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Flood plain analysis and flow simulation of river using HEC-RAS model

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Abstract: Awareness of flood zone is widely used in studies of river management, safety of beaches and environmental issues. Given the importance of this issue, determining flood zones with different return periods are necessary to identify high risk areas for flood insurance, create user mandatory limits in high risk areas, avoid risk of floods, organize and optimize rivers and determine available facilities in adjacent of rivers. The research estimates flood zones and economic losses caused by Karun River in Khuzestan province by integrating hydraulic model of HEC-RAS using GIS software through HEC-GeoRAS annexation. To determine flood zone, there is firstly created geometry file of the studied river in GIS environment using HEC-GeoRAS side-program. Then it is transmitted to HEC-RAS model and GIS of extending flood zone in return periods of 25, 50, 100, and 200 years will be evaluated after calculating the required parameters and sending results to the environment. In this method, it is necessary to have full topographic data of the region and hydraulic conditions along the river, in order to calculate flood zoning. Using the data, there have been determined flood zones for different levels in different return periods. . On the return periods of 100, and 200years across the distance of 2500 meters from the beginning of the area for 800 meters length and across the distance of 5380 meters from the beginning of the area for 1250meters length off the right bank, and the lengths of 2500 meters to 3300 meters, and the lengths of 7940 meters to 8730 meters off the left bank of the river, the water advances in to the farms, and residential areas, and, according to the findings, the torrent flood over higher return periods

Key words: *GIS model, HEC-RAS, flood zone, return periods*

Introduction

The studies show that the increasing flood damages are not caused by a short term return period, or the high intensity of flow; rather, the increased use of the plain lands, or the lands adjacent to the river flood are the main cause of the occurrence of the flood. [4]

The flood belongs to the greatest natural hazards which imposes heavy damages to different societies annually, and creates major problems in the development of many countries; but, as it is the case with many other natural phenomena, by efficient management the death tolls, the financial damages, and the undesirable effects can be reduced. Every surface water flow, regardless of where it derives from, will be considered as flood if the water flow on the river section exceeds its normal flow, and its duration is limited, the flood water exceeds the natural river bed, and the water flow encompasses the lowland and the river margins, and it involves financial damages and death tolls.[13] The most important factors effective on the intensity and the flood return period in each area, are the volume and duration of the surface run off on the upper basin, the conditions of the river, or flood, the physical characteristics of the basin (surface, morphology,…), and the hydrological characteristics of the basin (rainfall, storage, and evapotranspiration), and the activities of the river bed working on the occurrence and intensity of the torrent. [1]

Therefore, it becomes necessary to develop a comprehensive plan with the aim of controlling, and optimum utilization of the lands adjacent to the river by adopting appropriate management measures, which aim to reduce the flood damages. These can be categorized in to two groups of the structural, and non structural measures, or a combination of these two. [10]

For eliminating or reducing flood damages, in the non-structural approach of the flood management, no physical structures are constructed; while, in the structural approaches of the flood management some structures such as dams, embankments, and levees are constructed to divert the flood water, flood channels, etc. These structures make it possible, to some extent, to overcome the flood by storing, limiting, or balancing the stream. Generally, the flood water controlling structures are constructed in such a way to protect their areas in the time of the torrent with a definite return period. The safety is achieved by economic considerations, the tendencies of the related societies, the environmental effects, and other factors. [15]

Of the non-structural construction, which is regarded as the primary step in the studies of stream flood management planning, organizing and improving the river, and determining the available constructions adjacent to the river, is the stream flood zoning and preparation of flood hazard maps. [12]

It is appropriate to combine HEC-RAS with GIS Software for the torrent flood zoning model.[16] Using evaluation digital models of the earth's surface and performing 3-Dimensional analyses in ARC GIS environment are very useful to extract the necessary data of HEC-RAS model. The first copy of the software was released on 1997 that did not cover the unsteady flow. On 2001, the dynamic routing option was added to the software. The dynamic routing HEC-RAS was based on one- dimensional unsteady flow in a full network of the reconstructed channels. Over recent years, the erosion modeling and deposition options were also added to the software.[9]

By the torrent zoning it is meant to determine the extent of advancing the flood i.e. its height proportionate to the digital amount of earth's surface, and its characteristics over different return periods. Accordingly, the available approaches for providing the zoning maps can be categorized in to the following four groups:

- Observational; and, using hot water torrent flood
- Comparing the aerial photographs
- Manual calculations
- Using arithmetic models [2]

All the above approaches of preparing the flood zoning need the align flow, and transmitting the water surface digitals in to the topographical maps. All these approaches make use of the same trend of determining the water surface digitals on each cross-section (or other positions) for zoning, which is of course identified by the cross-sections, or the interpolation of the flood spread points. The main discrepancy of these approaches is the way of determining the surface water profile. [3] Rachel Chisolm (2010) in her report "Hydrological stream flood zoning model for Sanderson, Texas" has updates the stream flood zoning maps of the area on 1977 by using HEC-RAS, HEC-GEORAS, and GIS Software. Also, she has shown the representation of the effect of the torrent flood controlling structures in the flood zone in the steady and unsteady conditions, and has provided the flood zone maps over the return period of 100 years [7]. Ali Heydari Jaleh et al (2008) have carried out the flood hazard zoning for the border river of Aras. They concluded that by using geographical information system (GIS), and HEC-RAS software, we will get the ultimate result in less time, and with more accuracy of determining the torrent flood zone compared to other approaches. [5]

For an area of Atrak River (2010), Seyyed Ahmad Husseini et al attempted to determine the torrent flood zoning by using HEC-RAS, GIS, and HEC-GEORAS software over the return period of 25 years. They concluded that the use of these software will highly increase the ability and the accuracy of running the river torrent flood improvement plans. [8,17]

The primary step in the studies of the torrent flood management plans is organizing and improving, and identifying the river status of the available plants in the adjacent river torrent flood zone, and the preparations of the flood hazard maps.[14]

The flood zone is a term for an area of the river lands, and its adjacent lands which will be flooded over a definite return period. And, by flood zoning, it is meant to determine the advancement of the flood, its height proportionate to the digital earth's surface, and its characteristics over different return period. Also, determining the areas of the flood plains, and their representation is shown on a map called the flood zone hazard map. [2]

2- Materials and Procedures

2-1- Characteristics of the study area

In this research, the study area includes an interval of Karoon River from Ahwaz, Khuzestan province. The province locates at latitude from 29′ 58° to 32′ 58° North and longitude from 47° 42′ to 50° 39′ East in southwest corner of Iran. The studied area length is about 43.49 km^2, including 20.20 km from Ahwaz with farming structure and 23.27 km on downstream of Ahwaz with residential-industrial structure. The basin area is 276km^2, minimum and maximum heights are 1976 m, and 2122 m, respectively. The main stream of the study area is 10kms long. The slope of the area is 2%. It is cold and dry weather, and mountain climate in the region.

2-2- The Stream Flood Simulation Analysis

2-2-1- Hydrological data

The hydrological modeling of Karoon River has been done for torrent floods over25, 50, 100, and 200 years return periods.

2-2-2- Geometrical data

Having creating a new project in HEC-RAS software, the previously generated geometrical data of HEC-Geo RAS were transmitted to HEC-RAS software. The incorporated computer file included the schematic representation of the river, and the cross-sectional information of the river junctions.

The necessary geometrical information for each cross-section include the following: section number, the river's name and the area of the located section, align station points and their levels, the internal length downstream, Manning's roughness Coefficient, the main channel Cranberry's Station, and the convergence and divergence coefficients.

The final step is preparing the cross sectional layer. The position and the width of the cross-sectional layer is introduced. The cross sectional points are represented in the plan of the network by drawing lines off the shore from left to right. In the cross-sections in the geometrical borders of each river, there are the points of Variation in Debi, the slope, shape, and the roughness of the river bed. It was necessary to provide some 114 profiles of the river path by site visits and the use of aerial photographs. (Figur2-1)

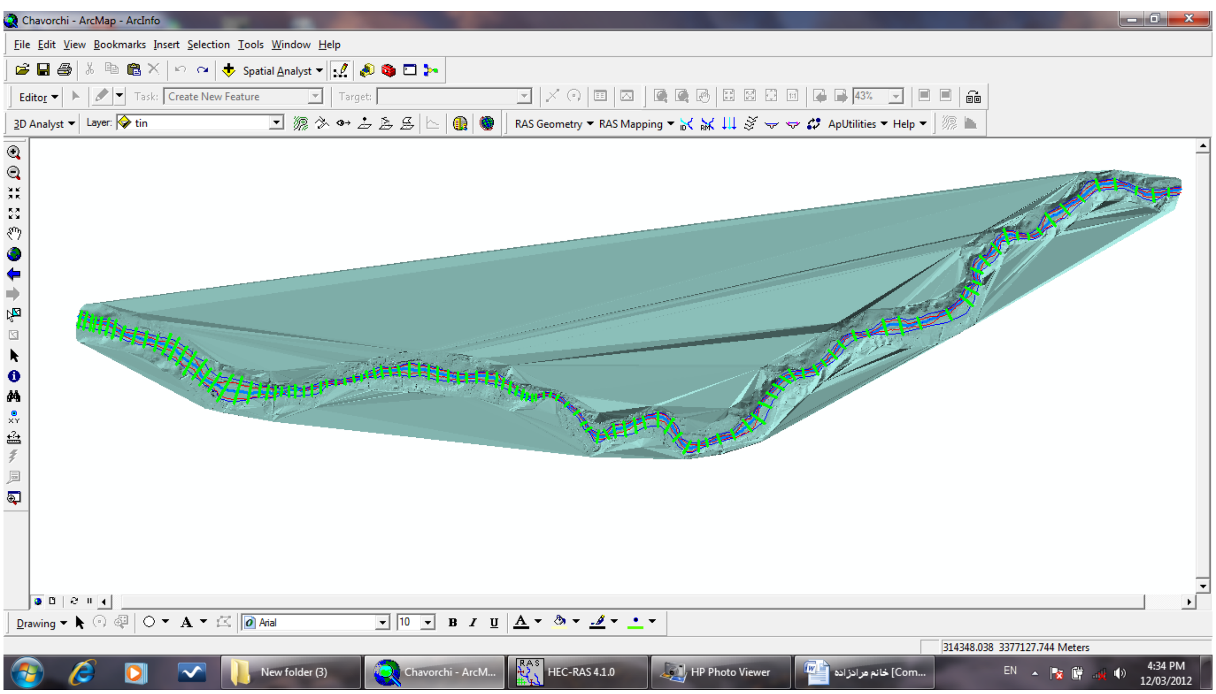

Fig.2-1- The layers created by HEC-Geo RAS

For the primary estimation of Manning's Roughness coefficient, there were different coefficients from site visits, and by using French's Table, which were considered. More accurate coefficients were provided in thecalibration step.

2-2-3- Hydrological data

Having entered the geometrical data, the data of the flood can be entered based on it whether the stream issteady, or unsteady; then, the related hydrological data will be different. In this study, due to the river conditions, determining the river bed limit, and the river privacy, the stream analysis will be permanent; so, the resulted hydrological data of the steady stream will be entered.

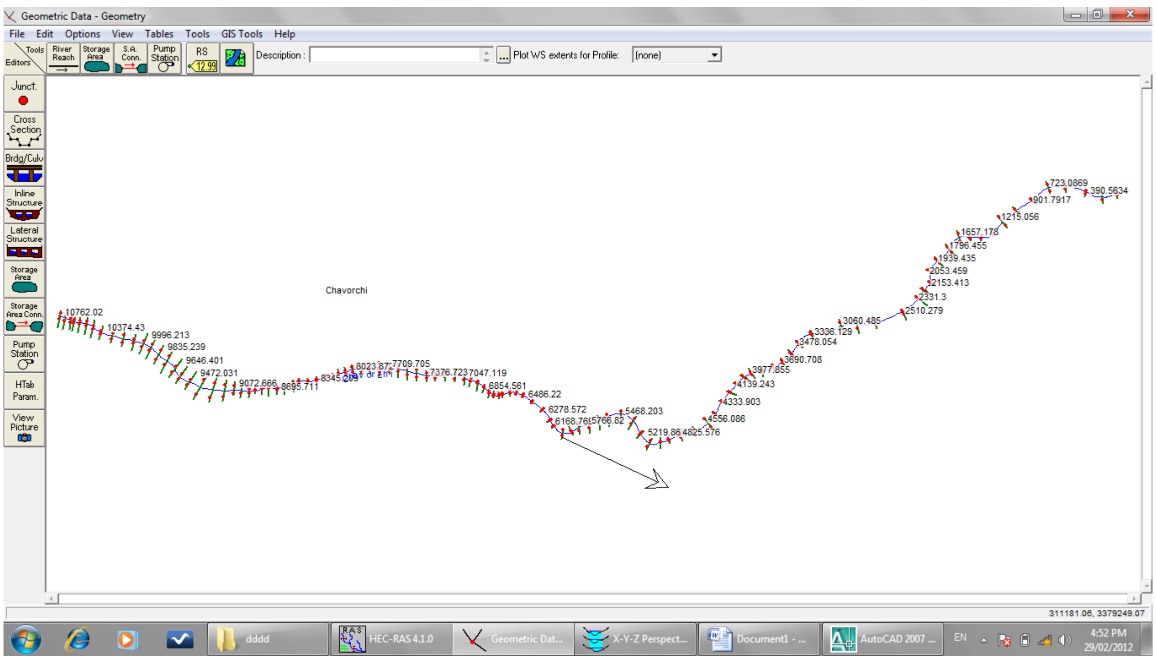

Fig.2.2- The schematic representation of Karoon River in HEC-RAS

The steady permanent stream date includes the number of calculated profiles, the peak Debi data, and the boundary conditions. Also, the required hydrological data were adopted from office of Regional Water Studies of Kerman.

2-3 Calculated Profiles

The numbers of the calculated profiles were determined based on the study objectives, for example profiles with the return periods of 25, 50, 100, and 200 years.

2-4- The model calibration and verification

The calibration and the verification of the model are the most important factors of applying the physical, and the arithmetic models to simulate the study phenomena. The calibration is performed based on the measured data, the definite conditions of the environment, and the conformity of the variable coefficients in the model so that the corresponding conditions are created in the model. In fact, in the calibration step some of the factors are reclaimed so that the calculated digitals by the model and the measured digitals will be in conformity. Of the parameters that should be calibrated in the model is the roughness coefficient of the bed resistance in order for the stream parameters such as its depth or Debi being agreeably in conformity with the measured quantities.

To do the calibration and the verification of the model, Debi-datum derived from the related information of one hydrometric station in the study area. The verification of the model was assessed, and, the roughness coefficient was adopted as the best choice. Finally, after doing some steps further, the flood water zoning of the different return periods can be illustrated.

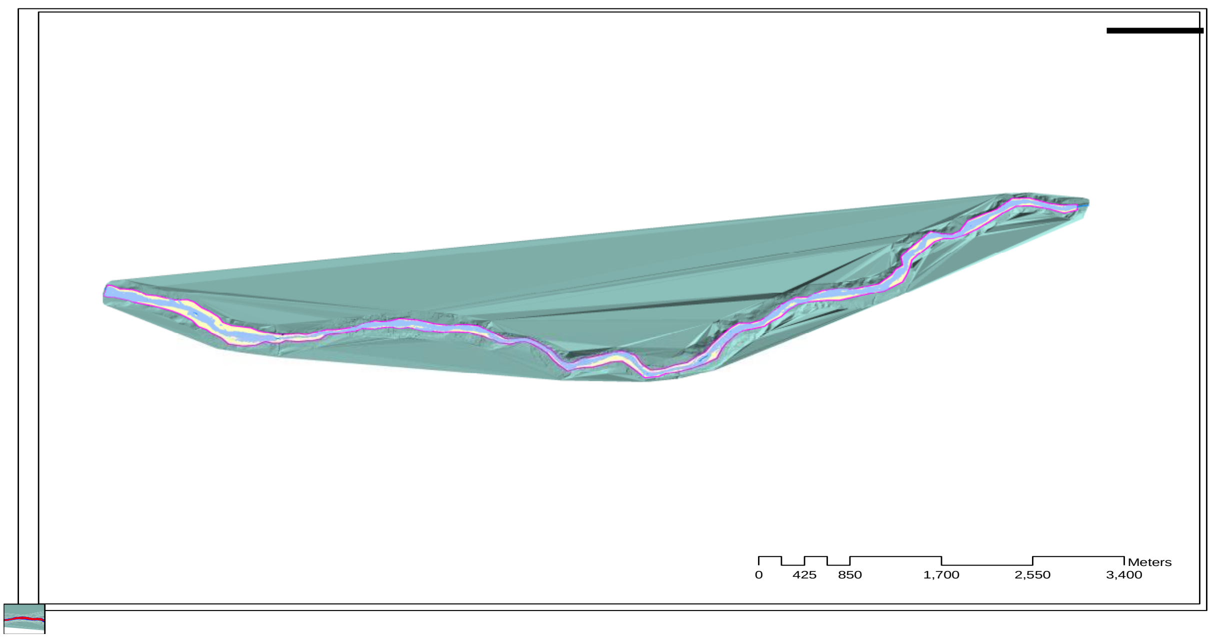

Fig.2.3- Flood zone with a return period of 50 years

Also, based on the available information, the three-dimensional view of the river in the model was drawn, in which, the geographical positions of the cross-sections are identifiable in Figure(2-4).

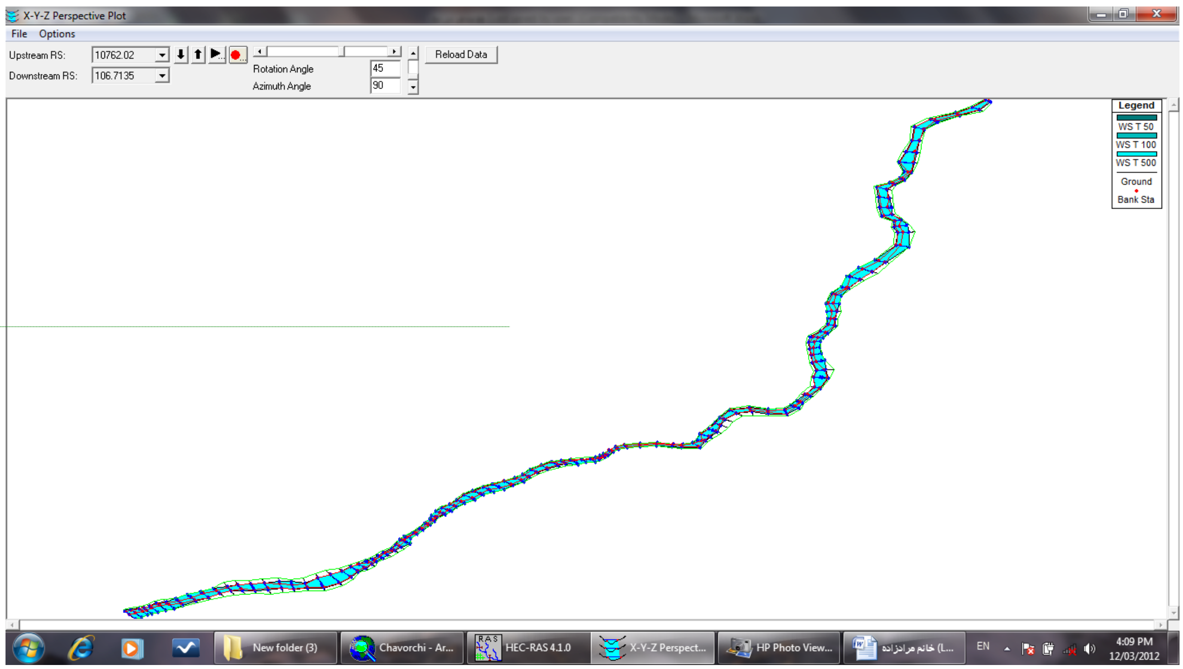

Fig.2-4- 3-dimensional view of the River

To enter the characteristics quantities of the river cross-sections, estimated Manning's roughness coefficient of the river were entered in to the model. Then, having entered peak Debi quantities of the river floodwater, and defining its boundary conditions, the appointed model was separately run for available paths in the different hydrological condition. Figure (2-5) represents a sample.

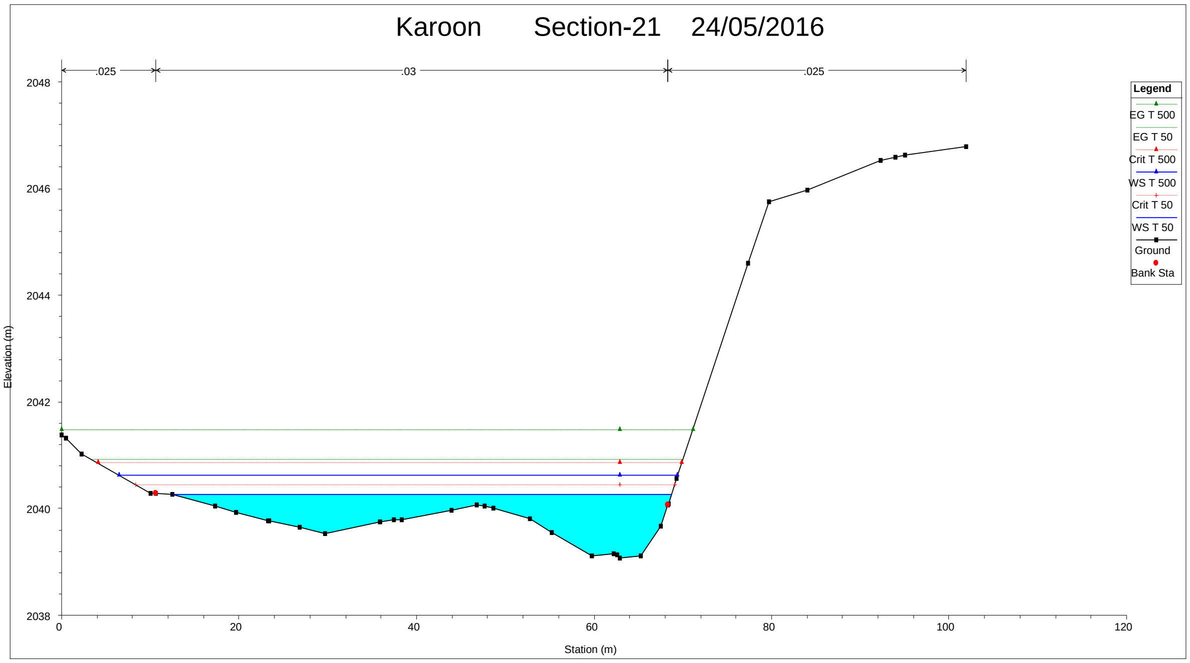

Fig2-5- Water surface levels in the cross-sections with return period of 25, 50, 100, and 200 years

After running the model, the flood zoning was carried out. Figure (2-6) represents a section of the study area.

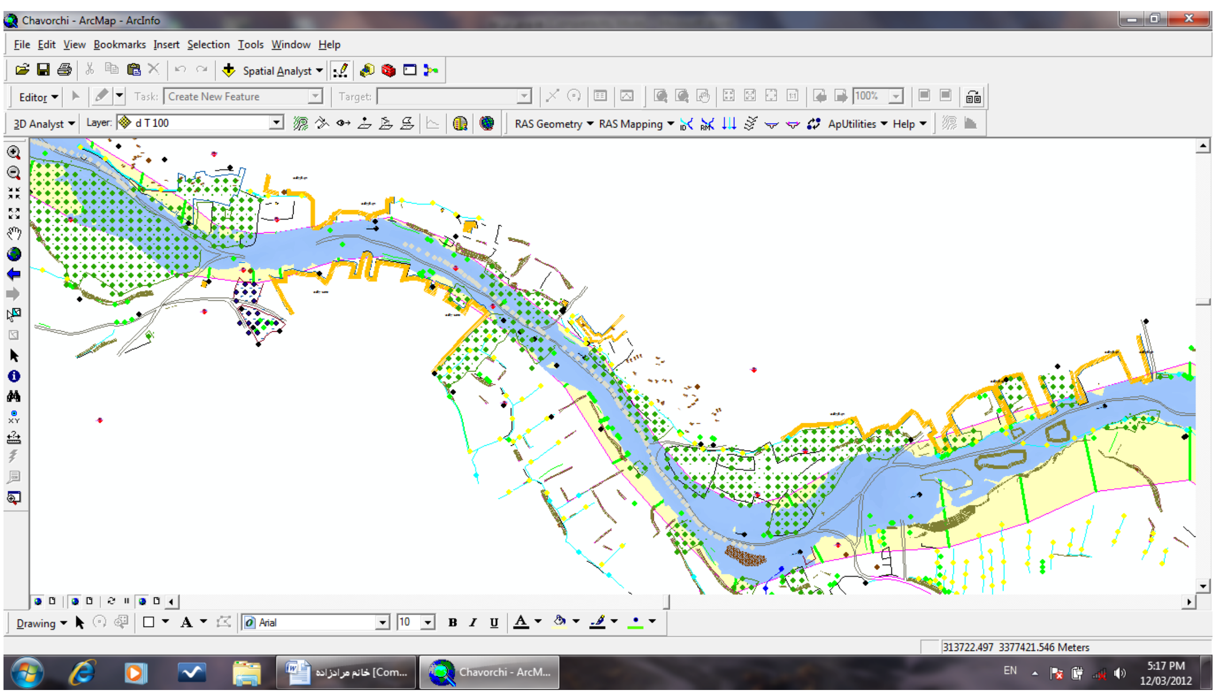

Fig 2-6- Flood zone in river based on CAD, with a return period of 200 years

After running the model, and zoning the torrent flood, in the critical area the hydrological digitals of the stream were determined, part of which has been represented in Table(1-2), based on which the river status, and flow regime has been determined, and in specific places, in which there is the conditions and possibility of getting flooded and destruction, the protective constructions were offered to be built.

Reach	River Sta	Profile	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
Karoon	723.0869	T 25	0.010139	2.54	43.78	71.12	1
Karoon	723.0869	T 50	0.011025	2.87	49.85	71.96	1.06
Karoon	723.0869	T 100	0.012595	3.52	62.05	73.52	1.18
Karoon	723.0869	T 200	0.013654	3.72	69.16	74.42	1.26
Karoon	577.3127	T 25	0.023976	4.08	27.16	40.7	1.55
Karoon	577.3127	T 50	0.02006	4.26	33.56	42.1	1.47
Karoon	577.3127	T 100	0.01552	4.62	47.97	54.45	1.36
Karoon	577.3127	T 200	0.01674	4.75	52.36	66.42	1.18
Karoon	390.5634	T 25	0.008539	3.07	38.99	52.54	0.98
Karoon	390.5634	T 50	0.009741	3.48	43.9	53.19	1.06
Karoon	390.5634	T 100	0.012204	4.32	53.36	54.41	1.22
Karoon	390.5634	T 200	0.014562	5.11	65.32	55.63	1.36
Karoon	239.7853	T 25	0.025637	3.57	30.72	56.17	1.54
Karoon	239.7853	T 50	0.021954	3.72	38.04	60.01	1.47
Karoon	239.7853	T 100	0.018033	4.13	52.42	62.9	1.42
Karoon	239.7853	T 200	0.016235	4.77	61.32	65.3	1.38
Karoon	106.7135	T 25	0.008736	3.24	35.74	42.34	1
Karoon	106.7135	T 50	0.00921	3.6	41.7	46.97	1.05
Karoon	106.7135	T 100	0.009833	4.25	55.06	51.52	1.12
Karoon	106.7135	T 200	0.009998	4.95	59.28	54.22	1.42

Table2-1- Hydrological stream quantities in the cross-sections

3- Conclusions

In Karoon River to Ahwaz, areas of the exposed lands with flood risk have no significant difference in different return periods. While, we will see considerable changes in floodplains, about 12 km downstream of Ahwaz between cross of 104 to 117, due to gradual changes in gradient of slopes overlooking rivers with little changes in figures of flood elevation level in the exposed lands with flood. In the primary study area with a return period of 25 years, due to the protective walls constructed most damages occurred to the gardens and forms. In the distance further, due to the protective walls constructed, with return periods of 50 years, within the distances between 5280 to 6530 off the right bank, and the distances within 5840 to 6530 m off the right and left banks of the river, we can see the flood advancing to the farms, and residential areas. Of course, due to topographic conditions of Karoon area and the lack of suitable locations, implementing organizing projects of the river is necessary to allow further exploitation of lands of the excluded zone and remove threat of residential and agricultural areas. Therefore, to achieve this objective, the current studies showed that option of diversion of water from upstream of Ahwaz to Maleh Creek is a good option technically and economically. In this option, flood of Karoon River will be transferred to Maleh Creek by creating a canal with 2.56 m^2 width and 10.6 km length. By increasing water capacity of the creek from 100 m^3/s to 650 m^3/s, the flood is finally deflected.

On the return periods of 100, and 200years across the distance of 2500 meters from the beginning of the area for 800 meters length and across the distance of 5380 meters from the beginning of the area for 1250meters length off the right bank, and the lengths of 2500 meters to 3300 meters, and the lengths of 7940 meters to 8730 meters off the left bank of the river, the water advances in to the farms, and residential areas, and, according to the findings, the torrent flood over higher return periods

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