Journal of Al-Azhar University Engineering Sector

Vol.18, No. 69, October 2023, 850 - 868

ASSESSING FLOOD RISKS IN ARID ZONES BY LINKING REMOTE SENSING TECHNIQUES AND GIS

Ahmed Maher [*1], Hany Ahmed[2], Karim Badr Hussein[2], M. Abo-Taha [3]

[1] Civil Engineering Department, Faculty of Engineering, Al-Safwa Higher Institute for Engineering, Cairo, Egypt.

[2] Civil Engineering Department, Faculty of Engineering, Al-Azhar University, Cairo, Egypt.

[3] Civil Engineering Department, Faculty of Engineering, Al-Ahram Canadian University 6th of October City, Giza Egypt.

***Correspondence:** maher21295@gmail.com

Citation:
Ahmed maher, Hany Ahmed, Karim Badr hussein and M.Abo-Taha, " Assessing flood risks in arid zones by linking remote sensing techniques and GIS", Journal of Al-Azhar University Engineering Sector, vol.18, pp. 850-868, 2023

Received: 13 May 2023
Accepted: 24 August 2023

DoI:10.21608/auej.2023.210774.1372

ABSTRACT

Regarding the importance of protecting arid areas in Egypt from flood hazards, this research was initiated to assess flood hazards in such zones by integrating hydrologic modelling, hydrodynamic modelling, remote sensing techniques, and GIS, where Sudr Valley was considered a case study. This study presents a proposal for new methods to assess expected flood hazards that impacted the arid projects by simulating the Sudr Valley modelling case. The study is based on applying the HEC-HMS program to draw valleys and outflow basins and compute their morphometric attributes thus computing the peak flow hydrograph of floods for different basin outflow. The candidate also implied the hydraulic model (HEC-RAS) to calculate flood flow components (depth and velocity) thus mapping floodplain areas. Results were obtained; analysed and represented on maps. The results highlighted that the updated information on Sudr Valley hydrology and morphology was important to decision-makers. In addition, the tooled modelling is applicable to delineate Sudr Valley. It was further recommended to follow the utilized methodology to visualize similar areas.

KEYWORDS: GIS, Remote Sensing, HEC-RAS, HEC-HMS, Floodplain

تقييم مخاطر الفيضانات في المناطق القاحلة بواسطة الربط بين تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية

أحمد ماهر [1]،*، هاني حمعه إبراهيم [2]، كريم بدر حسين [2]، محمد أبو طه [3]

[1]قسم الهندسة المدنية، معهد الصفوه العالي للهندسة، القاهرة، مصر

[2]قسم الهندسة المدنية، كلية الهندسة، جامعة الازهر، القاهرة، مصر

[3]قسم الهندسة المدنية، كلية الهندسة، جامعة الأهرام الكنديه، مدينة 6 أكتوبر،الجيزه ، مصر

***البريد الاليكتروني للباحث الرئيسي:** maher21295@gmail.com

ASSESSING FLOOD RISKS IN ARID ZONES BY LINKING REMOTE SENSING TECHNIQUES AND GIS

الملخص

من حيث أهمية حماية المناطق القاحلة في مصر من مخاطر الفيضانات، فقد بدأ هذا البحث لتقييم مخاطر الفيضانات في هذه المناطق من خلال دمج النمذجة الهيدرولوجية والنمذجة الهيدروديناميكية وتقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية، حيث تم اعتبار وادي سدر حاله دراسيه. تقدم هذه الدراسة اقتراحا لطرق جديدة لتقييم مخاطر الفيضانات المتوقعة التي أثرت على المشاريع القاحلة من خلال محاكاة حالة نمذجة وادي سدر. تعتمد الدراسة على تطبيق برنامج HEC-HMS لرسم الأودية وأحواض التدفق وحساب خصائصها المورفومترية وبالتالي حساب هيدروغراف تدفق الذروة للفيضانات لتدفق الأحواض المختلفة. كما أشار البحث إلى النموذج الهيدروليكي (HEC-RAS) لحساب عناصر تدفق الفيضان (العمق والسرعة) وبالتالي رسم خرائط حرم مجري الفيضان . تم الحصول على النتائج. وتحليلها وتمثيلها على الخرائط. وأبرزت النتائج أن المعلومات المحدثة التي تم الحصول عليها حول هيدرولوجيا وادي سدر ومورفولوجيا كانت ذات أهمية كبيرة لصانعي القرار. بالإضافة إلى ذلك ، فإن النمذجة مزودة بأدوات قابلة للتطبيق في ترسيم وادي سدر. ويوصي باتباع المنهجية المستخدمة لتصور مجالات مماثلة.

الكلمات المفتاحية : نظم المعلومات الجغرافيه , الاستشعار عن بعد ,نظام النمذجة الهيدرولوجية, نظام تحليل الأنهار,حرم مجري الفيضان.

1. INTRODUCTION

All over the world, assessing flood risks and taking measures to mitigate their risks is an important issue to consider. Accordingly, many researchers are interested in this field. Likewise, this is the case in Egypt, where many researchers are involved in flood risk mitigation in several areas in the Sinai Peninsula (i.e. Wadi Watir and Wadi Grendel). This is achieved within the framework of achieving the goals of Egypt's Vision 2030. For example, flood risk assessment was done by integrating hydrological modeling and hydrodynamic modeling [2], likewise, in floodplain management, where the Watir-Sinai Valley was taken as a case study [3]. Similarly, integrated planning and flood risk management has been done, establishing a conceptual framework for integrated infrastructure [22]. Similarly, hydrological models (e.g. HEC-HMS, NEXRAD, HEC-RAS) have been created to model a region in Texas [5] .

Moreover, federal flood management methods have been established [16]. Likewise, GIS and remote sensing techniques have been used to find the correlation between morphometric parameters using statistical correlation to determine the area under different flood conditions [1]. Moreover, the effect of high releases downstream of the Assiut Barrage (544.75 km from the Aswan Dam depression) was studied [4] .

Furthermore, hydrological parameters of the flash flood event that occurred on January 17, 2010 in Sinai were measured using multiple sets of remote sensing data and fieldwork of instrumented watersheds [11]. Moreover, the types of errors that cause inaccurate conclusions of hydrological analysis results have been studied [28]. Moreover, modeling of unsteady flow and sediment in a large tank has been done using header [26].

Moreover, torrential and flood maps were developed using remote sensing in Wadi Al-Arish, Sinai, Egypt [9]. Moreover, integration of spatial planning with the importance of flood risk management as an approach to flood risk mitigation has been done [22] .

Hence, this research arose with the neutrality of flood risk assessment by linking remote sensing techniques and geographic information systems, where Wadi Al-Sudr was taken as a case study within the framework of protecting arid areas in Egypt.

2. SITE VISITS AND STUDY AREA RECONNAISSANCE

Several visits were carried out to accumulate data about the area. Moreover, native residents were interviewed to obtain additional information. The assembled data and information were analysed to perceive a complete picture of the study area.

Based on the analysed data, the study area was reconnoitred, from which the study area, figure (1), was described, as follows:

- The Study Area is located between the latitudes 29°40'0.00" N and 29°50'0.00"N, whereas it is located between the longitudes 32°45'0.00"E and 33° 0'0.00" E.
- The study area is 609.81 km^2.
- The study area is located in Northeast Suez Gulf.
- It encompasses Wadi Sudr, which is the most significant wadi in South Sinai.
- Wadi Sudr leads to Suez Gulf.

Figure (1) Study area location in the Sinai Peninsula.

3. NUMERICAL MODELLING

This section elaborates on the implemented models, remote sensing, hydrologic modeling, and digital elevation model, as follows:

3.a. IMPLEMENTED MODELS

WMS & HEC-HMS hydrologic models were used. In addition, HEC RAS was tooled to calculate the flood limits, while ARC GIS was utilized to manage flood areas; estimate the torrential hazards; produce flood maps; envisage the hydrological condition; visualize the morphological consequences, and produce maps.

3. b. REMOTE SENSING

The remote sensing features were integrated with the geographic information systems and the severities of the urban progress were obtained.
In addition, ARC GIS remote sensing analysed the satellite images, and the flood path area expansion, within the boundaries, was obtained.

3. c. HYDROLOGICAL MODELLING

A hydrogeological model was implemented, where basins were delineated; the streams were defined and the morphological features were recognized.
Moreover, several models were utilized and a high delineation to Wadi Sudr was obtained, where the external boundaries delineation was achieved by GIS software. In addition, HEC-HMS software was tooled and the waterways were signposted.
Obvious was that the main basin has 11 sub-basins, where 7 are known by name to the native residents (i.e. Bedouins).

4.d. DIGITAL ELEVATION MODEL

Furthermore, a Digital Elevation Model "DEM" (i.e. 30 m resolution) was obtained from the Earth Explorer Website of the USGS, where streams were displayed per 200 m2. This is considered to be accurate; in terms of the available DEM; Figure (2).

5. RESULTS ANALYSIS AND DISCUSSION

Results of hydrogeological modeling, rainfall, losses, surface runoff, and hydrodynamic modeling were obtained; analyzed, and presented in figures (3) to (18) together with tables (1) to (4).

5. a RESULTS OF HYDROGEOLOGICAL MODELLING

Results were obtained; analyzed and represented in figures (2) to (7). Figure (2) designates the implemented DEM, while figures (3) to (7) represent the contour lines, slope intensity to the study area topography, streams in Wadi Sudr with 200 m^2 resolution, streams orders, and percentage of stream order, respectively. In addition, tables (1) and (2) designate % of stream order and sub-basin characteristics. Moreover, figure (8) represents the sub-basins in the study area.

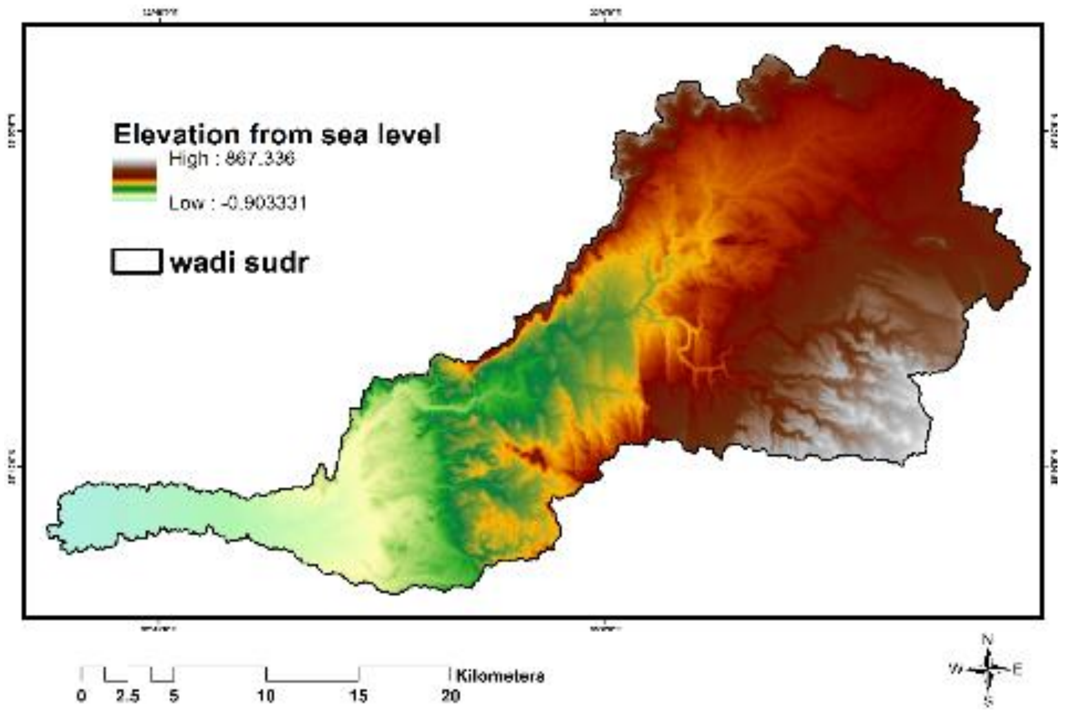


Figure (2) Implemented DEM.

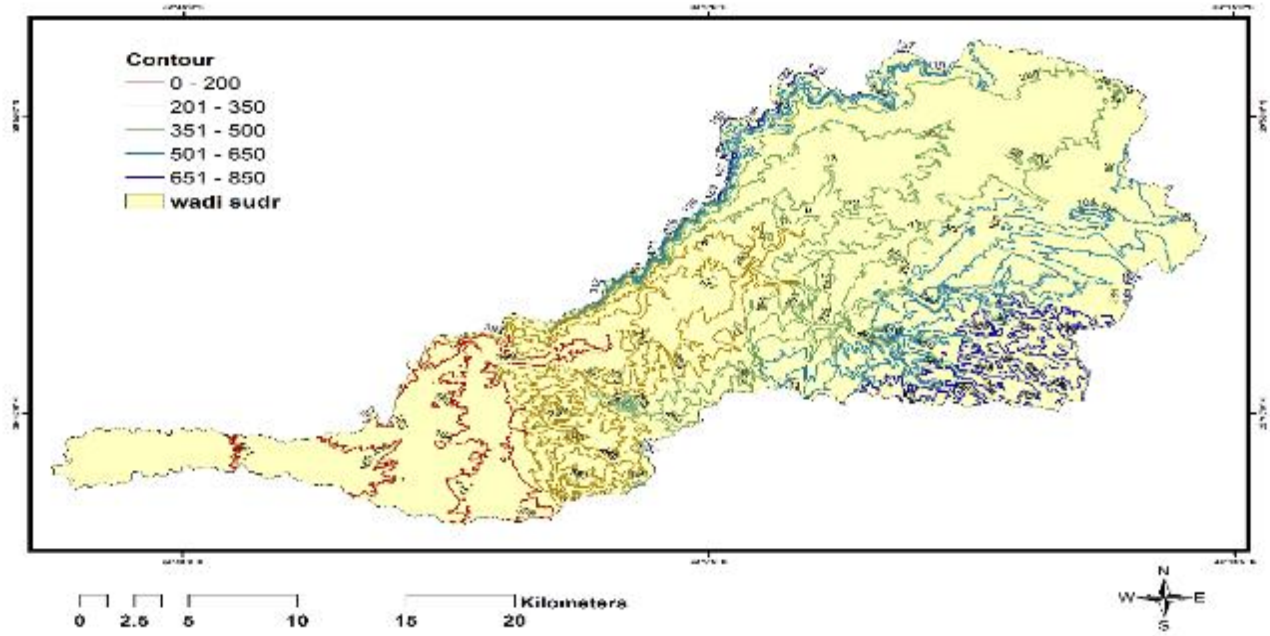


Figure (3) Contour lines in the study area.

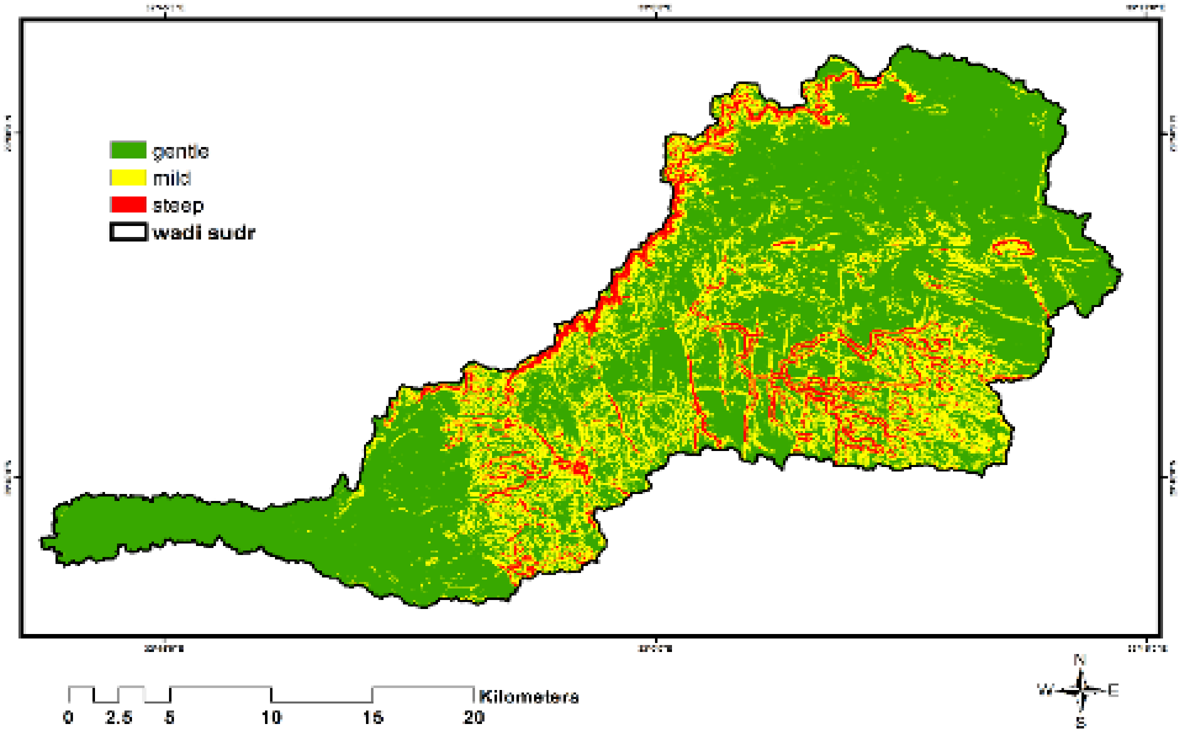


Figure (4) Slope intensity of the study area topography .

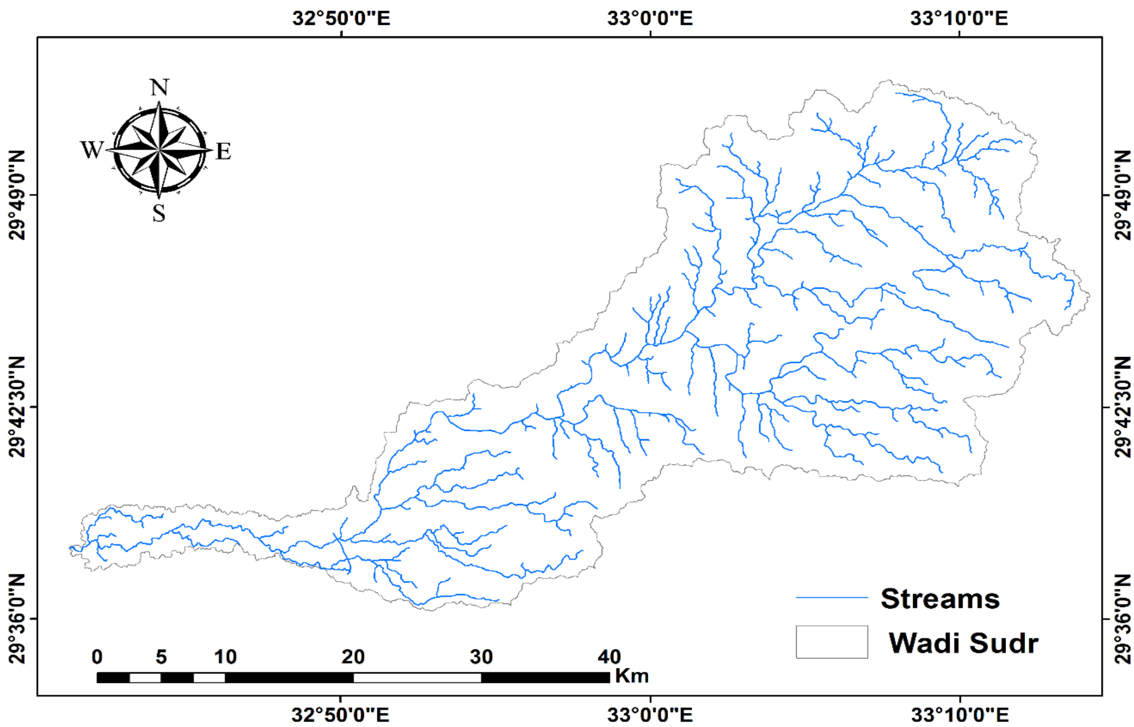


Figure (5) Streams in Wadi Sudr with 200 m^2 resolution .

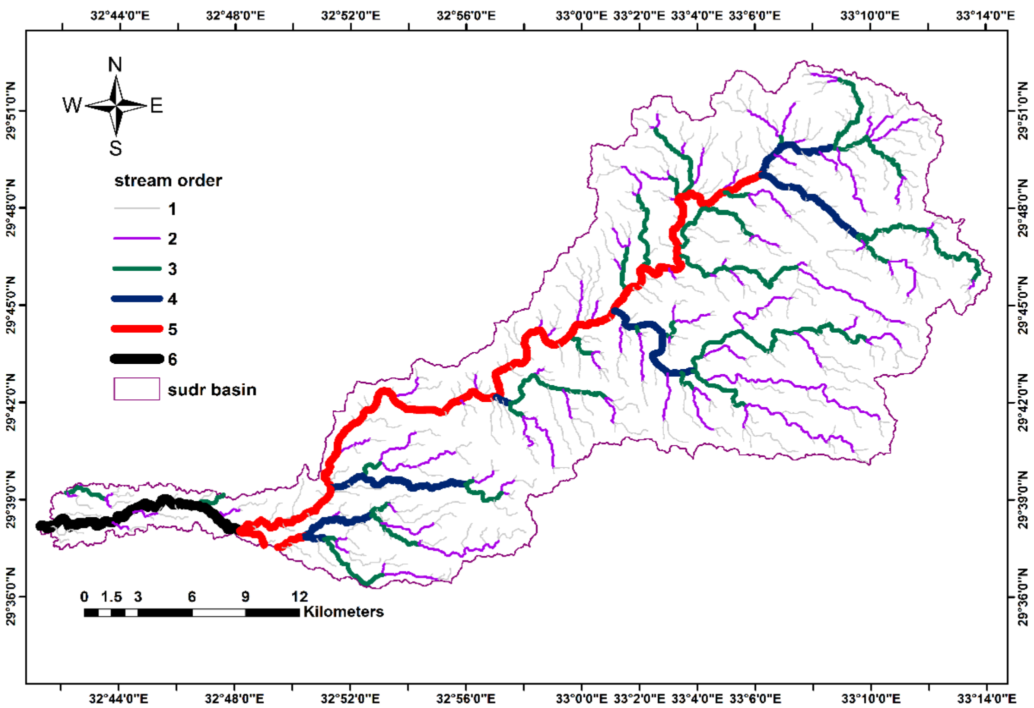


Figure (6) streams orders in Wadi Sudr without background.

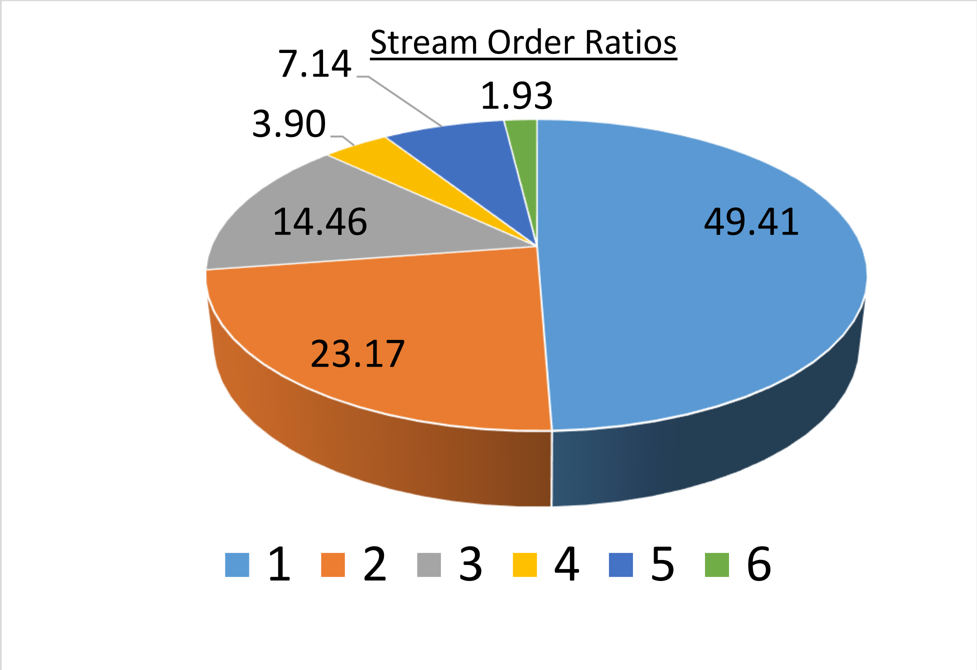


Figure (7) Percentage of streams orders.

Table (1) Lengths and % of stream order.

Stream Order	Length (km)	Percentage (%)
1	378.46	49.41
2	177.48	23.17
3	110.78	14.46
4	29.84	3.90
5	54.66	7.14
6	14.77	1.93
Sum	765.99	100.00

Table (2) Sub-basins characteristics .

Subbasin	Area(Km2)	Longest Flowpath Length (KM)	Longest Flowpath Slope (M/M)	Centroidal Flowpath Length (KM)	Centroidal Flowpath Slope (M/M)	10-85 Flowpath Length (KM)	10-85 Flowpat h Slope (M/M)	Basin Slope (M/M)	Basin Relief (M)	Relief Ratio	Elongation Ratio	Drainage Density (KM/KM^2)
1	70.619	15.92846	0.00716	6.31845	0.00541	11.94635	0.00556	0.06589	277	0.01739	0.59531	0.08221
2	46.623	21.35468	0.00897	9.71273	0.00849	16.01601	0.00744	0.08263	275	0.01288	0.3608	0.16082
3	44.462	19.63142	0.02015	9.40359	0.01356	14.72356	0.0127	0.16324	410	0.02088	0.38326	0.09817
4	41.535	17.08645	0.02555	8.56758	0.02609	12.81484	0.02154	0.20583	438	0.02563	0.42561	0.02562
5	35.124	13.68189	0.03179	6.3498	0.01559	10.26142	0.02752	0.13866	445	0.03252	0.48878	0.02684
6	37.215	16.76512	0.02326	8.33897	0.01424	12.57384	0.0158	0.15059	483	0.02881	0.41059	0.05604
7	38.951	14.43644	0.03221	7.19514	0.01787	10.82733	0.0263	0.13757	465	0.03221	0.48781	0.21302
8	122.8	26.40541	0.01572	7.43885	0.01344	19.80406	0.01546	0.11097	457	0.01731	0.47354	0.13817
9	41.456	16.82675	0.03025	8.95054	0.00793	12.62006	0.01267	0.16962	517	0.03072	0.43177	0.2887
10	37.371	19.75842	0.02445	10.08805	0.00615	14.81882	0.00904	0.14484	483	0.02445	0.34912	0.4155
11	104.3	40.36337	0.00969	23.42552	0.0041	30.27252	0.00817	0.06833	443	0.01098	0.28551	0.23942

4.b. RESULTS OF RAINFALL

Rainfall data were attained; examined and presented, where Figure (9) and Table (3) are provided to represent the statistical analysis of Wadi Sudr Station and the rain depths for different return periods, respectively.
It is to be noted that images were acquired. They represent the statistical analysis of the available data on rain, which is similar to the study area. This was achieved by Weibull-Distribution-Method, where this method incorporates probability theory and statistics. It is a continuous probability distribution, which is named after a Swedish mathematician.
This is similar to the maximum moment's method, which is authorized by the Egyptian Code for protection from flooding rains danger.

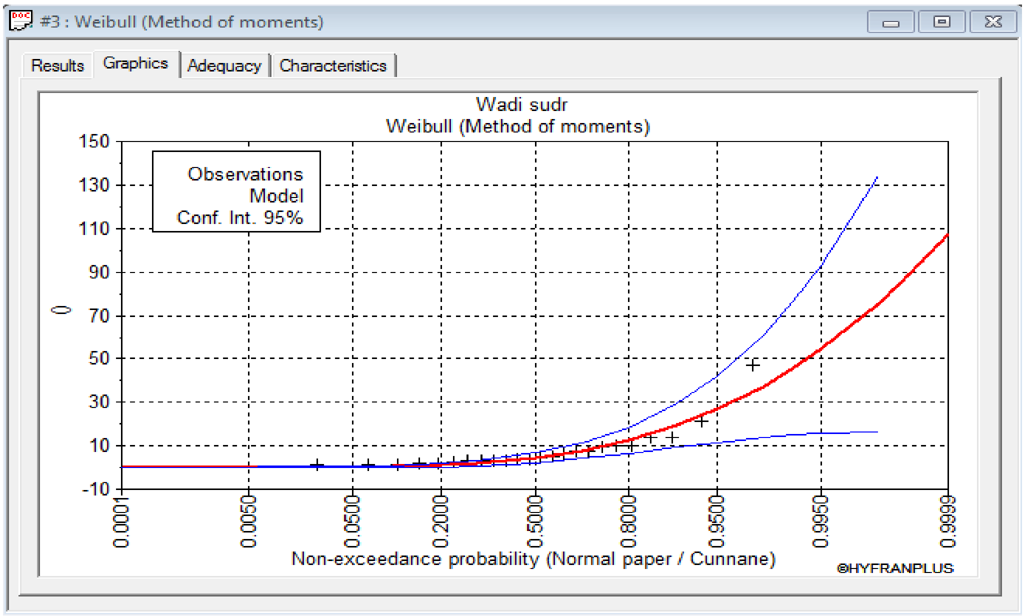


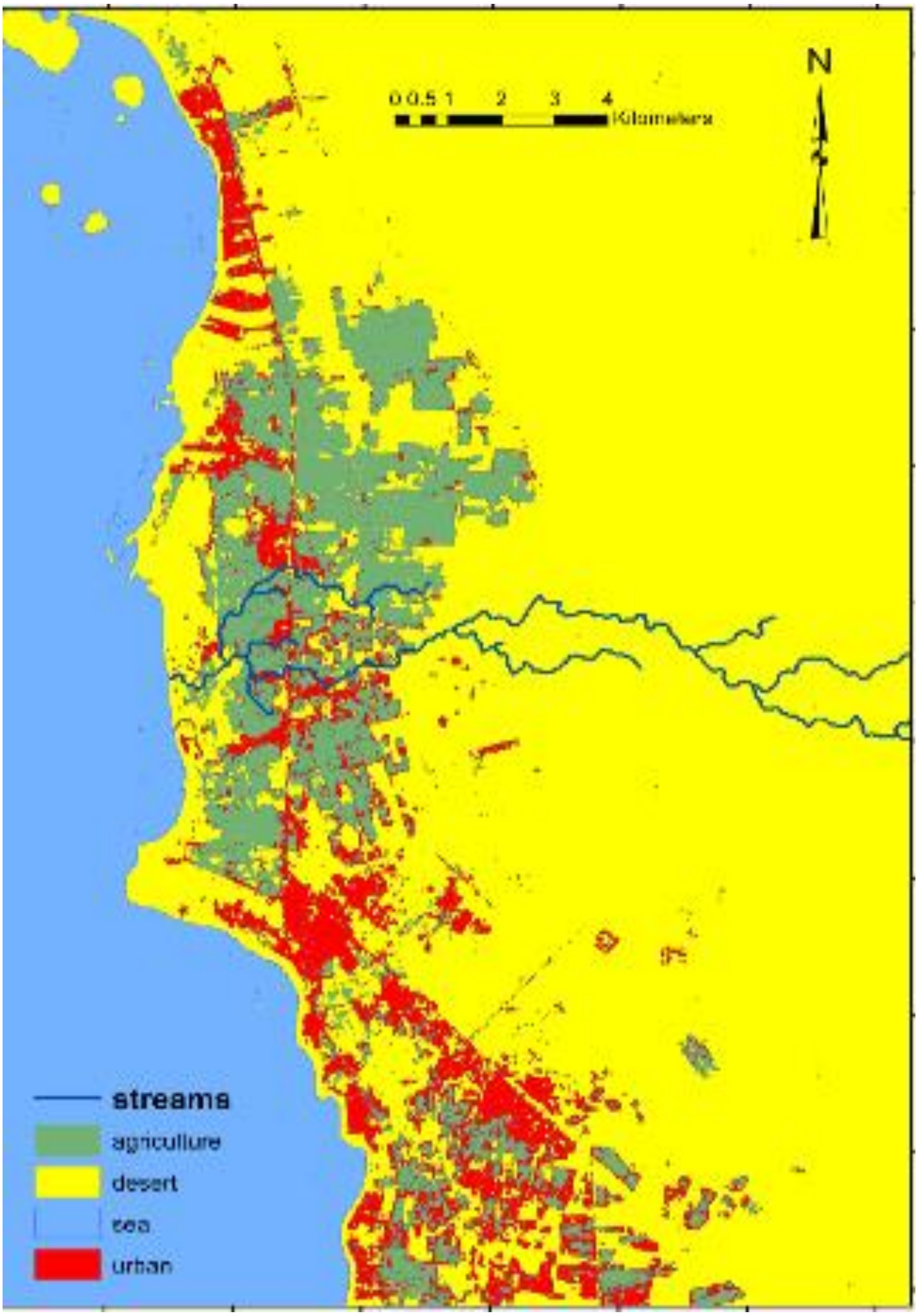
Figure (8) Statistical analysis of Wadi Sudr Station.

Table (3) Rain depths for different return periods.

Return Period	10	25	50	100
Max24 Hr. Precipitation Depth(Mm)	19.4	29.3	37.3	45.7

4. c. RESULTS OF LOSSES

Results were obtained; investigated and presented, where figures (8) and (9) are presented. They designate the land uses and geological map of the study area, respectively.
As for the rainwater losses, the soil type and land use were signposted. Regarding the deep seepage, the Curve-Number-Method used, where for the desert and urban areas, the utilized numbers were 86 and 87, respectively. Focusing on the images, paintings from satellite imaging were employed, where the images were divided into several layers according to the wave frequency of the obtained image. Concentrating on the soil, it was obtained from the geological map, figure (9).



Figure(8) Land uses in the study area.

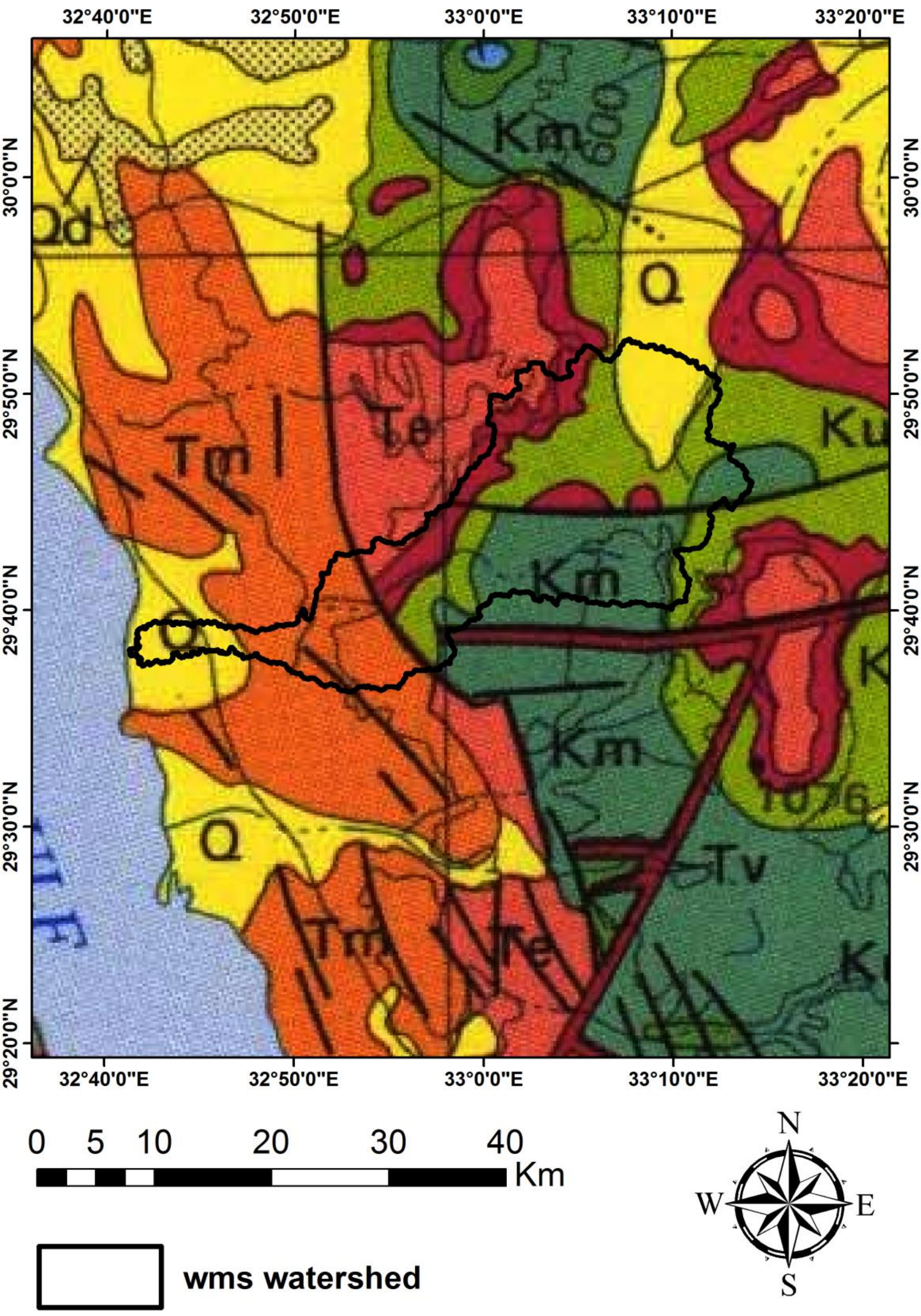


Figure (9) Study area geological map .

4.d. RESULTS OF SURFACE RUNOFF

Results were acquired; investigated and provided, where HEC HMS Program and the hydrography were obtained and presented in Figure (10). The figure indicates the losses in ml and surface runoff depth in mm.

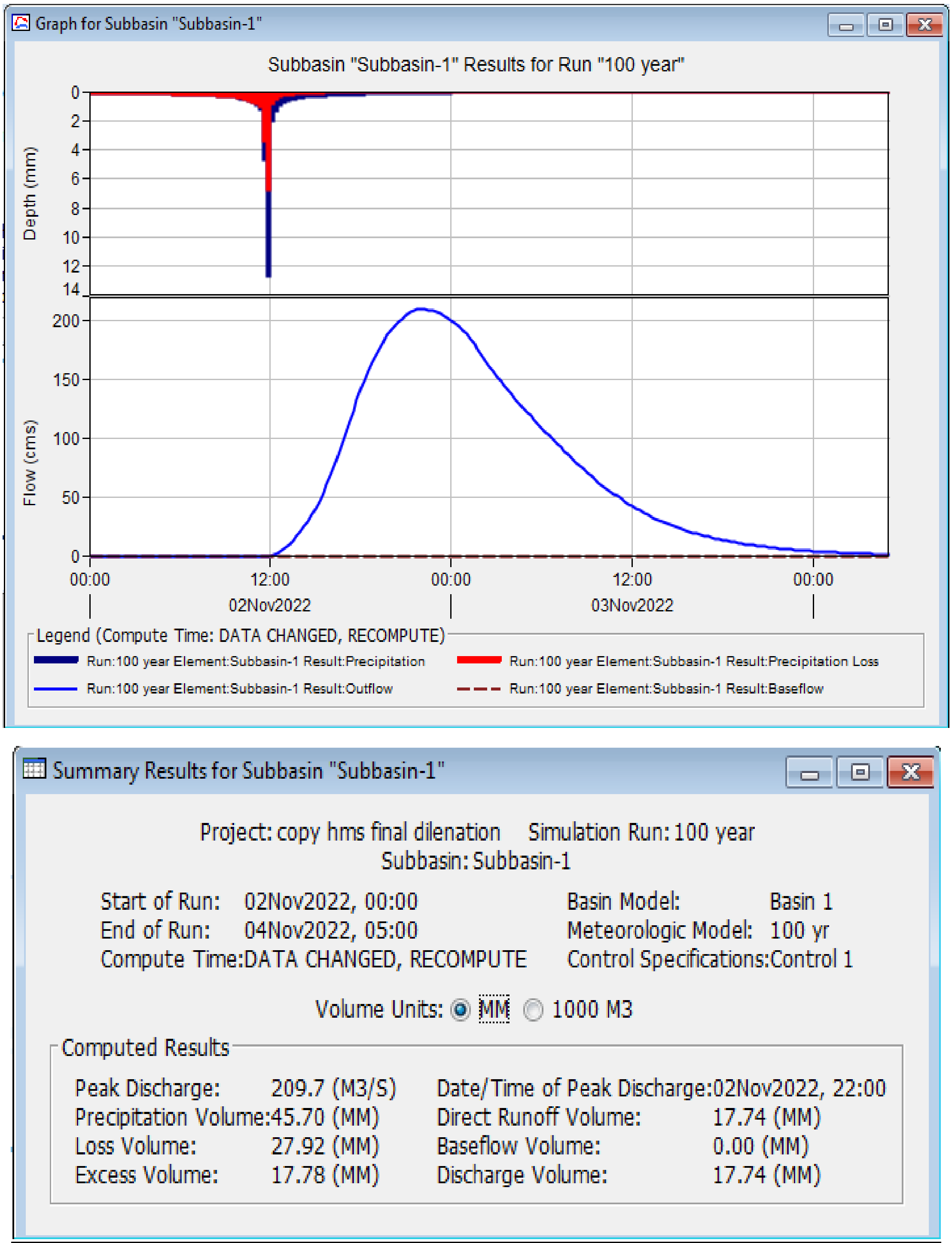


Figure (10) Hydrograph from HEC HMS Program.

4.e. RESULTS OF HYDRODYNAMIC MODELLING

Results were obtained; inspected and provided, where the HEC RAS Program was utilized to calculate flood limits, at specified return periods and time, where the 2-D simulation was tooled in flood map calculation, for a 100 years return period. During this period, the study area was sustainable, in terms of the Egyptian Code for flood danger protection. In addition, a link was established between the GIS program and the HEC RAS program to reflect the inundation maps, where figures (11) and (12) are provided to represent the limits of flood inundation with maximum depth and maximum velocities, for a return period of 100 years, respectively.

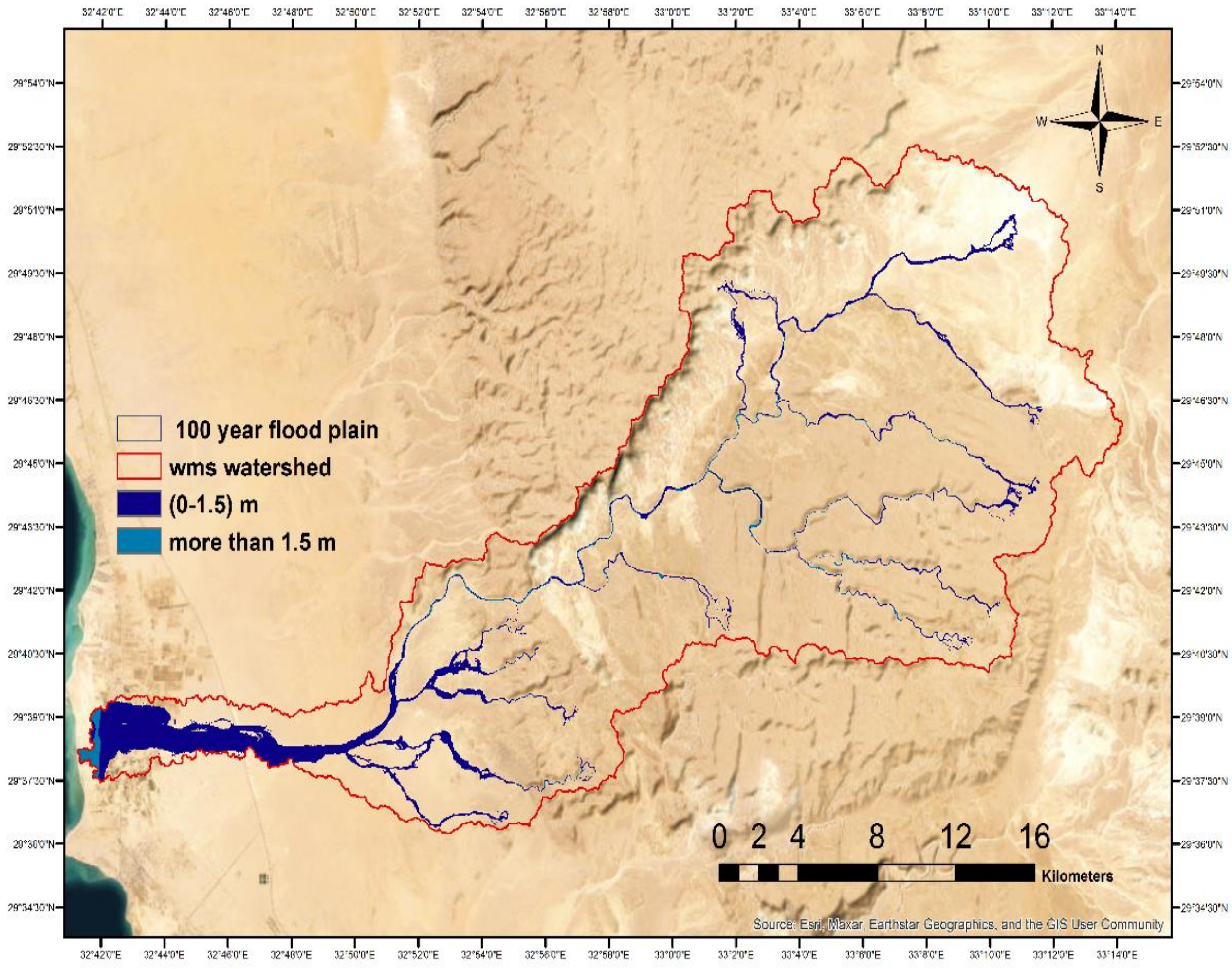


Figure (11) Limits of flood inundation and maximum depth

(100-year return period).

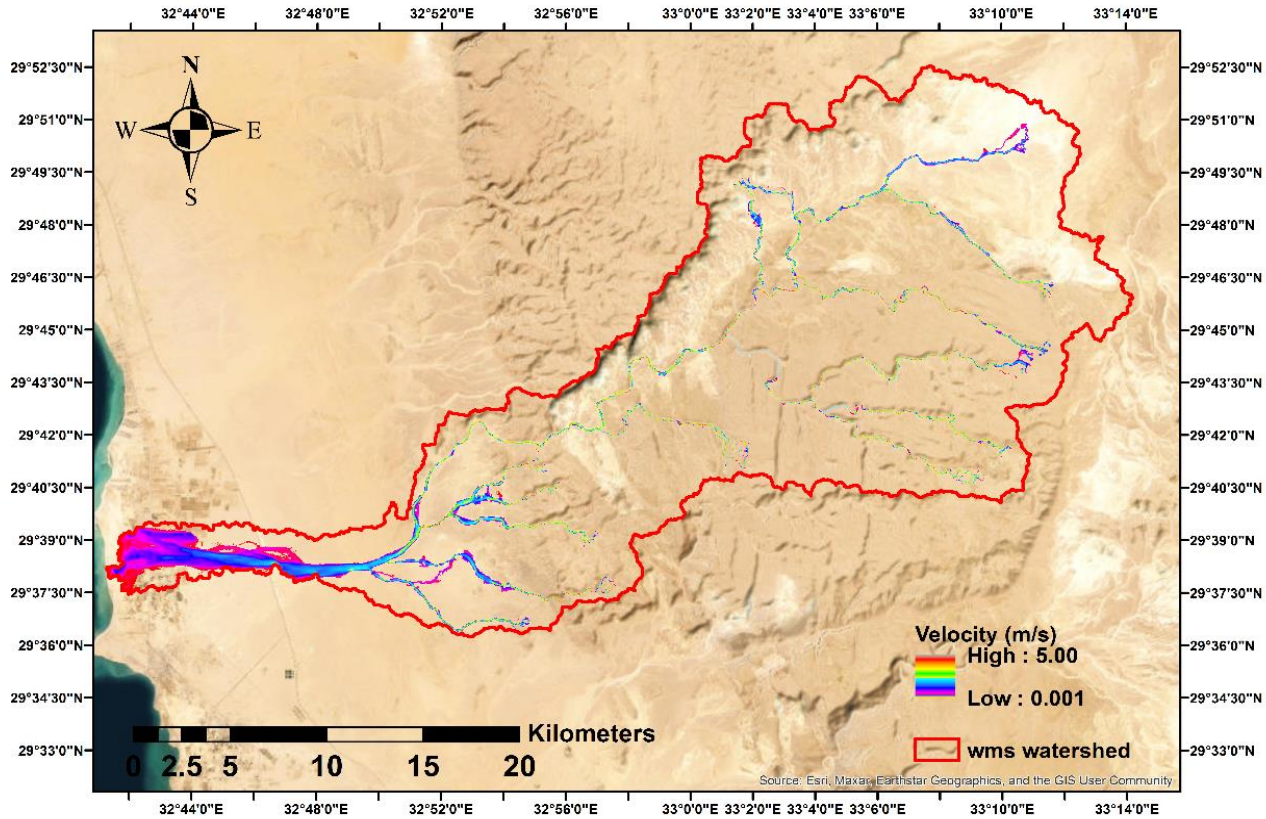


Figure (12) Limits of flood inundation and maximum velocities

(100-year return period).

5. ASSESSING RISKS TO URBAN AREAS

Remote sensing techniques were linked to GIS and the zones in need for flood-protection places by works were designated. Accordingly, maps were produced for the Sudr Valley Delta Region, where most of the population is concentrated. This was achieved by utilizing high-resolution satellite maps of "type 1 Land Sat-8" and by involving ARC GIS.

A set of maps was produced, where urban developments during 2000-2022 were obtained. Moreover, its relationship to the flood plain and its impact on the increasing possibility of expansion was assessed under the immersion risk or exposure to flood risk.

This will provide decision-makers with adequate information to signpost their decision about urban expansions within the framework of Egypt 2030 vision.

Accordingly, figures (13) to (17) are provided to represent boundaries of flood inundation, flooded areas, flood inundation boundaries, in Jan 2000, and flood inundation boundaries in Jan 2012, for 100 year return period, in Wadi Sudr Delta, respectively. Moreover, table (4) is provided to list the flood inundation boundaries during a return period of 100 years.

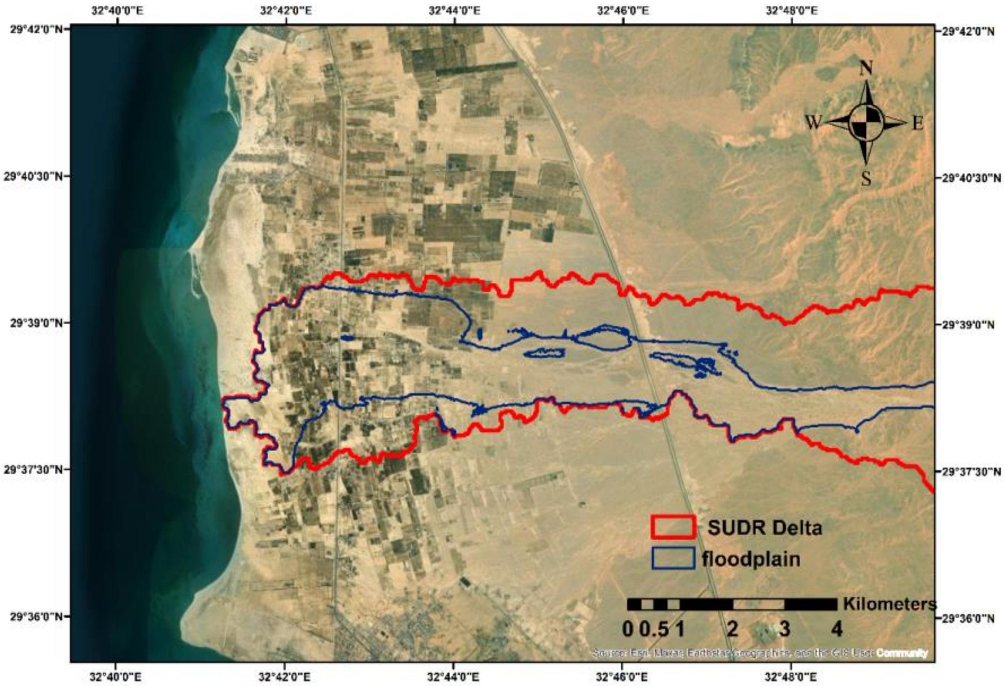


Figure (13) Boundaries of flood inundation in Wadi Sudr Delta (100-year return period).

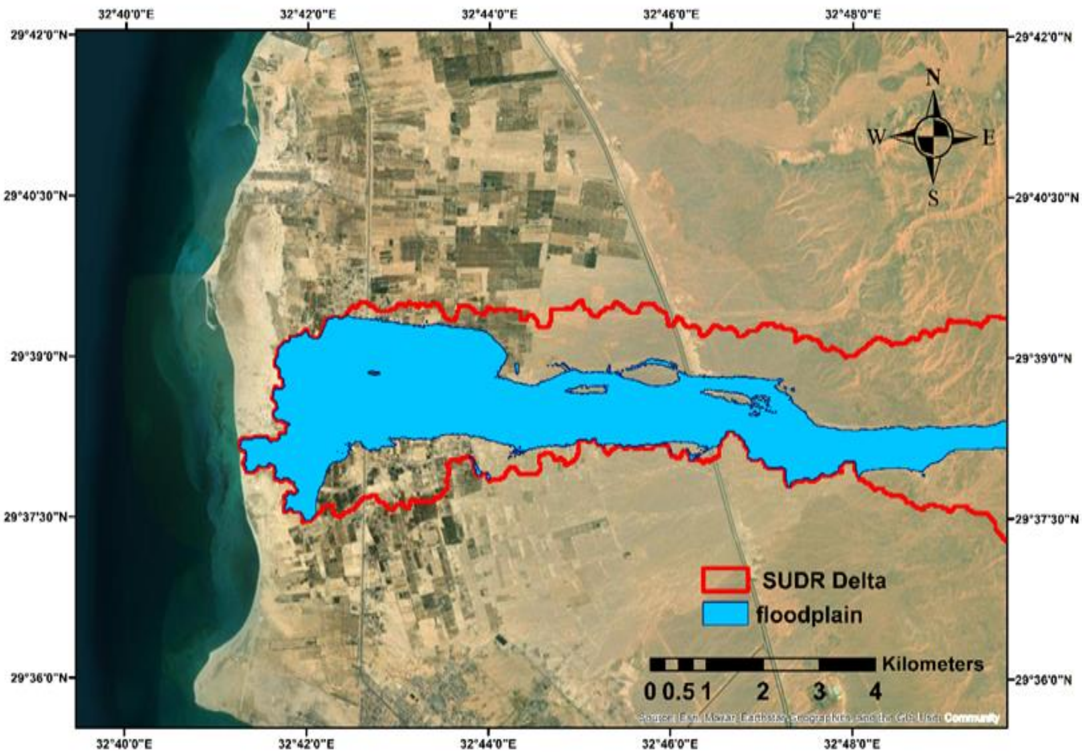


Figure (14) Flooded areas in Wadi Sudr Delta (100-year return period).

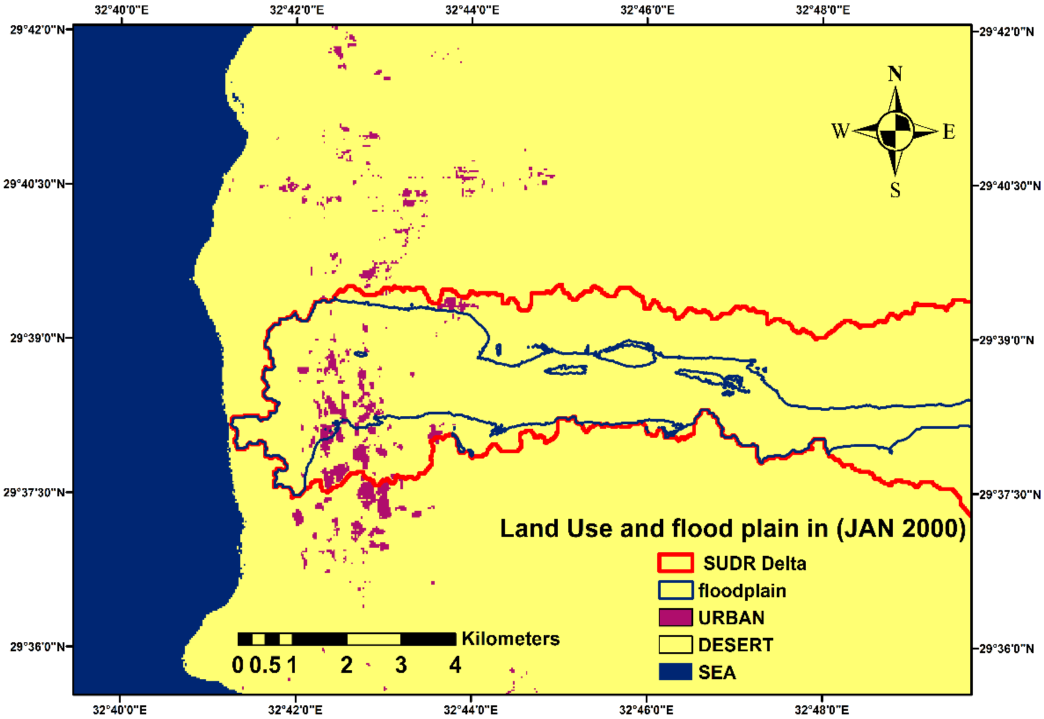


Figure (15) Flood inundation boundaries in Wadi Sudr Delta (100-year return period) (Land use at Jan 2000).

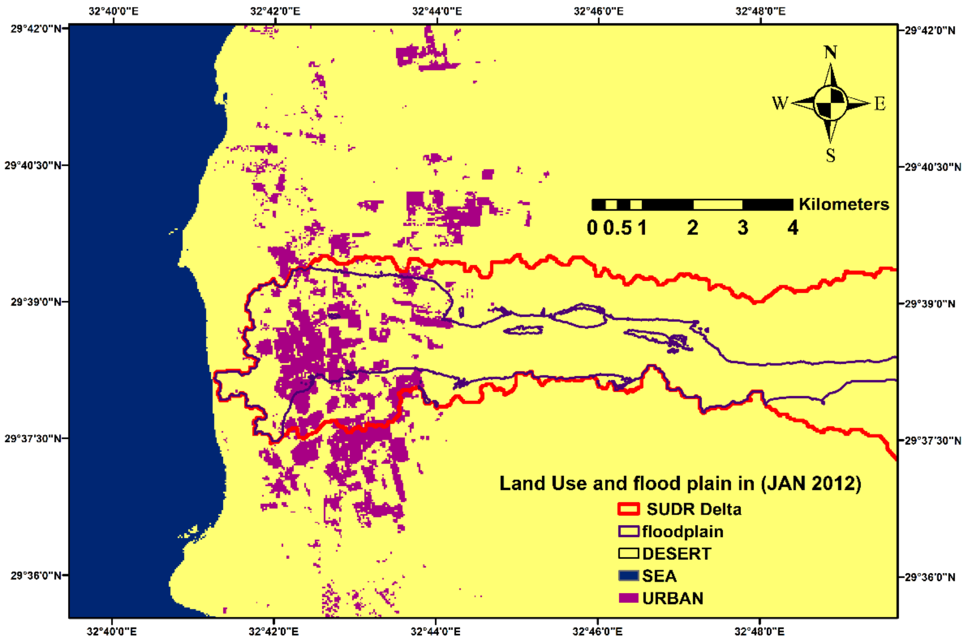


Figure (16) Flood inundation boundaries in Wadi Sudr Delta (100-year return period) (Land use at Jan 2012).

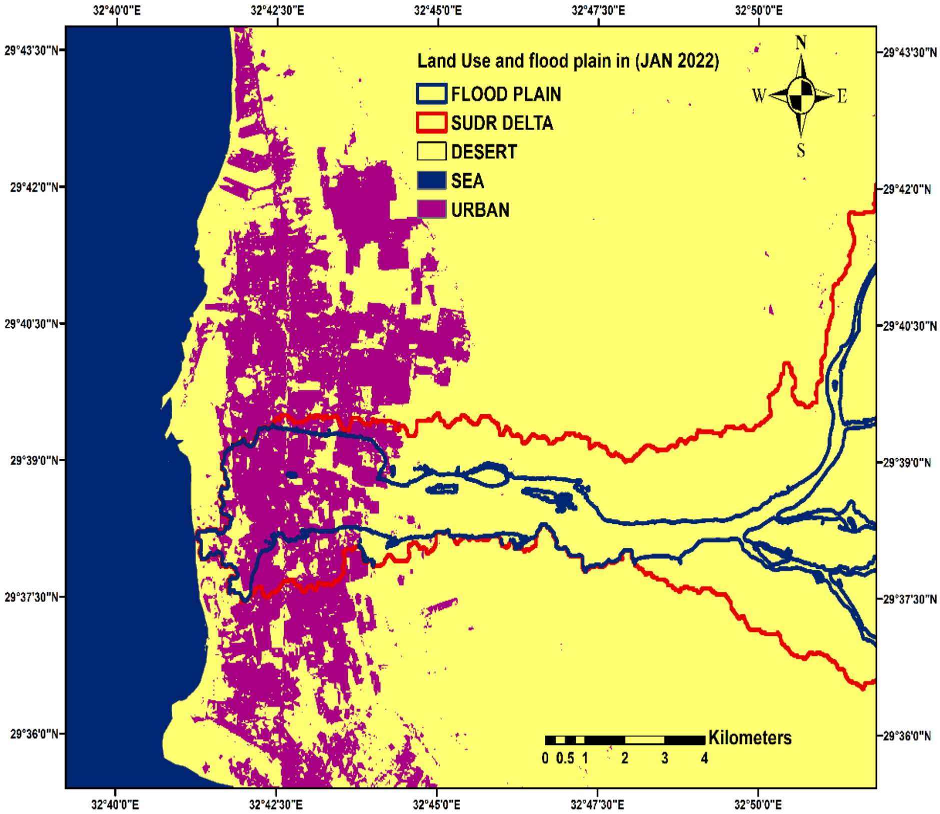


Figure (17) Flood inundation boundaries in Wadi Sudr Delta (100-year return period) (Land use at Jan 2022).

Table (4) Flood inundation boundaries during 100 years.

Year	Urban areas (km^2)	Increase in urban areas (km^2)
1990	2.9	---
2000	3.55	0.65
2012	18	14.45
2022	69	51

5. CONCLUSIONS AND RECOMMENDATIONS

Based on the obtained results, the following conclusions were deduced:
The obtained results contributed to producing updated information on Sudr Valley hydrology and morphology.
The implemented programs proved their reliability in delineating the study area
The tooled models and GIS visualized inundation maps (maximum depth and maximum speed) during 1990-2022.
Based on the deduced conclusions, the following recommendations were suggested:
Utilize the implemented methodology to visualize similar areas.
Flood and urban expansion should be considered during designing mitigating measures to achieve Egypt's 2030 vision.

6. REFERENCES

[1] Abdel-Lattif, A., & Sherief, Y. (2012). Morphometric analysis and flash floods of Wadi Sudr and Wadi Wardan, Gulf of Suez, Egypt: using digital elevation model. Arabian Journal of Geosciences, 2(5), 181-195.

[2] Abo-Taha, M. L., Ahmed, H., & El-Molla, A. (2022). Mapping flood hazards by multi-criteria decision analysis technique in geographic information system (GIS-MCDA). Journal of Al-Azhar University Engineering Sector, 17(62), 26-38.

[3] Ali, N. M. Y. (2017). "Floodplain Determination and Management Case study: Wadi Watir-Sinai " (Doctoral dissertation, Faculty of Engineering, Ain Shams University, Cairo, Egypt).

[4] Attia Karima et al, (2010), "Inundations by High Releases Downstream High Aswan Dam", Nile Basin Water Science and Engineering Journal, Vol.3, Issue. 2.

[5] Benavides, J. A. (2001). *Information technologies in water resources: Modeling flood control alternatives for the Clear Creek Watershed within a GIS framework*. Rice University.

[6] Castellarin, A et al, (2010), "Floodplain management strategies for flood attenuation in the river PO, Published online 7 June 2010 in Wiley Online Library, (wileyonlinelibrary.com) DOI: 10.1002/rra.1405.

[7] Elsiad, A. A., Ramadan, M. E., & Magdy, A. (2017, May). Quantitative evaluation of drainage basin characteristics using GIS-based morphometric analysis: a case study of Wadi Sudr, Sinai, Egypt. In Twentieth International Water Technology Conference, IWTC20, Hurghada (pp. 110-119).

[8] Environmental Systems Research Institute (ESRI), (1999-2013), "ARC GIS 10.2 User's Manual".

[9] Farahat, M. S., Elmoustafa, A. M., & Hasan, A. A. (2017). Developing flash floods inundation maps using remote sensing data, a case study: Wadi AL-Arish, Sinai, Egypt. Am J Eng Res (AJER), 6(5), 172-181.

[10] Fathy, I., Negm, A. M., El-Fiky, M., Nassar, M., & Al-Sayed, E. (2015). Runoff hydrograph modeling for arid regions: case study—Wadi Sudr-Sinai. Int Water Technol J IWTJ, 5(1), 58-68.

[11] Gabr, S., & El Bastawesy, M. (2015). Estimating the flash flood quantitative parameters affecting the oil-fields infrastructures in Ras Sudr, Sinai, Egypt, during the January 2010 event. The Egyptian Journal of Remote Sensing and Space Science, 18(2), 137-149.

[12] Ganoulis, J, (2003), "Risk-based floodplain management: A case study from Greece", International Journal of River Basin Management, 1(1), P.41-47.

[13] Gomma, H. (2021). Floods Hazards Assessment By Integrating Hydrologic Modeling And A Geographic Information Systems (Multi-Criteria Decision Technique). Journal Of Al-Azhar University Engineering Sector, 16(61), 1007-1023.

[14] Goodell, C. and C. Warren,(2006), "Flood Inundation Mapping using HEC-RAS", Obras y proyectos, revista de ingeniería civil, Edición N2, p. 18-23.

[15] Haitham Saad, et al, (2013), "Reliability Assessment of Water Structures Subject to Data Scarcity Using the SCS-CN Model", Hydrological Science Journal 61(4), 696-710

[16] Hegger, D. L., Green, C., Driessen, P. P. J., Bakker, M. H., Dieperink, C., Crabbé, A., ... & Goytia Casermeiro, S. (2013). Flood risk management in Europe: similarities and differences between the STAR-FLOOD consortium countries.

[17] Jones, J.L., J.M. Fulford, and F.D. Voss, (2002), "Near-real-time simulation and Internet-based delivery of forecast-flood inundation maps using two-dimensional hydraulic modeling: a pilot study of the Snoqualmie River", Water-Resources Investigations Report, DIANE Publishing, Washington.

[18] Lich Tran Gia, et al, (1992), "Boundary conditions for the two-dimensional Saint-Venant equation system" Applied mathematical modeling 16(9), 498-502.

[19] Lotfy, A. (2016). Assessment of spatial rainfall variation on runoff in Wadi Sudr, Sinai Peninsula. In Proceedings of the Second International Symposium on Flash Floods in Wadi Systems: Disaster Risk Reduction and Water Harvesting in the Arab Region (pp. 196-196).

[20] Farahat, M. S., Elmoustafa, A. M., & Hasan, A. A. (2017). Developing flash floods inundation maps using remote sensing data, a case study: Wadi AL-Arish, Sinai, Egypt. *Am J Eng Res (AJER)*, *6*(5), 172-181.

[21] Negm, A., Nassar, M., Al-Sayed, E., & El-Fiky, M. (2014). Estimation of Lag Time and Peak Discharge of Flash Flood of Wadi Sudr in The Sinai Peninsula. The Egyptian International Journal of Engineering Sciences and Technology, 17(4), 9-10.

[22] Ran, J., & Nedovic-Budic, Z. (2016). Integrating spatial planning and flood risk management: A new conceptual framework for the spatially integrated policy infrastructure. *Computers, Environment and Urban Systems*, *57*, 68-79.

[23] Punit Kumar Bhola and Ashish Singh, (2010), "RF-RO MODELING OF RIVER KOSI USING SCS-CN METHOD AND ANN", Ph.D. thesis, National Institute of Technology Rourkela, Department of Civil Engineering, India.

[24] Qi, Shuhua, et al, (2009), "Inundation extent and flood frequency mapping using LANDSAT imagery and digital elevation models", GIS science & Remote Sensing Journal, 46(1), p. 101-127.

[25] Sadrolashrafi, S.S et al, (2008), "Flood modeling using WMS Software: A case study of the Dez River Basin, Iran", River Flow, Kubaba Congress Department and Travel Services ISBN 978-605-60136-3-8.

[26] Shelley, J., Gibson, S., Williams, A., 2015. Unsteady Flow and Sediment Modeling in a Large Reservoir Using HEC-RAS 5.0. Fed. Interag. Sediment Conf.

[27] Soil Conservation Services (SCS), (1985), “National Engineering Handbook”, Section 4: Hydrology. US Department of Agriculture, Soil Conservation Service, Engineering Division, Washington DC.

[28] Sonbol, M. A. Mtalo, F. El-Bihery, M. and Abdel-Motteleb, M, (2005), "Watershed Modeling of Wadi Sudr and Wadi Al-Arbain in Sinai, Egypt", an international conference of UNESCO Flanders fust FRIEND/NILE project towards better cooperation, UNESCO 12-14 November.

[29] Tassew, B. G., Belete, M. A., & Miegel, K. (2019). Application of HEC-HMS model for flow simulation in the Lake Tana basin: The case of Gilgel Abay catchment, upper Blue Nile basin, Ethiopia. Hydrology, 6(1), 21.

[30] The Egyptian code of water resources and irrigation works.

[31] US Army Corps of Engineers (1994), "Flood runoff analysis engineer Manual", US Army Corps of Engineers 609 Second Street Davis, CA 95616 - 4687, USA.

[32] US Army Corps of Engineers (2019), "HEC-HMS hydrologic modeling system User’s Manual", Hydrologic Engineering Center (HEC), US Army Corps of Engineers 609 Second Street Davis, CA 95616 - 4687, USA.

[33] US Army Corps of Engineers (2019), "HEC-RAS River Analysis System Hydraulic User’s Manual", Hydrologic Engineering Center (HEC), US Army Corps of Engineers 609 Second Street Davis, CA 95616 - 4687, USA.

[34] V. Moya Quiroga, S. Kure, K. Udo, A. Mano, (2016), "Application of 2D numerical simulation for the analysis of the February 2014 Bolivian Amazonia flood: Application of the new HEC-RAS version 5", RIBAGUA - Revista Iberoamericana del Agua, Volume 3, Issue 1, Pages 25-33.

[35] Wahlstrom, M., Guha-Sapir, D, (2017), “The human cost of weather-related disasters”, UNISDR, CRED, Geneva, Switzerland.

[36] WRRI, (2009)," Construction of protection works from floods at Wadi Sudr – North Sinai", Water Resources Research Institute (WRRI), Delta-Barrages, Cairo, Egypt.

[37] WRRI, (2010)," Flood atlas in Sinai", Water Resources Research Institute (WRRI), Delta-Barrages, Cairo, Egypt.

[38] WRRI, (2020)," Flash Floods in Egypt: Protection and Management Wadi Sudr – North Sinai", Water Resources Research Institute (WRRI), Delta-Barrages, Cairo, Egypt.

[39] Yang, X. and B. Rystedt, (2002), "Predicting Flood Inundation and Risk Using GIS and Hydrodynamic Model: A Case Study at Eskilstuna, Sweden", Indian Cartographer, Vol. 22, p. 183-191.