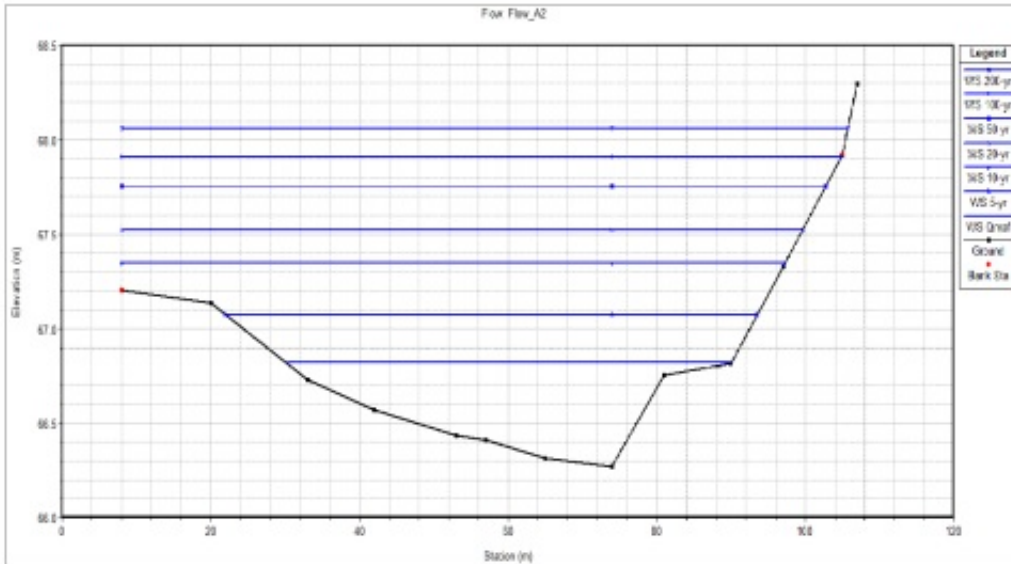
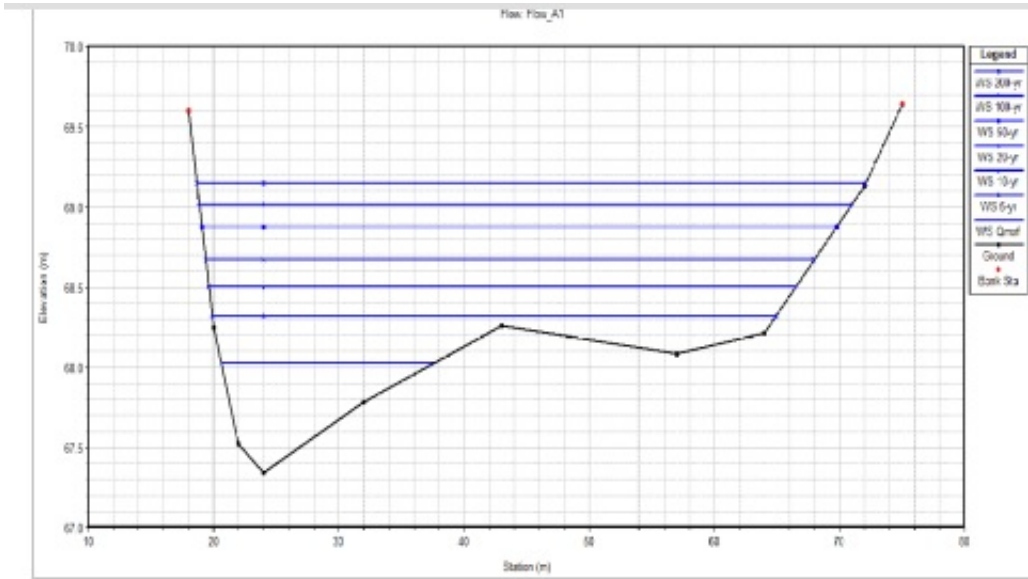


## Hydraulic analysis result

The topographic survey and 8 cross section line that's done before it's the main input to find the hydraulic structure of the wadi by using manual and HEC-RAS program. In this chapter try to measure a total of the physical elements available in each wadi channel connected to the dam path to determine the quantities of water, velocity of the flow, the amount of water flow, and the amount of final loss and that through comparison with the path of the channels and also the type of soil available and finally according to the geological structure of the land, The final step is to analyze and run model. These results and present them in the final form, illustrating all of the previously mentioned drawings with repetitions of up to 200 years. These results will be available for every cross section to add finally in one form, but will be detailed for all basins in appendix B, in this chapter I will take 1 section for every wadi and other as shown previously in appendix B,

the final result will be as follow:





**Figure 18.**

## Dam Design Result

The following table gathers the main characteristics of the dam and its reservoir.

<b>Dam Design</b>	
Z bottom (masl)	81
Maximum dam height (m)	23
Alignment length including saddle dams (m)	160
Parapet wall level (masl)	No Parapet
Dam crest level (masl)	104.5
<b>Reservoir</b>	
Maximum water depth (m)	20
Volume at MWL (Mm <sup>3</sup> )	14.8
Volume at FSL (Mm <sup>3</sup> )	9.7
<b>Spillway</b>	
Z spillway (masl)	99.8
Z gonu (masl)	100.31
Z PMF (masl)	102
L spillway (m)	240
Qs max (m <sup>3</sup> /s)	5527
<b>Plots</b>	
reservoir surface at MWL (km <sup>2</sup> )	2.7
number of impacted houses	3
Cost estimate (Millions OMR)	54
With 10% contingencies (Millions OMR)	58

**Figure 19.** final design of the dam

## Construction program

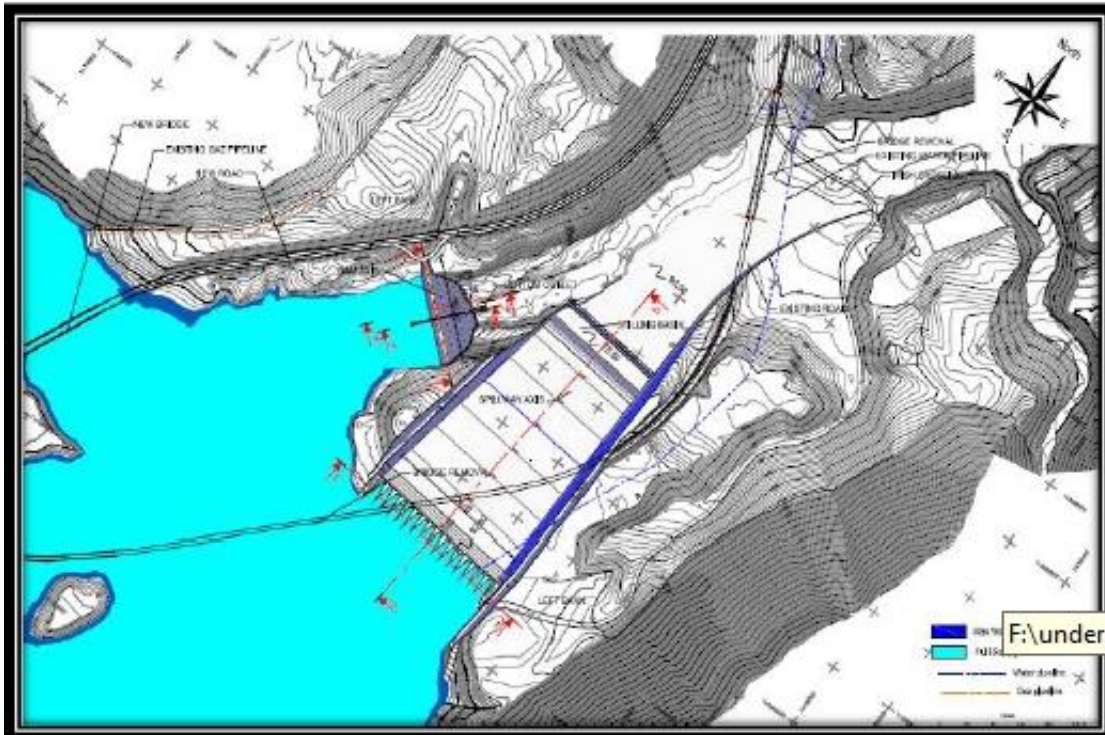
According to the earthworks of the spillway and foundation treatment quantities, the expected construction period will be about 24 month including 3 month of preparation period. This estimation is based on ask some experience people in dam construction in Oman. As the spillway



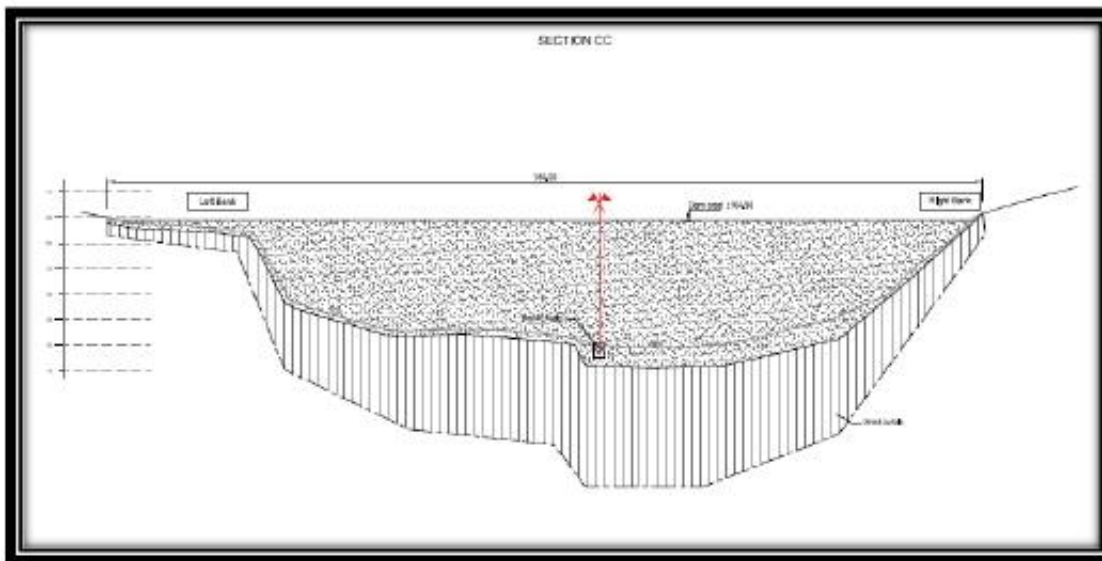
could not be used as a diversion during the construction phase, it will be necessary to leave a breccia at the middle of the dam to leave the wadi flowing during the construction. This breccia will be quickly filled as the level of the dam allows the complete storage of the 10 years return period flood laminated with the bottom outlet. In case of a CFRD dam where the water tightness is completed after completion of the rock fill dam body, it will be necessary to reinforce the downstream slope in order to allow the flood to run without damage on the dam. (REEDY, S, 2015).

## **Main impact**

- As already mentioned, even if the dam site was promising, many constraints limit the potential of this dam site, who limits the possible water storage at about El. 102 m amsl. The only way to create a significant reservoir is to design a wider spillway as possible located at the highest elevation as possible: This will lead necessarily to an extra cost.
- Few houses located at low elevation near the Wadi would have to be relocated,
- Tracks and enclosures located within the reservoir could be submerged for a while during flood events.
- The existing Al Kamil - Sur road would have to be removed on the left bank of the reservoir over some 2.3 km; a new bridge will be constructed and one or two existing removed.
- Existing water pipelines (2), located along the existing road (in the future spillway tailrace) will be relocated.
- Low power lines will be relocated (the existing high power line will not be affected by the present project).
- Closures dykes would have to be erected to prevent high level water in the reservoir to reach the low parts of the village.
- On another hand, such a dam will allow to recharge the aquifer on both upstream and downstream sides of the dam: Flood storage and smooth water release.
- Mitigation of the most frequent floods, downstream ward.



**Figure 20.** preliminary 3D design of dam



**Figure 21.** foundation and (width-length) of the dam

## Result Summary

Generally, we notes determine and analysis rainfall and wadi gauge station which is to use as input in HEC-RAS program, then also determine important standard like curve number, land use and type of use which is to use as a second input to find the discharge and total flow of the wadi. The main important things in this step is to know the amount of water of that wadi which primary to can determine the capacity of the dam, than find the topographic survey result for all channels A1,A2,A3 and maxing with the result of the flow to determine accuracy amount of water that's will inter to the planning dam. Than work for main important parts which is geological structure and soil investigation to determine the type of dam use and also type of materials for all parts which



depended to the type of soil as show in the table 4.3 and 4.4. In geological parts generally to measure the type of rocks and layer that's very important to select the location of dam and dam lack or reservoir and also to find the geological structure of the area. Finally according to all result and standard determine the final design of the dam as shown in table 4.14 with impact and estimate cost which shown in table 4.20 to 4.25, and the final sketch and design as shown in figure 4.27 to 4.30.

## **Conclusion and Recommendation**

Related to the result for final designing of the dam and according to the urban growth in the area, constructed dam is the best solution to avoid any type of risk for people which are close to the wadi as well as effected directly by the floods and planning to provided high greater degree of protection to the inhabitant area located mainly from downstream of existing Al Fulaij recharge dam till the sea. Some of identified dam sites can also be considered as good potential recharge dam sites, in this study my plan is to reach our objective from showing the result, for first objective which is determine the location of the dam and find geotechnical structure: as a recommended from ministry of regional municipalities and water resource about the location, as show in result which describe for the benefits of that location and geological structure as shown in , other things in this goal is to find the geotechnical structure which can measure by the soil investigation test as s which show the information of drilling in different 18 location along the dam and the result of chemical properties of the area which very important for the material use of the dam. the second objective is analysis trend data from 1980 to 2018 to measure flow and highest amount of water in this wadi, which show the result of analysis data during this periods with calculate the highest amount of water and wadi station recorded during this periods, this result which make everything easy to find the hydrology of the wadi with help of topographic survey. The final objective is to prepare final design of the dam and using models. The study was concluded with several important recommendations as show below:

1. Prevent use of the wadi channels for any personal purposes such as temporary houses or also change the course of water channels, which leads to the deviation of water from the original path and the impact of pumping factors and the occurrence of floods from other areas of neighboring houses located below the site of the dam, also prevent the crushers companies and commercial trucks from tampering and change the surface of the wadi.
2. Put buffer zone between the channels of the wadi and houses, also between the dam and houses for not less than 50 m from two sides.
3. Trying to move some houses on the line connected between the dam and the sea directly to avoid any kind of danger to them at the stage of discharge and put a safety distance of not less than 30 m.

## **Acknowledgements**

The research was conducted in collaboration with the Department of Civil Engineering, Middle East College/ Knowledge Oasis Muscat, Oman

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