Flood damage assessment of vulnerable area in Riyadh city, Saudi Arabia (case study: Al-Thumama Bridge)

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Overview

- Introduction
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Introduction

- Flood/Flash flood causes losses which include loss of life, soil erosion, damages of properties, and environmental damages.
- Saudi Arabia is one of the countries that are prone to the risk of floods that cause different types of damages.
- The highest past flood events (the worst flood in the area in 50 years) and their damages in north-western regions of Saudi Arabia were on the 24th of December 1985, Estimates of damage were not recorded, except at least 32 people were killed from the flood.
- In January 1997, mainly affected Yanbu and peripheries of Jeddah. It was noticed that the rain lasted for 24 hours where 10 people were killed and an area of over 130,000 km^2 of land was damaged

- Also, in Asir, a province in the Southwest of Saudi Arabia, on Monday, 25th of March 1997, the area was exposed to heavy rains causing floods and resulted in 16 fatalities and an area about 100,000 km^2 of land was damaged
- In the western part of the country, especially in Jeddah (November 2009 and January 2011), different areas have been affected.
- In 2016 a heavy rain storm lasted for more than 12 hours on AlDulm located in the south of ALKharj town, has resulted in the detention of many vehicles inside and causing damage to many properties.
- The flood damages happened at Thumama Bridge were due to one of the heaviest storms that hit Riyadh city in November 2013. The storm in whole Riyadh caused an evacuation of people in danger and then sheltering them. Riyadh city is considered one of the cities are vulnerable to flood risk in Saudi Arabia due to urbanization and recent development as well as climate changes

Figure (1) : The Failure part in Thomam Bridge

Study Area

Al Thumama Bridge is one of the bridges located at the Wadi Banban pathway in Riyadh.

The bridge was vulnerable to flood damages in 2013 and led to bridge failure. The bridge was consisted of 13 openings with a total length of 195 meters

The catchment area of Wadi calculated by WMS is equal to 381.0 km^2

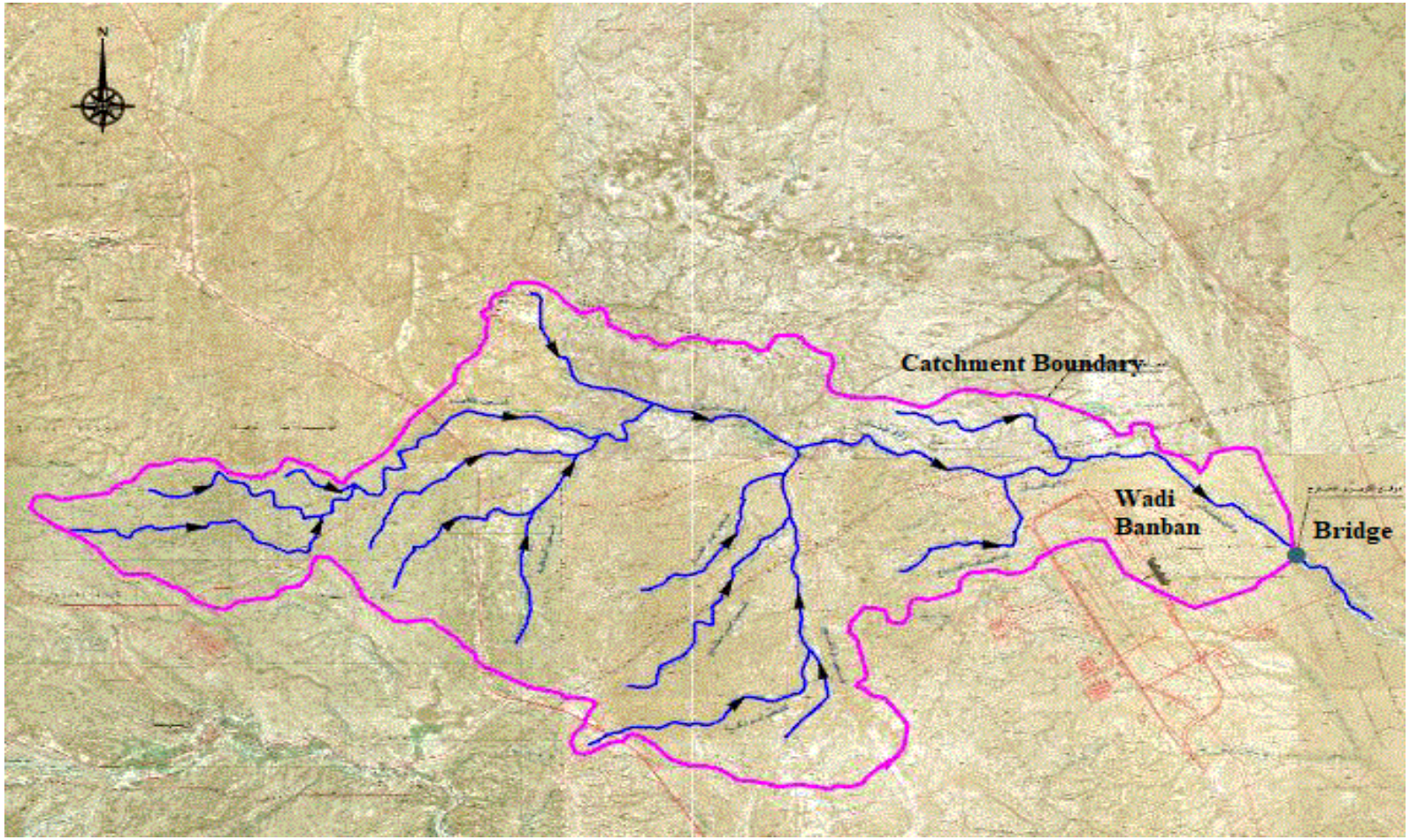

Figure (2): The catchment area and location of Thumama bridge

Research Methodology

- **Meteorological analysis**
- Updated the IDF Curves for Riyadh station

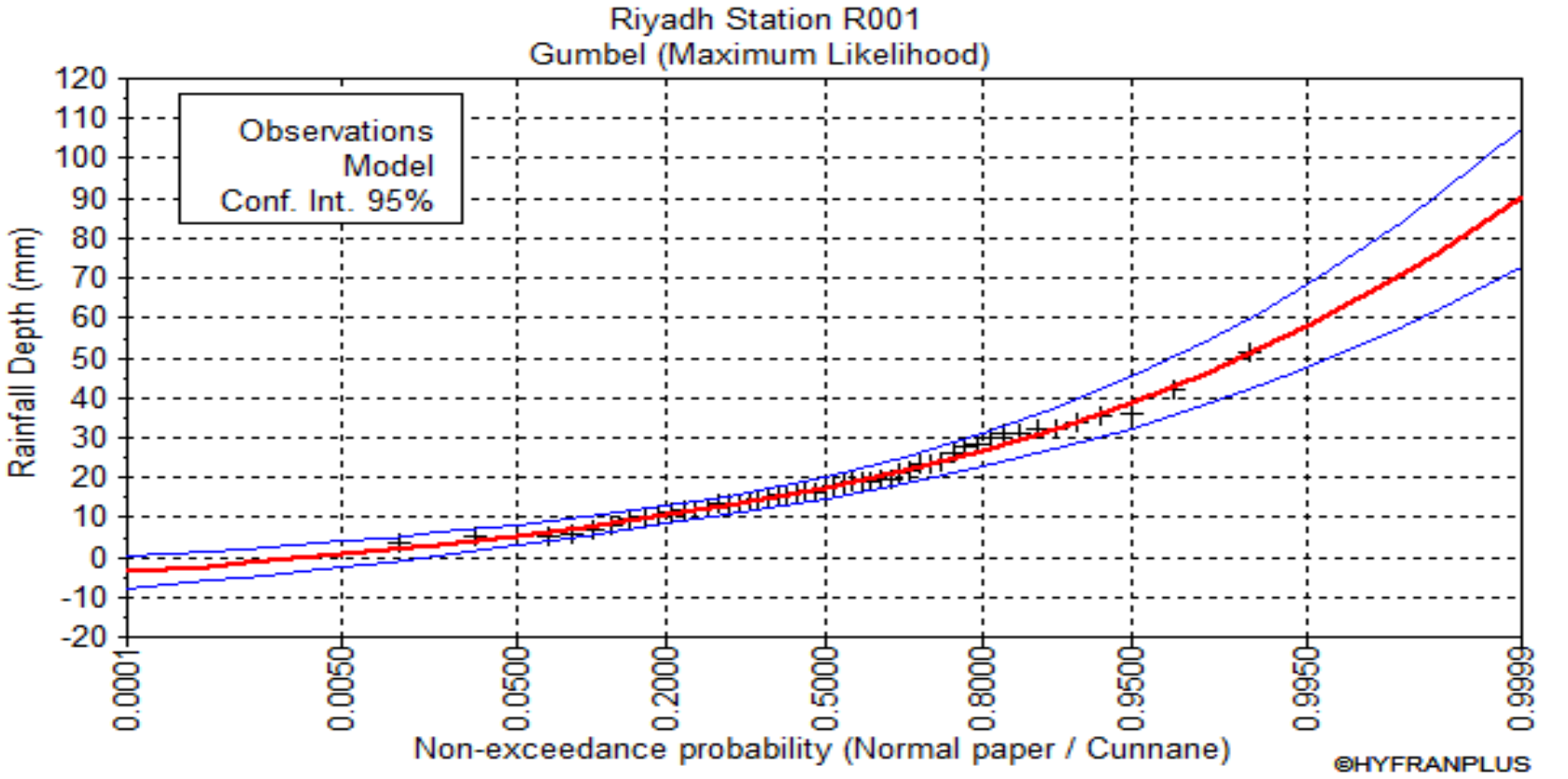

Figure (3): Gumbel fit of maximum daily data of Riyadh station (R001)

- **Determination of the Drainage Basin and the Morphological data**
- Watershed Modeling System (WMS) was used to determine the drainage basin, boundaries of the drainage basin, the pathways of the channels and branches of AlThumama Bridge catchment area.
- **Equivalent Curve Number (CN)**
- The Weighted CN value of the basin was estimated to be 80.71 according to the land uses and the hydrological soil groups

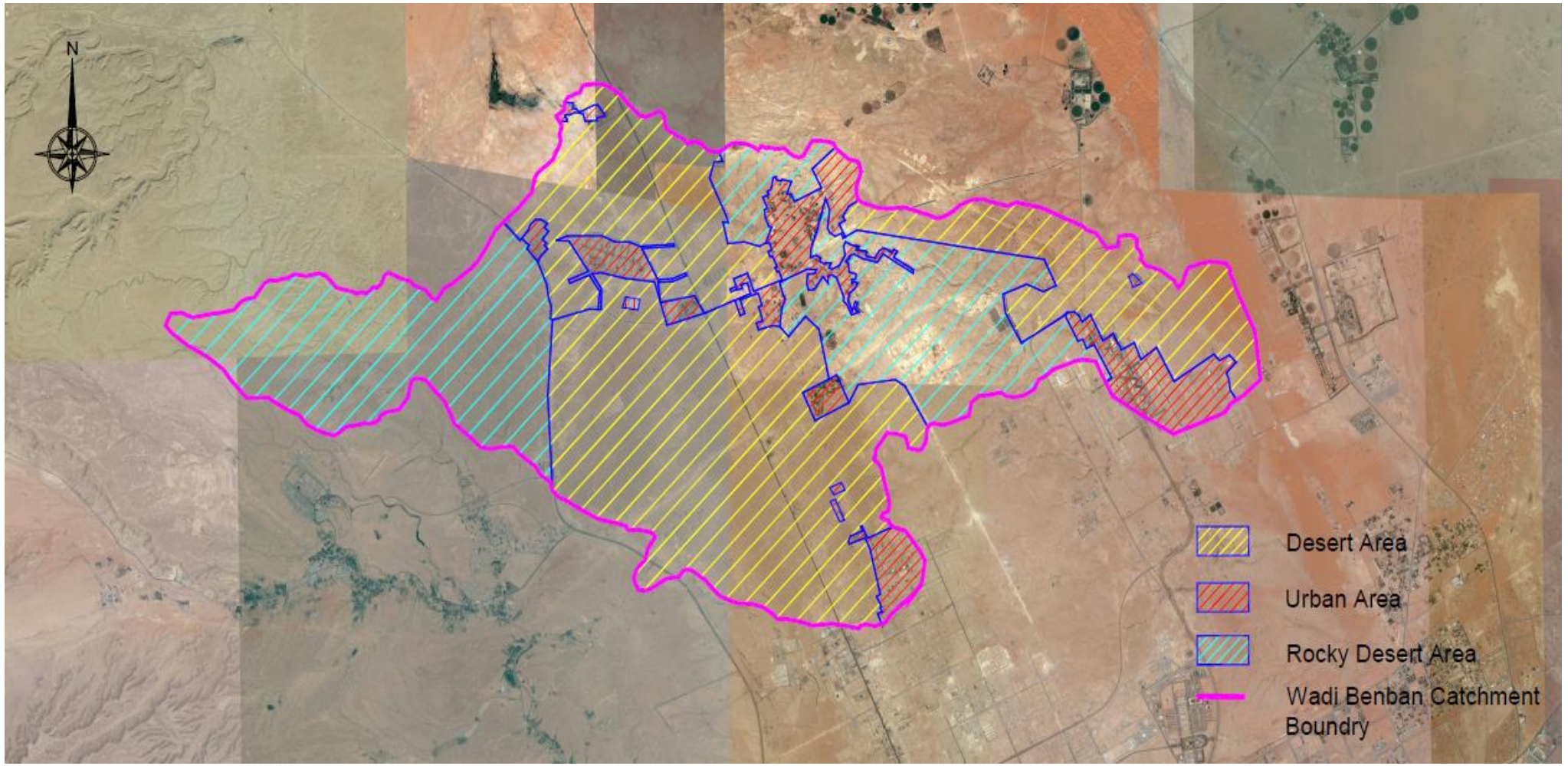

Figure (4): Boundaries of the catchment and land use (MOT, 2014)

Hydrological Analysis

- Hydrological analysis is conducted to define the hydrological parameters for the main Wadis contributing with the study area such as time of concentration (t_c), Lag time (T_{lag}) as well as the peak discharges resulting from their catchment areas
- This is done by the Hydrologic Modeling System (HEC-HMS) (the methodology of SCS-CN method).

Hydraulic analysis and HEC-RAS Computation

- Determination of hydraulic characteristics such water depth, water velocity, the water levels in front of and behind the bridge, in addition to the dimensions of the water section at a specific location as well as the scour depth at the piers.
- Definitions of reaches and geometry of floodplain and Manning roughness values are required by the Hydraulic model (HEC-RAS). WMS and HEC-HMS were used in the preparation of HEC-RAS input data in this study. The extractions of channel centerlines and the flood plains were made from the DEM

Results

- The prediction of rainfall depths for 50 and 100-years were estimated to be 46.5.6 and 52.2 mm, respectively. …
- The methodology of SCS-CN method was performed to estimate the peak flows at the catchment outlet point to be 256.0 m^3/s and 291.0 m^3/s for 50 and 100 years return period respectively
- The weighted Curve Number value of Wadi basin was estimated to be 81
- In the hydraulic modelling, the Manning roughness coefficient was increased to 0.03 (Earth channel-weedy) to dissipate the energy at the Baffles and drops.
- The scour was estimated assuming that the valley cross section does not tolerate the high water velocities.

- Scour depth was estimated using HEC-RAS, the results obtained show scour depths against the flood of 100 years equals to 5.7 m for pier(1) and 5.6 m for pier(2).
- On the other hand, the water velocity was estimated to be 6.3 m/s where it is somewhat high, so we may add more baffles to reach the allowable water velocities. Another alternative solution may be proposed by altering the cross section of the valley at the upstream and downstream of the bridge to make sure that there is no hydraulic interference between the water section and the pier locations, as well as avoiding the high water velocities.

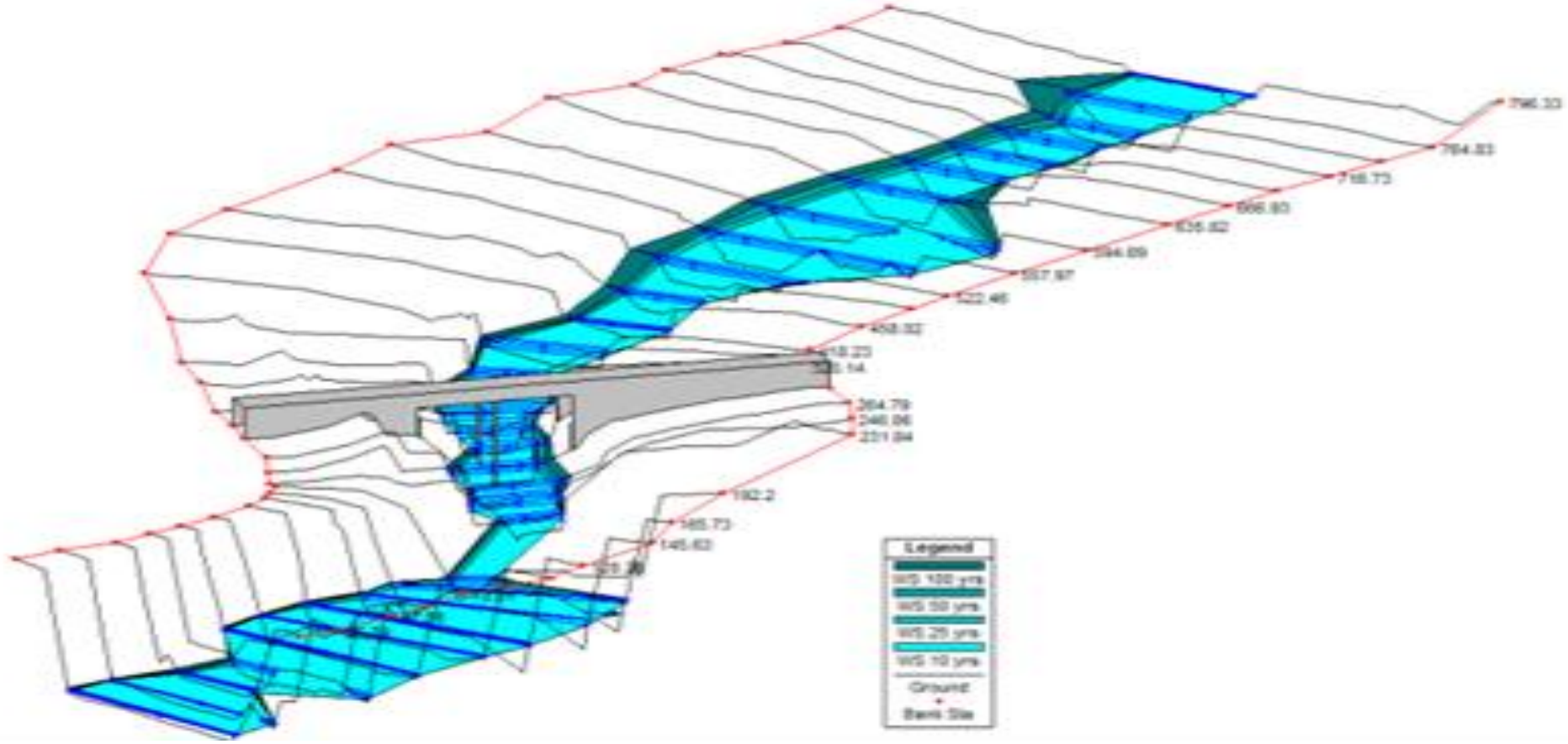

Figure (5): Longitude projection of water surface for the wadi

Conclusion and Recommendations

- The current research demonstrated estimates of the expected flows beneath the bridge and suggests the appropriate hydraulic section and to investigates the resulted scour depths at the bridge piers due to the expected flows
- The study has shown the effect of flooding on the chosen site of the area
- The value of the weighted curve number was eatimated based on the urban development and land-use changes. The hydraulic modeling was done by HEC-RAS to determine the hydraulic characteristics for different sections to include the water levels, flow velocity and the expected scour depth at the bridge piers…
- Another parameter was considered in the hydraulic modeling which is the Manning roughness coefficient, which was increased to 0.03 to dissipate the energy at the Baffles and drops.

Conclusion and Recommendations (cont.)

- The study has shown significant values of the scour depths at the bridge piers due to the high water velocities under the bridge which happened during the storm event.
- This problem may lead to the bridge collapse if those values of the scour depths did not take into account during the bridge design .
- So the study recommended taking into account the expected scour depth which obtained from the hydraulic modeling which guides the designer to use deep foundations at the piers of the bridge.
- Also, it is recommended to use some accessories or devices in the stilling basin to dissipate the energy at the downstream of the valley.
- Also, it is recommended to strengthen the soil type of the bed to match it with the calibrated value of the roughness coefficient used in the modeling to reduce the flow velocity and hence dissipate the high kinetic energy which causing much scour.