Flood Risk Assessment and Protection Guidelines for Infrastructure Planning in Qatar

Abdullah Al Mamoon
amamoon@gmail.com
Ministry of Municipality and Environment, Doha, Qatar

ABSTRACT

This paper presents key features of "Flood Assessment and Protection Guidelines" (FAPG) prepared by the Ministry of Municipality and Environment (MME), Qatar. It is intended that the FAPG will provide guidance and assistance to a wide range of entities including government agencies, developers, engineers, planners and policy makers for locating flood prone areas across Qatar, assessing potential flood hazard and subsequent mitigation. A flood modelling was carried out using two-dimensional rain on grid (RoG) hydraulic modelling approach. A series of flood risk maps covering both rural and urban areas of Qatar were then prepared as per the degree of flood risk to people, property and infrastructure. These maps have been provided as digital flood inundation layers in an interactive GIS web-based flood mapping portal.

Keywords: Flood risk; Mitigation; DEM; Planning; Qatar

1 INTRODUCTION

Qatar lies in the northern hemisphere desert (FAO, 2008). Although countries with arid climate receive very little rainfall, occasional flash flooding due to short duration and high intensity rainfall is not uncommon (Mamoon e al., 2014). For example, a devastating flood in Nov 2009 in Jeddah, Saudi Arabia caused deaths of over 100 people and major destruction of urban infrastructure (Al-Saud, 2010). Storm events in Qatar typically consist of relatively high intensity rainfall bursts over short duration. A significant rainfall event on October 19, 2018 in Qatar caused widespread flooding of highways, underpasses and many parts of Doha city (Mamoon & Rahman, 2018).

Flooding within the state of Qatar can be attributed to the nature of storm events coupled with environmental characteristics including relatively flat topography and a lack of well-defined overland flow paths. In urban areas within Qatar, overland flows resulting from significant rainfall events generally make their way to the urban road and drainage network (Figure 1).

The main challenges in flood modelling in the arid regions include lack of recorded flood data, infrequent occurrence of floods and lack of defined water courses (Xao Lin, 1999; Sen, 2008; Morin et al., 2009; Mamoon et al., 2015). Flood assessment in Qatar involves several major challenges (Mamoon et al., 2015):

- Availability and accessibility of relevant GIS and terrain data in Qatar.
- Quality of topographic data for the development of an accurate digital terrain model (DTM). Current terrain data available for Qatar is limited to 1.09 m vertical accuracy for urban areas and 1.58 m accuracy for rural areas.
- Lack of available historical rainfall and flood data for flood model parametrization

and calibration (Mamoon et al., 2013; 2014).
- The complexity of the study area which includes relatively low design rainfall intensities, poorly defined flow paths and potential for high transmission losses typical of arid regions (Pilgrim et al., 2009).

Figure 1: Flooding in Doha, (a) Trapped rainfall-runoff collecting on the low point of a main road in Doha; (b) Example of road drainage network exhibiting capacity exceedance/overflow.

Qatar is currently in the midst of a rapid infrastructure development. As development continues to progress, concern has been raised amongst decision makers on the potential environmental risk and socio-economic damage that may be caused by both frequent and significant flood events. In order to develop an effective planning framework that aims to address flood hazards in Qatar, The Ministry of Municipality and Environment carried out a comprehensive national flood study (MME, 2017) in line with the Qatar National Vision 2030 and fulfilling the objectives of the Qatar National Development Strategy 2017-2022. Consequently, using the results and recommendations of this study, a national flood code guideline titled “Flood Assessment and Protection Guidelines” was developed (MME, 2019).

This paper presents some important features of FARG and describes how these can be applied for adaptation and effective flood management in Qatar.

2 STUDY AREA

Qatar is located on the north-eastern side of the Arabian Peninsula (Figure 2). It has a land area of 11,571 km^2. The average annual rainfall in Qatar is found to be in the range of 55.5–99 mm (Mamoon & Rahman, 2016). Rainfall in Qatar mainly occurs in the period from October to May showing a higher degree of spatial and temporal variability with respect to intensity and duration (Mamoon et al., 2014). A sharp gradient in average annual rainfall was noticed, with north having higher values than the south (Mamoon et al., 2016).

3 DEVELOPMENT OF “FLOOD ASSESSMENT AND PROTECTION GUIDELINES” (FAPG)

The FAPG entails development of a set of flood codes based on the results and recommendations of Qatar's National Flood Study (MME, 2017). The purpose of flood codes is to identify rural and urban areas of Qatar that are at risk of flooding and regulate development occurring in these areas to ensure development does not cause or increase risks and/or hazards associated with flooding to people, property and infrastructure.

3.1 Data Collection and Review

A significant amount of data was collected for the flood study that includes climate, rainfall, topography, soils, historical flooding, infiltration, tidal levels, land use, infrastructure and storm water management etc.

A detailed gap analysis was undertaken to identify any major data gaps, additional data requirements and limitations. Current terrain data available for Qatar is limited to +/- 0.27 m vertical accuracy for urban areas and +/-1.58 m accuracy for rural areas. In light of the stated accuracy of the topographic data in rural areas, the flood levels estimated by 2D hydraulic models will have an accuracy limitation of at least +/- 1.58m in the vertical. In areas of relatively flat terrain, this inaccuracy will translate into a relatively greater uncertainty in horizontal flood inundation extent.

3.2 Flood Modelling

A detailed computer modelling of flood behavior for a range of design flood events is crucial for preparation of flood risk inundation maps that would assist in development of land use planning solutions. Two alternative flood modelling approaches are compared on a pilot catchment situated in Qatar. The first method involved the application of a coupled hydrologic/hydraulic modelling approach, whilst the second method was based on a 2 dimensional (D) 'rain on grid' hydraulic modelling approach. In the 'rain on grid' approach, design storm events (rainfalls) are directly applied across the two-dimensional hydraulic modelling domain of the study area to simulate the dynamic propagation of flood water across the study area (Figure 2).

An assessment of the results from the two methods demonstrated that the 2D 'rain on grid' hydraulic modelling approach was the preferred method for implementation in Qatar as this needed less data and provided a more realistic simulation of the rainfall runoff process, higher resolution model outputs, and greater efficiency and potential for automation in model setup phase.

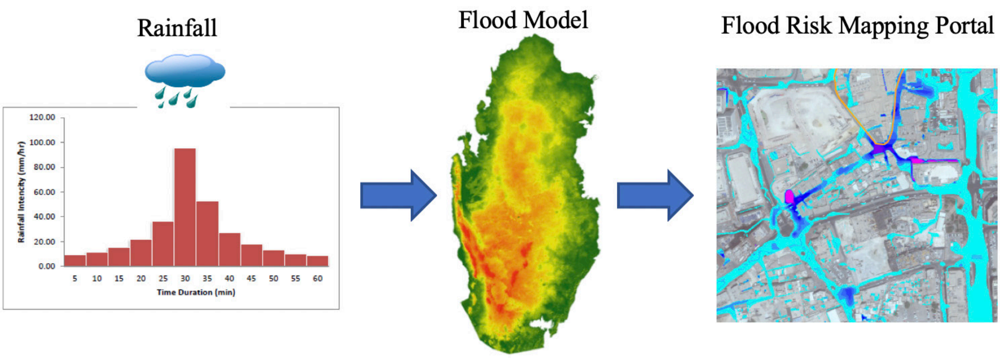

Figure 2: Rain on Grid method

3.2.1 Model Setup and Design Event Analysis

Hydraulic modelling was undertaken using two-dimensional (2D) TUFLOW GPU (Graphics Processing Unit) software. In order to model the required study area at a sufficient level of resolution, the State of Qatar has been delineated into 10 sub-catchments with a flood model developed for each sub-catchment (Figure 3a). Key features of the model include a detailed digital elevation model (DEM) with a cell size of 5m x 5m, a land use layer, building representation, walls/fences and cross drainage infrastructure.

The flood models were validated against the 25th December 2015 storm event in Qatar and a sensitivity analysis was undertaken to confirm the validity of key model parameters. Based on a review of modelled results against limited on ground flood records, the nature and pattern of flooding estimated by the flood model was found to be generally consistent with that experienced on ground.

Design event flood modelling was undertaken for the 10% AEP (10 year ARI) and 1% AEP (100 year ARI) design events for storm durations ranging from 15 minutes to 120 minutes. Flood modelling results for these design events are provided in the form of flood level, depth, velocity and hazard maps.

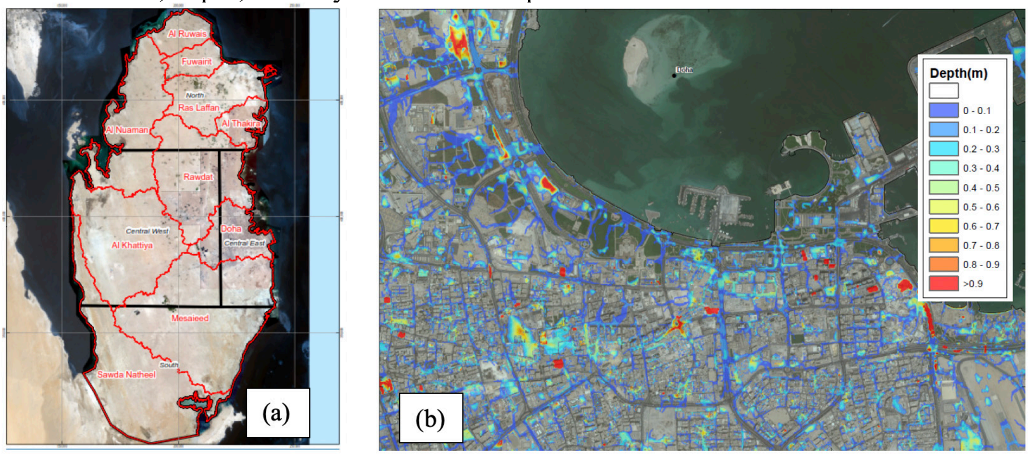

Figure 3: Flood Maps, (a) Flood Model Extent; (b) Flood Hazrad Overlay Map showing depths.

An analysis of flooding for the Probable Maximum Flood Event (PMF) was also undertaken. A climate change assessment was also undertaken to estimate and map the nature of flood risk for Year 2050 and Year 2100 future climate scenarios.

3.3 Flood Risk Assessment

Flood risk is a function of the likelihood of an event occurring and the potential impact (consequence) of the event on receptors. To estimate the degree of flood risk to people, property and infrastructure, flood inundation maps were prepared that illustrate the spatial variation of flood depth, velocity and flood hazard (depth x velocity) for each of the design events modelled (Figure 3b). These maps have been provided as digital flood hazard layers in the Qatar Flood Mapping Portal. Four flood hazard categories have been used to define the degree of flood hazard associated with each design flood event. Table 1 illustrates the depth, velocity, and depth velocity product associated with each flood hazard category.

Table 1: Flood Hazard Overlay Categories

Items	Low Hazard	Medium Hazard	High Hazard	Extreme Hazard
Depth (m)	<0.30	0.31 to 0.60	0.61 to 1.20	>1.2
Velocity (m/s)	<0.38	0.39 to 0.80	0.81 to 1.50	>1.5
Depth x Velocity (m^2/s)	<Medium	D+0.64*V <0.82	D+0.69*V <1.38	>High
Typical means of egress	Sedan	Sedan early, but 4WD or trucks later	4WD or large trucks.	Large trucks.

3.4 Qatar Flood Portal

In order to illustrate the nature and risk of flooding, an interactive GIS web based flood mapping portal (Qatar Flood Mapping Portal) was developed (Figure 4). The Portal provides a broad scale understanding of the range of potential flood conditions that could occur across the State of Qatar.

The portal's functionality enables the user to open up a high-resolution map of Qatar, zoom in on a particular catchment area and visualize (and query) the flood level, depth, velocity and degree of flood risk at any property location within Qatar for any of the design flood events that were modelled. The Portal also includes flood inundation maps for a range of potential future climate conditions.

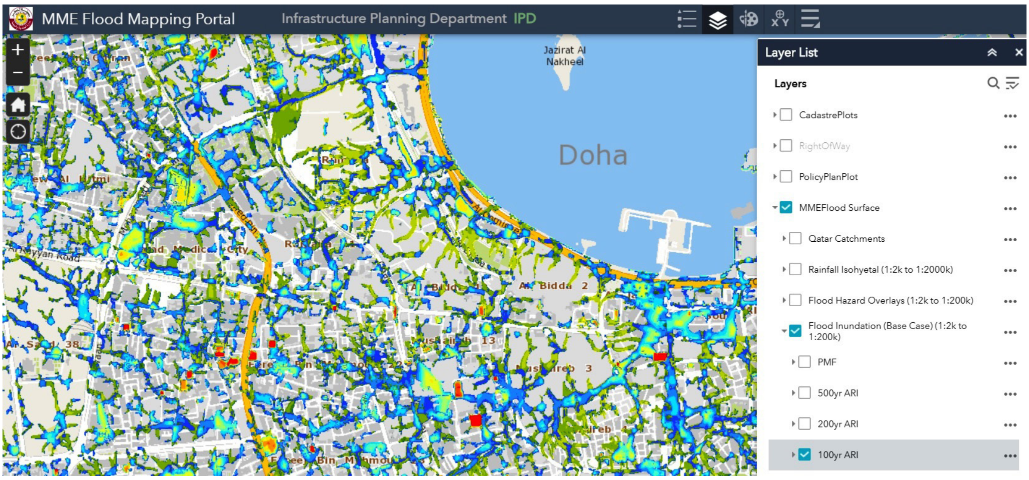

Figure 4: Qatar Flood Portal

In instances where a detailed understanding of local flood conditions is required (e.g. when undertaking detailed design of infrastructure or assessing the potential impact of a development), it is recommended that site-specific flood modelling of the local catchment be undertaken.

4 FLOOD CODES

This code applies to assessing any type of development that lies within a flood affected area covered by the Flood Hazard Overlay (MME, 2019). Flood Code sets out performance requirements and acceptable solutions during the building permit and development application process. All development-related proposals in Qatar are to be evaluated against the following criteria:

- Whether the cumulative impact of development is likely to cause or increase the adverse impacts of flooding to people, property and infrastructure.
- Whether the development is likely to cause or worsen flood hazard.
- Whether the risks associated with the development are fully known, quantifiable and capable of mitigation to MME's satisfaction.
- Whether flood mitigation works, intended to reduce flood risk, hazard and damage, do so without adversely affecting other land and/or premises, property and infrastructure.
- Whether extra burden is placed on the State of Qatar's emergency management response efforts during a flood emergency.

5 CONCLUSION

Qatar Ministry of Municipality and Environment has developed a national flood code titled "Flood Assessment and Protection Guidelines" for flood risk assessment and development control in Qatar. A flood modelling was carried out using two-dimensional TUFLOW software employing 'rain on grid' hydraulic modelling approach. A series of flood hazard overlay risk maps covering both rural and urban areas of Qatar were prepared using four flood hazard categories namely low, medium, high and extreme. These maps have been provided as digital flood inundation layers in an interactive GIS web-based flood mapping portal that enables the user to conduct flood risk assessment at any location across the State of Qatar. The climate change effect on flooding has also been incorporated in flood inundation maps. The FAPG provides clear procedures and technical guidance, assistance, and the necessary requirements in dealing with floods to a wide range of entities such as; government agencies, developers, urban planners, engineers, and decision makers, for locating and protecting flood prone areas and assessing potential flood risks and required mitigation.

REFERENCES

Al-Saud, M. (2010). Assessment of Flood Hazard of Jeddah Area 2009, Saudi Arabia. *Journal of Water Resources and Protection,* 2, 839-847.

Food and Agricultural Organizations (FAO), United Nations (2009). AQUASTAT, (Water report 34).

Mamoon, A. A., Jeorgensen, N. E., Rahman, A. & Qasem, H. (2013). *Estimation of Design Rainfall in Arid Region: A Case Study for Qatar Using L Moments*, 35th IAHR World Congress. September 8 to 13, Chengdu, China, 1-9.

Mamoon A. A. & Rahman A. (2016). Rainfall in Qatar: Is it changing? *Natural Hazards*, Sept 2016. DOI: 10.1007/s11069-016-2576-6.

Mamoon, A. A., Joergensen, N. E., Rahman. A. & Qasem, H. (2016). Design rainfall in Qatar: sensitivity to climate change scenarios. *Natural Hazards, 81*(3), 1797-1810.

Mamoon, A. A. & Rahman. A. (2018). Qatar Rainfall and Runoff Characteristics – A New Direction of Engineering Education and Practice in Qatar, Proc. *1st International Conference on Advancement in Engineering Education (iCAEED 2018)*, Sydney, Australia. pp. 186-195, ISBN: 978-0-6480147-9-9.

Mamoon, A. A., Jeorgensen, N. E., Rahman, A. & Qasem, H. (2014). Derivation of new design rainfall in Qatar using L-moments based index frequency approach. *International Journal of Sustainable Built Environment*, *3*, 111-118.

Mamoon, A. A., Regan, B., Sylianteng, C., Rahman, A. & Abd Alkader, A. A. (2015). *Flood Study in Qatar – Challenges and Opportunities*, 36th Hydrology and Water Resources Symposium, Hobart, Australia.

Ministry of Municipality and Environment (MME), (2019). *Flood Assessment and Protection Guidelines.*

Ministry of Municipality and Environment (MME), (2017). *Flood Study for the State of Qatar.*

Morin, E., Jacoby, Y., Navon, S. & Bet-Halachmi, E. (2009). Towards flash-flood prediction in the dry Dead Sea region utilizing radar rainfall information. *Advances in Water Resources*, *32*, 1066-1076.

Pilgrim, D., Chapman, T. & Doran A. (2009). Problems of Rainfall-Runoff Modelling in Arid and Semiarid Regions. *Hydrological Sciences Journal, 33*, 4, 379-400.

Sen, Z. (2008). *Wadi Hydrology*. The USA: CRC Press.

Cite this article as: Al Mamoon A., "Flood Risk Assessment and Protection Guidelines for Infrastructure Planning in Qatar", *International Conference on Civil Infrastructure and Construction (CIC 2020)*, Doha, Qatar, 2-5 February 2020, DOI: https://doi.org/10.29117/cic.2020.0078