

GeoFlood Enhancement for Robust Flood Inundation Mapping in Flat Terrain Zones

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The primary purpose of this supplementary material is to document and describe the datasets obtained from Hamouda et al. [1] as well as the hydrologic and hydraulic models. The provided datasets include a fully configured HEC-HMS hydrologic model along with all required inputs for transforming rainfall into runoff hydrographs, as well as a HEC-RAS hydraulic model and the complementary datasets necessary to route the HEC-HMS outputs and simulate flood extents. As presented in the case study section of the main manuscript, two case studies are analyzed, as illustrated in Figure 3 (of the main paper).

HEC-HMS Model

The HEC-HMS model setup requires several spatial and hydrometeorological inputs. Rainfall information is derived from intensity-duration-frequency (IDF) curves shown in **Table SB1** & **Table SB2**, while topographic data are obtained from the Shuttle Radar Topography Mission (SRTM) digital elevation model with a spatial resolution of 30 m [2]. Soil characteristics are extracted from the Global Hydrologic Soil Groups [3], and land-cover data are obtained from the Sentinel-2 Satellite image [4].

The delineated upstream catchment maps are presented in **Figure SB1** & **Figure SB2**, and their key characteristics are summarized in **Table SB1**. The Curve Number (CN) for each sub-basin is derived as a function of soil type, land-use classification, and terrain slope, with average CN of 77 and 85 for case study (A) and case study (B), respectively.

In addition, the HEC-HMS model requires estimation of the time of concentration, which is primarily governed by the length and slope of the longest flow path within each catchment, which was obtained using WMS. The model outputs consist of runoff hydrographs corresponding to the selected rainfall return periods, which are subsequently used as inflow boundary conditions for the hydraulic simulations presented in **Figure SB3**.

Table SB1: IDF values for Case Study (A).

T (year)	Rainfall Intensity (mm/hr)								
	10-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
5	60.4	44.6	26.4	15.3	9.1	6.6	3.9	2.3	1.3
10	74.1	54.7	32.4	18.8	11.2	8.1	4.8	2.8	1.6
25	90.7	67.0	39.6	23.0	13.8	9.9	5.9	3.4	2.0
50	102.7	75.9	44.9	26.1	15.6	11.2	6.7	3.9	2.2
100	114.4	84.5	50.0	29.0	17.4	12.5	7.5	4.3	2.5

Table SB2: IDF values for Case Study (B).

T (year)	Rainfall Intensity (mm/hr)									
	10-min	15-min	20-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
5	38.9	29.2	24.0	18.5	10.9	6.9	5.3	3.2	1.8	1.0
10	50.1	37.6	30.9	23.8	14.0	8.9	6.8	4.1	2.4	1.3
25	65.5	49.2	40.4	31.1	18.4	11.7	9.0	5.4	3.1	1.7
50	77.9	58.6	48.1	37.0	21.9	13.9	10.7	6.5	3.7	2.1
100	91.0	68.4	56.1	43.2	25.5	16.2	12.4	7.5	4.3	2.4

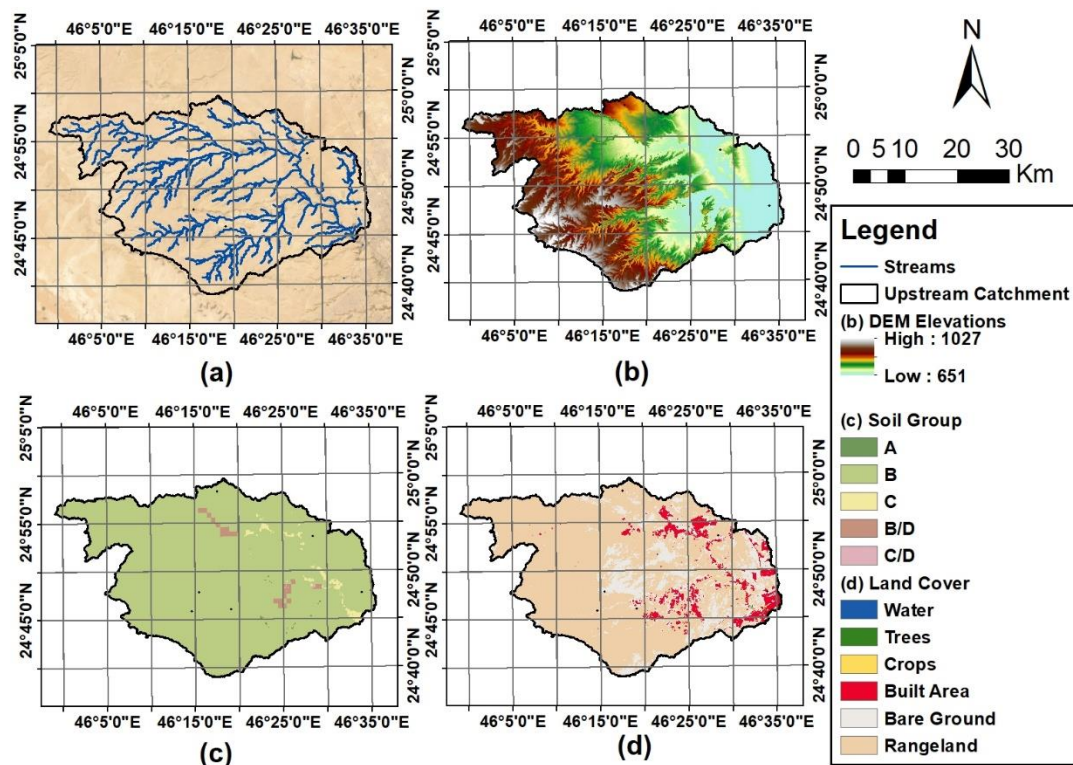


Figure SB1 Case Study (A) upstream catchment; (a) catchment boundaries and streams; (b) DEM; (c) soil map; (d) land cover map.

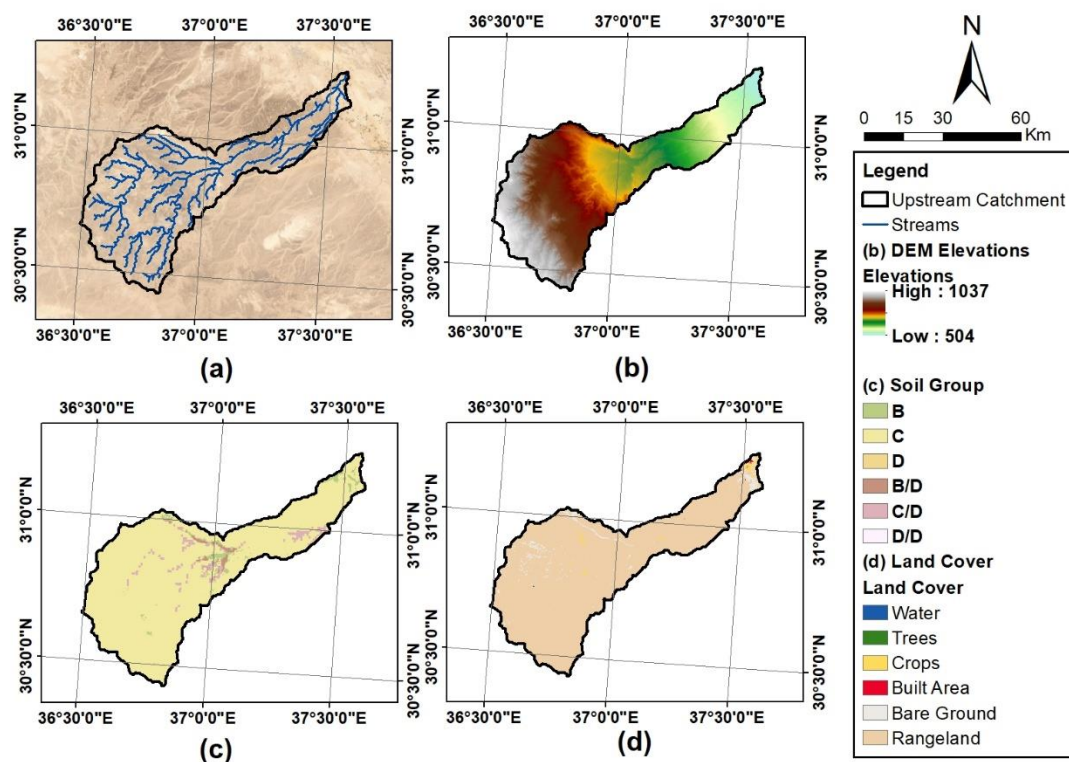


Figure SB2 Case Study (B) upstream catchment (a) catchment boundaries and streams; (b) DEM; (c) soil map; (d) land cover map.

Table SB3: HEC-HMS data summary.

Study Area	Return Period	Rainfall Depth (mm)	Peak Discharge (m ³ /s)	Catchment Area Upstream of Model (km ²)	Average Basin Slope	Average CN
Wadi Hanifa Case Study (A)	5	31.4	22.6	1461	1.21%	77
	10	38.5	40.9			
	25	47.2	74.7			
	50	53.4	110.7			
	100	59.5	154.9			
Wadi Bayer Case Study (B)	5	24.7	27.6	3175	0.88%	85
	10	31.8	104.3			
	25	41.6	306.6			
	50	49.5	543.4			
	100	57.8	880.2			

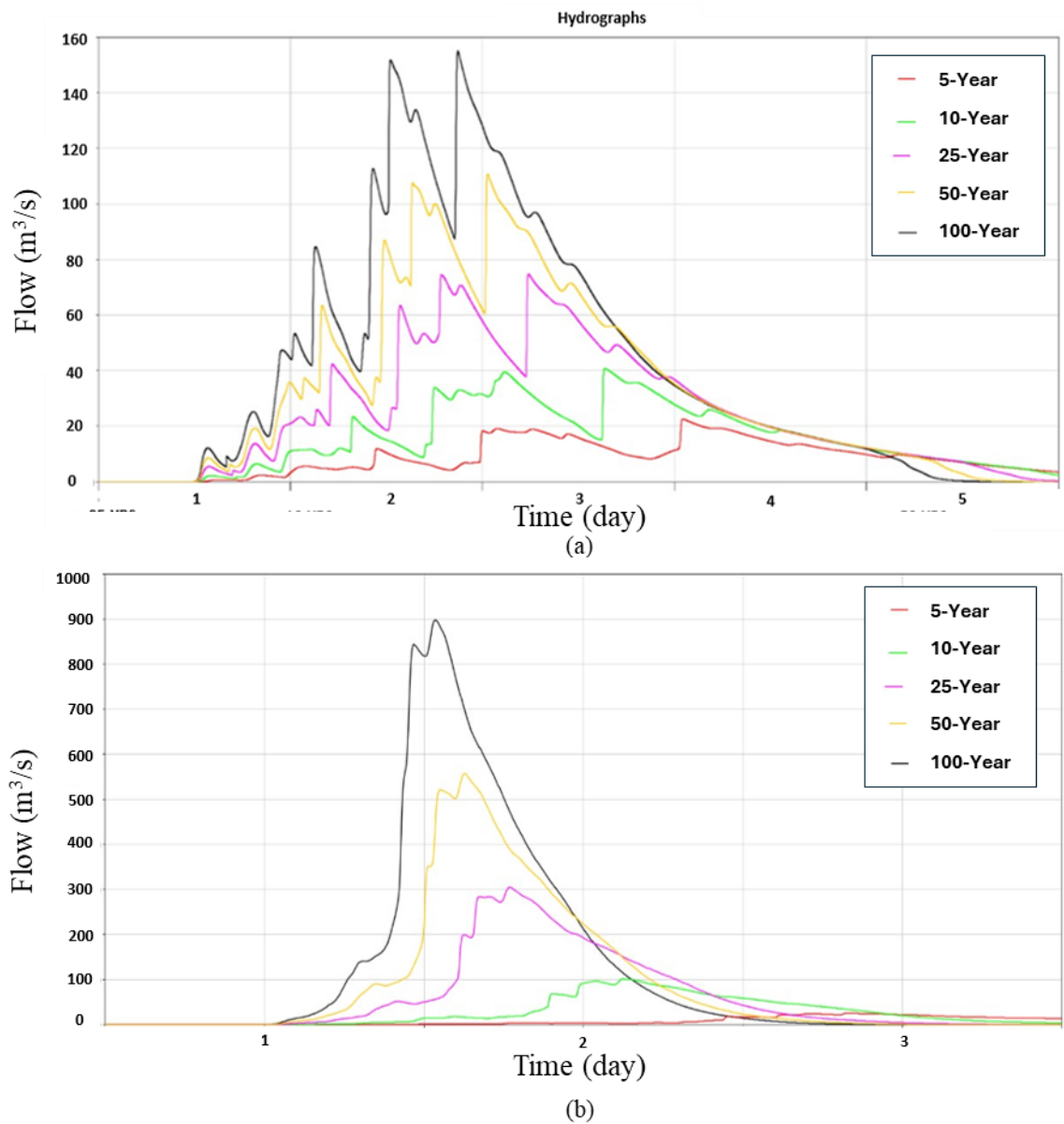


Figure SB3 HEC-HMS flow hydrographs output; (a) Case Study (A); (b) Case Study (B).

HEC-RAS Model

The HEC-RAS hydraulic model requires a high-resolution digital elevation model (DEM) derived from drone imagery from a private consultant. The DEM spatial resolution is 0.5×0.5 m for Case Study (A) and 1.0×1.0 m for Case Study (B). The upstream boundary condition for the HEC-RAS model is defined using the flow hydrographs generated by the HEC-HMS simulations. Channel roughness is represented by Manning's coefficient, adopted in accordance with Kingdom of Saudi Arabia (KSA) design standards, with a value of $n = 0.04$ for natural wadi channels. The downstream boundary condition is specified as normal depth.

To perform two-dimensional hydraulic simulations, a computational 2D mesh must be defined. For Case Study (A), Hamouda et al. [1] selected a mesh size of 3×3 m, resulting in approximately 250,000 computational cells. For Case Study (B), a coarser mesh of 10×10 m was adopted, producing a comparable number of grid cells. This approach ensures a balance between computational efficiency and model accuracy, particularly given HEC-RAS limitations, where excessively fine or excessively large meshes may lead to numerical instability or reduced model responsiveness. Figure 4 and

Figure 5 in the main manuscript show the HEC-RAS model and the boundary conditions, while Table 1 shows the main characteristics for the GeoFlood model, which is similar to the HEC-RAS model.

Remarks

All the main data **required** to perform the study done by Hamouda et al. [1] to get the hydrograph data are presented in this document. The only data not provided is the high-resolution DEM, which is used for the HEC-RAS and GeoFlood models and is not publicly available; however, this could be provided upon request from the corresponding authors.

Appendix B. References

1. Hamouda, M. A.; Awadallah, A. G.; Abdel-Maguid, R. H. Extension of the Geomorphic Flood Index Classifier to Predict Flood Inundation Maps for Uncalibrated Rainfall Depths in Arid Regions. *Nat. Hazards* **2024**, 120 (5), 4633–4655. <https://doi.org/10.1007/s11069-023-06393-0>.
2. NASA Shuttle Radar Topography Mission (SRTM) (2013). Shuttle Radar Topography Mission (SRTM) Global. Distributed by Open-Topography. <https://doi.org/https://doi.org/10.5069/G9445JDF>.
3. Ross, C. W.; Prihodko, L.; Anchang, J. Y.; Kumar, S. S.; Ji, W.; Hanan, N. P. Global Hydrologic Soil Groups (HYSOGs250m) for Curve Number-Based Runoff Modeling (Version 1). *ORNL Distributed Active Archive Center* **2018**. <https://doi.org/https://doi.org/10.3334/ORNLDAAAC/1566>.
4. Karra, K.; Kontgis, C.; Statman-Weil, Z.; Mazzariello, J. C.; Mathis, M.; Brumby, S. P. Global Land Use/Land Cover with Sentinel-2 and Deep Learning. In IGARSS 2021-2021 IEEE International Geoscience and Remote Sensing Symposium. *IEEE*, **2021**.