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Investigation the Effects of High Resolution Digital Elevation Model (DEM) In Flood Modelling

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Abstract: ***The extreme weather condition and unplanned housing developed by people in the lower lands of the wadi streams have contributed in the occurrence of such flash floods. Flash floods cause much damage such as the landslides and mudflows, bridge collapses, damage to buildings and businesses, psychological harm to people that can reach to death. Because small topographic features affect floodplain storage and flow velocity, a hydrodynamic model setup of these regions imposes more stringent requirements on the input Digital Elevation Model (DEM) compared to upland regions with comparatively high slopes. This study presents an approach is aiming to simulate the effect of high resolution DEM in flood depth and flood extent. The main objective of this research is to analyze the effect of high resolution digital elevation model (DEM) in flood inundation modeling. The results show that, increasing of the grid cell sizes from 30m to 10m has influenced the maximum modeled flood depth to decrease from7.33 m to 6.61m, whereas the average of flood depth increased from 1.62m to 1.83m. The highest of peak discharge and runoff volume were obtained when the condition is wet. The flood simulation results showed that the higher resolution DEM has increased the average flood depth due to the fact that buildings act as barriers to the flow and water accumulates leading to increase in the water depth. Also, a decrease of a flood extension area is obtained due to the area that is occupied by the buildings.***

Keywords: Digital elevation model; floodplain; hydrodynamic model

1. Introduction

Jeddah city which is located on the Red Sea coast of Saudi Arabia, have faced several flash floods especially on 25th of November 2009 and on 26th of January 2011. The topographic structure of the region has hilly terrain which is close to the urbanized area. The extreme weather condition and unplanned housing developed by people in the lower lands of the wadi streams have contributed in the occurrence of such flash floods. Flash floods cause much damage such as the landslides and mudflows, bridge collapses, damage to buildings and businesses, psychological harm to people that can reach to death.

Flood modeling is becoming an essential tool to study the effect of floods on urbanized areas and to draw inundation map that is caused by flood. Precise DEMs are therefore required for the accurate modeling of floodplain hydrodynamics, commensurate with the 2-D model. High-resolution satellite-based altimetry is an obvious source, especially for large regions and global coverage. Both space-based and airborne DEMs are used for 2-D floodplain hydrodynamic models targeting small basins, e.g., [1, 7] and for evaluating floodplain-elevation profiles in continental-scale river models, e.g., [2, 17]. Early inundation modeling studies have become possible because airborne Light Detection and Ranging (LiDAR) provide high spatial resolution (1 m) topography with high vertical accuracy (±15 cm), e.g., [3, 11, 13].

The main objective of this research is to analyze the effect of high resolution digital elevation model (DEM) in flood inundation modeling.

2. Study Area

The case study is in Wadi Breman and its downstream area shown in figure 1 that consist of an upper catchment and a low land flood plain, suited in the east of Jeddah city as shown in fig. it lies between latitude 21.75° to the north and longitude 39.53° to the east. The watershed spans across an area of approximately 306.67 km^2 in the upstream area which is used for hydrologic modeling computation. The downstream part has an area of 50 km^2 which is an urbanized area for hydraulic modeling computations. The elevation range from 23 m in the lower land area and 248 m above the main sea level in the upstream land area. Therefore, the lower land of the flood plain has a slop gradient of 0-2% making the area susceptible to flooding during the season.

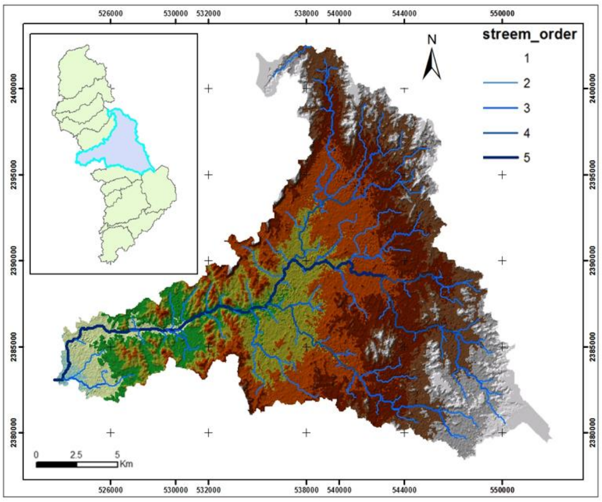


Figure 1: The study area of research in wadi Breman, Jeddah.

The basin boundary is then used as a boundary condition for the other variables such as landuse-landcover and soil type. WMS software has an affordable to assess parameters within the basin. Table 1 shows the main parameters assessed and then automatically considered in driving either loss rate or direct runoff methods.

Table 1: Main parameters of the Upstream area of Wadi Breman, Jeddah.

Basin Name	Area (km^2)	Basin Length (m)	Basin slope(m/m)	Mean Basin Elevation (m)
Wadi Breman	306.67	30356	0.0912	139.46

Land use information was obtained from satellite imagery by utilizing spot 5 data. A shown in figure 2, based on visual interpretation and field survey, four classes have been determined, i.e., bare soil, mountains, buildings, and green areas.

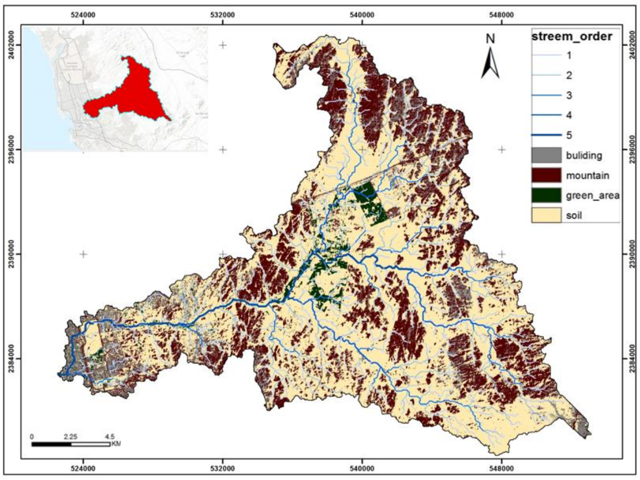


Figure 2: Land use type based on Spot5 imagery for wadi Breman

Generally, Saudi Arabia has a desert climate with extreme heat during the day, an abrupt drop in temperature at night, erratic rainfall. In Jeddah, heavy thunderstorms are common in winter such as in November, December, and January. Figure 3 shows the time series the maximum daily rainfall depth recorded in the period from 1970 to 2014. Along the period, there were relatively heavy storms happened in Jeddah in 1971, 1979, 2009, and 2011. The thunderstorm of January 26th is the largest in the recent memory, with rainfall reaching around 124mm.

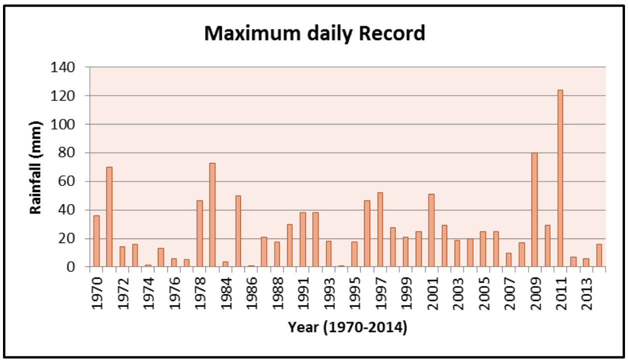


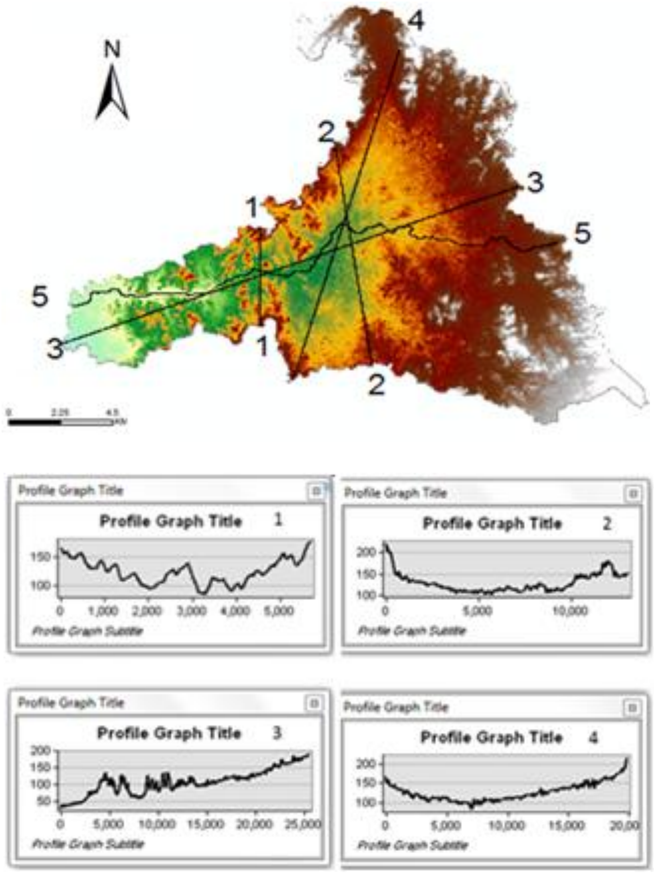
Figure 3: Maximum daily rainfall depth in Jeddah, Saudi Arabia

3. Digital Elevation Model (DEM)

DEM provides an opportunity to take into account the important role that the topographic characteristics (elevation, aspect, slope and sky view) play in the spatial and temporal distribution of solar radiation in complex topography. The influence of the topography can be computed, using the DEM, through a geometric procedure whose accuracy depends on the DEM resolution [5].

The first step for estimating (DEM) is to collect data, which is a digital representation of the elevation of the ground. In surveying, more sophisticated instruments and methodologies might be employed (i.e. Traditional Surveying Techniques, Global Positioning System (GPS), Airborne laser scanning (LIDER), Arial photogrammetry, Synthetic Aperture Radar (SAR) Interferometry, Remote Sensing and Cartographic Digitization) to collect data for DEM generation.

As known, DEM 90 m is a low resolution where the important topographic features and properties were not incorporated explicitly. Such DEM's are particularly useful for flood simulation in rural areas [10]. In urban areas, some features such roads, embankments, buildings, river banks, fences, and dykes have great effect on flood propagation. These features may be found and extracted from LIDAR data. Unfortunately, LIDAR data is huge and expensive. Figure 4 shows cross sections in DEM 90 m, Wadi Breman, Jeddah.



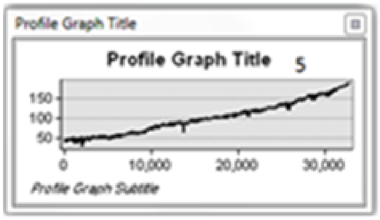


Figure 4: Cross sections in DEM 90 m Wadi Breman, Jeddah

4. Storm Design

In dry regions, overland flow as the initial phase of surface runoff can be defined as the flow of water over the land surface towards a stream channel. The processes begin when rainfall intensity at any time during a storm exceeds the infiltration rate of soil, when water accumulates on and near the surface. The soil infiltration usually declines exponentially with the time reaching a constant final value. When surface depressions are filled, water spills over to run downslope. Whereas in drier, truly arid regions (annual rainfall below 100 mm) plant cover is only concentrated in small patches and in most areas organic matter is totally absent on the ground surface. The surface soil is largely the first point of contact by rainfall. Physical and chemical properties of surficial material thus play a primary role in runoff generation [16].

There are two rainfall data sources used in this study. The first is an observed meteorological data. It was obtained from the rain gauge station located in King Abdulaziz Airport. The Ministry of Water and Electricity operates this station for a weather control in flight affairs in Jeddah airport. Its location is about 15 km to the upstream area of Wadi Breman. The amount of rainfall that have been recorded during the storm event in 25th November 2009 is 70 mm.

The second source of data is a real time global rainfall online data which is available as an open source for world community through UNESCO's Global network for Water and Development Information (UNESCO G-WADI).

5. Methodology

In order to determine the depth of flood waters and to determine the size or width of floodplains, we must first examine the watershed to determine the amount of water that will reach a stream and be carried by the stream during a flood event.

All detailed flood studies examine the areas through which floodwater will flow. This requires a determination of ground elevations and obstructions to flow (such as buildings, bridges, and other development) for these areas. Accurate data on the channel geometry and changes in the floodplain are obtained from ground surveys, aerial photography, or topographic maps.

The first step is a reconstruction of DEMs with grid sizes of 30m, and 10m from the DEM 90m. the reconstruction DEM was conducted in ArcGIS software by utilizing resample tool and selecting cubic resampling technique. The output DEMs have more cell or grid values produced show that there is no big difference with the original DEM. The changing of the grid sizes into smaller grid cells, generally may not affect the hydraulic gradient. These results are different when the resample processes were conducted from high resolution to the lower resolution DEM as studied by Haile and Rientjes (2004) that there are different hydraulic gradients at the downstream boundary.

The second step is adjusting the reconstructed DEM by incorporating the building as a raster format using the GIS operations. The grid value for bare land, fences and embankments, and three floors buildings are 0m, 6m, and 12m respectively. Which refers to the real height of the objects. By utilizing raster calculator in ArcGIS, the two raster's data could be incorporated to become a new raster datasets as an adjusted DEM for hydraulic modeling. The adjusted DEM resembles a digital surface model (DSM) with the urban features, although topographically are similar with the original DEM, 90m resolution. The different grid sizes affect the size of urban feature. It shows the DEM 10m performs better than the lower DEM resolution. In the 10m DEM, buildings, fences and embankments can be visualized clearly with small generalizations.

The third step is a processing in WMS started by converting the raster datasets of the adjusted DEM to be in ASCII format, and then do the other converting to be a TIN format.

6. Results and Discussion

Hydraulic modeling has been successfully executed by using the coupled HEC-RAS and WMS software to estimate the flood depth and inundation map for different resolution DEM. Both one and two-dimensional approaches have been dealt with in the computational domain. Several data have been used such as DEM of different resolutions, land use map to determine the Manning's roughness coefficient (n), geometric data derived from topographic map and satellite imagery.

The results show that, increasing of the grid cell sizes from 30m to 10m has influenced the maximum modeled flood depth to decrease from7.33 m to 6.61m, whereas the average of flood depth increased from 1.62m to 1.83m.

There are two main results in hydrologic modelling, i.e., peak discharge and runoff volume. These results are described under different moisture conditions, i.e., dry, normal, and wet condition. This was done to get the flood hydrograph ranges due to the uncertainty and the limit conditions in the study area. Thus, in the dry condition both the peak discharge and runoff volume results are the lowest compared to the other conditions. The highest of peak discharge and runoff volume were obtained when the condition is wet. In addition, the peak discharge results during the flood event in 25th November 2009 ranges between 64.2m3/s to 362.5m3/s.
There are two main results in hydraulic modelling, i.e., the flood velocity and flood depth of the 1-D model approach, and flood depth and inundation map of 2-D model approach.

The maximum flood velocity from different scenarios (rainfall intensity and CN condition) ranges from 3.65 to 8.39 m/s, and the average velocity ranges from 0.81 to 2.11 m/s. therefore, the maximum flood depth ranges from 2.24 to 7.51m, and the average flood depth ranges from 0.91 to 1.87m. the stream slope influences for both velocity and flood depth. Therefore, the flood depth and inundation map in 2-D, the maximum flood depth ranges from 7.57 to 9.93m, which the averages of the flood depth ranges from 1.62 to 1,93m. the increase of peak discharge values have resulted in increasing of the areal extent of the flood.

7. Conclusion

It is important to remember that floodplain map boundaries are only as accurate as the topographic map on which they are drawn. An adjusted high resolution DEM has been reconstructed with inner grid cell sizes and with the incorporation of the urban features (e.g. buildings and streets). The flood simulation results showed that the higher resolution DEM has increased the average flood depth due to the fact that buildings act as barriers to the flow and water accumulates leading to increase in the water depth. Also, a decrease of a flood extension area is obtained due to the area that is occupied by the buildings.

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Author Profile

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