Introduction to "Flash Floods in Egypt"

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Abstract

This chapter highlights the hydrogeological technical elements contained in the 17 chapters presented in the book according to its five themes. Therefore, this chapter contains information on analysis: extreme rainfall analysis and critical design aspects of flash floods, recent technologies for investigating flash flood, environmental approaches in flash flood, hazards, risk and utilization of flash floods, and prediction and mitigation of flash flood.

Keywords

Egypt • Sinai • Aswan • Extreme rainfall • Statistical analysis • Design aspects • Risk analysis • Hazard • Prediction • Harvesting • Early warning system • Monitoring • Environment • Assessment • Mitigation • Management

1 Background

Egypt which is located in the north of Africa is an arid country. Its water demand is now more than 100 billion cubic meters per year and about 50% of this demand is fulfilled form the Nile River waters. With the rapid growth of population, agricultural expansion, among other activities, the water demand increased. Egypt is planning to reuse the agriculture drainage water and the treated wastewater, and to harvest the flash floods from everywhere in Egypt as well. The book could thus greatly assist decision-makers in maximizing storing and using water from the harvest flash floods. From our results, climate change seems to affect patterns of rainfall. Therefore, Egypt received a different rainfall pattern for the last few years. One of these observations is recognized in the Aswan governorate in October 2019. It is documented in this book to help the concerned authorities to harvest, manage, and ultimately utilize the harvested heavy rains for the benefits of the communities in Aswan. The presented materials in the book are useful for different arid countries in the MENA regions as well. This book could be considered a follower to the previously published books by Springer on the water resources and agriculture in Egypt, Negm (2019a, b).

2 Themes of the Book

Therefore, the book intends to address the following main theme.

- Analysis and Design Aspects
- Recent Technologies For Investigating Flash Flood
- Environmental Approaches In Flash Flood
- Hazards, Risk, Harvesting, and Utilization of Flash Floods
- Prediction, Mitigation, and Management of Flash Flood.

3 Chapters' Summary

The next subsections present the main technical elements of each chapter under its relevant theme briefly.

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3.1 Analysis and Design Aspects

This theme is covered in three chapters. Chapter one deals with the analysis of extreme rainfall events and the critical design aspects of flash floods with examples from Egypt and Oman.

Chapter 2 is titled "Statistical Behavior of Rainfall in Egypt." In this chapter, the statistical characteristics of extreme rainfall in Egypt have been investigated based on historical daily rainfall records for 30 stations throughout the country. Six types of rainfall data from daily records have been collected: monthly rainfall, annual rainfall, the monthly number of rainy days, the annual number of rainy days, monthly maximum daily rainfall, and annual maximum daily rainfall. Generally, there is a great variation in all different aspects of the rainfall across the country. The rainfall indices have higher values in the north of the country than those in the middle and the south. The results indicate that Egypt's rainy season extends from October to March when a significant amount of precipitation is received by some stations. The dry season, on the other hand, extends from April to September. Furthermore, this research seeks to derive the design rainfalls through the GEV distribution along with the L-moments using annual maximum daily rainfalls in these stations. In the case study, the GEV distribution fits well with the annual maximum daily rainfall data. Although all stations not located on the north have low values of rainfall characteristics, some locations (e.g., Hurghada) have high values of design extreme rainfall. Therefore, further studies are required about the study of extreme rainfall at these sites.

Following this, Chap. 3 is concerned with the "Critical Analysis and Design Aspects of Flash Flood in Arid Regions: Cases from Egypt and Oman." It presents a brief review of flood definitions in general and in particular, flash floods. Also, two main case studies related to flash floods are presented in this chapter. The two main case studies from the Arab Republic of Egypt and Sultanate of Oman are investigated. Extreme events caused by cyclonic and convective storms are covered by the cases discussed. The presented cases caused damages to the properties and fatalities. For each case, detailed hydrological and hydraulic analyses carried out and the results are presented. Hydrological and hydraulic analyses are used to study the considered two cases to evaluate the effect of each case and compare it to the regular flood events (if any). Meanwhile, this chapter casts light on the difference between the effect of thunderstorms and cyclones on the corresponding peak flow and flood volume. It showed that cyclonic events were accompanied by a very high value of rain depth, which may be corresponding to thousands of years on the frequency distribution curves. These events of precipitation have created huge volumes of water which fill all dams and run the spillways to near maximum design flow values. The distribution of storms over 24 h, however, was almost uniform, suggesting moderate strength of rainfall.

3.2 Recent Technologies for Investigating Flash Flood

Chapters 4 and 5 cover this theme. Chapter 4 is titled "Developing an Early Warning System for Flash flood in Egypt: Case Study Sinai Peninsula." It explains how to develop an early warning system for flash floods in Sinai Peninsula. An early warning system is essential as flash floods can occur anywhere. When it comes to arid and mountain catchments where catastrophic events are more prevalent than wet and flat areas, it becomes more critical. Egypt can be considered one of the arid and semi-arid Arab countries in the coastal and Nile Wadi systems facing flash floods. In Egypt, particularly in the Eastern Desert, Red Sea Mountains, and Sinai, flash floods are occurring widely.

The Sinai Peninsula can be considered as the most important Egyptian areas common and subject to synoptic circumstances causing heavy rainfall due to its natural geography and context complex, causing severe damage due to flash flooding. This makes the study and analysis of the flash flood on the Sinai Peninsula a crucial and significant job. Because of the above-mentioned challenges, the latest numerical mesoscale meteorological model named the Weather Research and Forecasting (WRF-ARW) is selected to forecast rainfall and simulate the synoptic situation related to some flash flood events over Egypt. Mainly the US National Centre develops WRF for Atmospheric Research (NCAR) in collaboration with many other research centers and universities. WRF allows forecasting weather in complex terrains such as the one in Sinai and at the same time is considered for its orographic features' characteristics.

Also, flash floods occur along the Red Sea, where a series of mountains are there. Chapter 5 is presented to discuss "Flash Flood Investigations in Northern Red Sea Governorate Case El-Gouna." Understanding the flooding and its effects on human life and ecosystem requires fundamental analysis of the boundary conditions that geography, geology, atmosphere, and hydrology usually provide for the proper modeling of the flooding event for forecasting. In this chapter, all of these aspects were systematically analyzed and findings were introduced in a hydrological flow model. A morphological analysis of slopes in correspondence to the geological setting of the catchment of Wadi Bili is presented and the results of all analyses are discussed.

3.3 Environmental Approaches in Flash Flood

Chapters 6–9 address the environmental solution to flash floods. Chapter 6 is titled "Environmental Flash Flood Management in Egypt." It is well know that flash floods have an adverse impact on human health and ecosystems. This may be extended to cause damage to infrastructure, livestock, and plants. Floodwater can cause a number of significant health effects, including deaths and/or injuries, contamination of drinking water, loss of electricity, disruption of the environment, and displacement among other effects. Therefore, this chapter will present the Egyptian national environmental action plan to face the natural environmental hazards (earthquakes–flash floods–dust and sand storm). Moreover, it will highlight the environmental and disaster risk reduction in Egypt and Arab Countries, and present the tools for implementing disaster risk reduction in environmentally hazardous zones.

The Egyptian experience with the floods has shown that much is remaining to be done to improve the use of water resources and protect our infrastructure that crosses dangerous areas. However, there are major challenges in the region, such as lack of continuous data for both flow and precipitation; lack of real-time data transmission; soil erosion problems in mountain areas; maximization of flood uses rather than flood risk management; the absence of a flash flood early warning system; the absence of a disaster risk management plan; little interest in the users of the flood; and the availability of a model to describe the hydrological conditions of the Arab region.

Due to the environmental problems of the flash flood, harvesting and management are essential. Chapter 7 with the title "Flash flood management and harvesting via groundwater recharging in wadi systems: An integrative approach of remote sensing and direct current resistivity techniques" aims to discuss how to (i) mitigate the flashflood hazards and assess the water resources in wadi systems using an integrative approach of remote sensing (RS), geomorphological, and geophysical data. The chapter addressed two case studies in two Egyptian wadis in which we use an innovative integrative approach to flash flood research and management. In workflow design, the chapter introduces a suggested strategy using the surface geological data and geophysical measurements. To reduce the uncertainty of geophysical data inversion, the conventional and non-conventional inversion algorithms are applied. Based on geophysical data inversion results, this chapter shows that it is possible to recognize sites for successful dam construction and groundwater bearing zones exploration. From the hydrogeological point of view, RS and GIS are used to estimate a hydrograph and runoff modeling for wadi systems. Accordingly, the calculated flashflood total discharges and the storage capacity can be recognized. Finally, the chapter provides some solution for scare water management, via locating potential areas suitable for surface water harvesting to promote the percolation of trapped water into the alluvium aquifers.

Harvesting and management of flash floods, and monitoring of needs: Chap. 8 deals with the "Environmental Monitoring and Evaluation of Flash Floods Risks Using Remote Sensing and GIS Techniques." Therefore, this chapter attempts to synthesize the relevant database in a spatial framework to evolve a flood risk map for some study areas with the application of remote sensing and GIS techniques. The study has also focused on the identification of factors controlling flash floods risks in two study areas in Egypt. Satellite images of the study area have been collected and required field data have been gathered. Depending on the digital elevation model (DEM), this study extracts drainage networks and watersheds using ArcGIS Basins' watersheds, drainage network, stream order, flow direction, and other basin characteristics. The watershed model was created in the GIS of the first study area, Firan catchment in Sinai. Hydrological characteristics of basins have been identified. Also, the runoff volume of flash floods has been calculated for the second study area Wadi Hashim 2 in the Egyptian Northern coast through the identification of land use from GIS, soil texture, and rainfall from field measurements. The location of the required Dam for flash floods has been proposed. Finally, GIS and remote sensing techniques have proved to be a successful tool for flash flood monitoring and assessment.

Following the above chapter, Chap. 9 discusses the "Sustainable Development of Mega Drainage Basins of the Eastern Desert of Egypt: Halaib-Shalatin as a Case Study Area." The authors assess the South Eastern Desert of Egypt for the rainfall water harvesting (RWH) capabilities, with the determination of their optimum methods and techniques. Achieving this aim will assist in poverty alleviation, Bedouin and urban allocation, supporting animal husbandry, accelerating agricultural development, improved agricultural and food production for local inhabitants, combating desertification, resolving unemployment problems, and raising individual incomes. Bedouin and natives as the main end-users will be a major target of the project. Innovative ways to improve the capture, storage, and use of rainwater will have their own-bearing on the sustainable and profitable production of dry season vegetable crops in South Eastern Desert. According to the worldwide trends and techniques in RWH, which is applied aggressively in many neighboring countries, Egypt should enter the era of catching every water droplet for domestic and agricultural development. The findings of the current research work could set a good example to be applied both in other parts of the country and around the world. The chapter , therefore, focuses on using effective tools of monitoring and management of natural resources, based on the integration of modern techniques of remote sensing (RS), geographic information systems (GIS), and watershed modeling systems (WMS) to provide a plan for the RWH. Sustainable water supply is vital for the development of communities in arid regions, such as that of the South Eastern Desert of Egypt. The economic importance of the area is enormous, besides the fact that it has long been a target zone for mineral resources excavation and mining. One of the challenges facing this arid area is the limited water resources needed for agricultural, industrial, mining, or domestic uses. Bedouin depends mainly on rainwater, which constitutes the main source feeding their hand-dug wells and fracture springs. Rainwater harvesting (RWH), as a historical and worldwide trend, could fulfill the gap of water scarcity in arid or semi-arid regions. RWH is the accumulation and storage of rainwater for reuse before it reaches the aquifer system (Groundwater). The RWH could be used also for maximizing the recharge possibilities of groundwater. As a non-conventional water resource, RWH could provide water for gardens, livestock, irrigation, mining, cleaning of bathrooms as in the first flush, etc. The collected water is diverted to a deep pit with percolation in many places with similar climatic conditions to refill the groundwater for later use and protection, particularly in accumulations of structurally regulated groundwater. The harvested water could be used as drinking water if the storage is a tank that can be accessed and cleaned when needed. Additionally, the chapter's recommendations will be a good source for the up-to-date databases, which could be used effectively by the decision-makers, researchers, executive authorities, planners, and related governorates.

A second case study titled "Torrents Risk in Aswan Governorate, Egypt" is reported by Prof. El-Sayed Omran, the Dean of the Institute of African Research and Studies and Nile Basin Countries, Aswan University, Aswan, Egypt. In October 2019, Egypt was hit by a flood, which the country has not seen in terms of rising rates for 50 years. Floods started in mid-August on average and then increased in October, with rainfall on the Ethiopian plateau significantly higher than previous rates. Compared to previous years, the water level in Lake Nasser has reached a high level this year, 2019. Torrents and rain helped to raise Lake Nasser's level. This culminated, in the first time employees, were seen in the High Dam terminal (a river port on Lake Nasser, a gateway for passengers and commercial goods between Egypt and Sudan. The construction of the port began in 1964 after the transformation of the Nile River into the construction of the High Dam) the presence of high water in a pavement-side area that has long been totally dry.

Aswan's torrents arise as a result of precipitation on the government's eastern hills, where water flows into a group of valleys west to the Nile. The most prone areas are Wadi al-Sarraj area, Wadi Ajam area, Umm Habbal area, and Wadi Haymour Allaqi area. The streams that flow into Lake Nasser represent the minimum risk of torrents as there are no urban communities. Eastern Nile basins in the area between Edfu and Aswan cities are very risky, particularly in the area of Kom Ombo and east of Aswan city. In May 1979, the flood flow disrupted the railway lines and affected Edfu, Kom Ombo, and Aswan centers. About 300 families have been displaced and the falling of torrential rocks on some parts of the agricultural road and railway lines. Floods were repeated in 1980 and 1987, 2005, 2010, and 2014 (Saber et al. 2017). In 2010, some villages in Aswan city were severely hit by that torrent. About 500 families were evacuated from their houses that were at risk and lost their livestock and harvest, but they were indemnification by the Government through the donation account they have created for the Egyptian flash floods (Al-Momani and Shawaqfah 2013).

3.4 Hazards, Risk, Harvesting, and Utilization of Flash Floods in Sinai and Egypt

On the one hand, Sinai is one of the most vulnerable parts in Egypt, which is subjected to severe flash floods almost every year. On the other hand, Sinai is progressively suffering from an overwhelming water crisis. Flash flood and runoff water could be an answer to this issue. Therefore, this section which consisted of Chaps. 11–14 is devoted to discuss the flash flood issues in Sinai.

Chapter 11 is titled "Egypt's Sinai Desert Cries: Flash Flood Hazard, Vulnerability, and Mitigation." This chapter has three objectives. The first chapter objective is to determine the flood hazard occurrence in the vulnerable areas of Sinai. Remote sensing (RS) and geographic information system (GIS) are utilized to provide improved spatial considerate of basin response to storm rain events and flood monitoring. It is critically essential to precisely predict the occurrence of flash floods in terms of both timing and magnitude.

The second objective is to draw the vulnerability map for several wadis in southern Sinai. Flash floods in Sinai are an inadequately understood feature due to a lack of accurate environmental and hydrological data, which are challenging and expensive to develop and manage in such a region. It is important to understand that risk is determined not only by the climate and weather events, i.e., the hazards but also by the exposure and vulnerability to hazards, which have been induced by human activity. The produced risk map is useful to know the locations that have a high flood risk in order to avoid loss of life and reduce damages to property.

To mitigate flash flood damages and efficiently harvest the highly needed freshwater, the third chapter's objective is to manage and mitigate the flood hazard and minimize their effect. The main watersheds flowing through Sinai are classified into four categories where 4% of watersheds have very high risk, 10% have high risk, 38% have moderate risk, and 48% have moderate to low risk.

Flood risk assessment and flood mapping will help to show which places are most at risk and in what circumstances. After that, governments can take the correct strategy for flood risk reduction or mitigation. Because of the rapidity of flash flood occurrence and its power, flash flood experts recommend the use of early warning systems for reducing vulnerability. Flood risk assessment helps to create flood vulnerable map, and from the historical rainfall data, we can make an early warning system. The early warning system is very important to protect the city by reducing the losses and victims in the region.

However, the Chap. 12 titled "Egypt's Sinai Desert Cries: Utilization of Flash Flood for a Sustainable Water Management" is presented to discuss the utilization strategies of flash floods in Sinai. This is important for Sinai because its flash floods constitute a potential for non-conventional sources of freshwater. However, most floodwater discharges waste as runoff into the Suez Gulf, and if used effectively, this could satisfy some of the water requirements for a variety of uses. The wise use of floodwater to enable the sustainable management of water resources is a significant challenge in these fields. Therefore, the chapter objective is to put the best ways to mitigate and utilize the floods water as a new supply for water harvesting in Sinai.

Different low-cost storage mechanisms for floodwater harvesting were identified to suit the different technical and socio-economic conditions. Firstly, an underground concrete reservoir is one of the most appropriate water harvesting techniques and easily maintained by the Bedouins themselves. Secondly, a Haraba is a low-cost alternative to capture floodwater, often used by Bedouins. Thirdly, one of the potential technically and highly requested by the stakeholders is a low-cost gabions dam with an underground reservoir as the one constructed in Wadi Ghazala.

Low earthen or stone dykes in the Wadi beds (locally known as Oqum) are recognized. They are usually protected by vegetation remains. Masonry dams for the storage of water are also identified.

The total amount of rainfall and flash floods that could be used annually is estimated at around 1.3 billion cubic meters. This quantity can be increased to 1.5 billion cubic meters.

The establishment of the various dams leads to the presence of communities around the areas of these dams to work with agriculture and grazing, as well as to reduce wastage of water, and reduce the speed of the flooding and thereby protect the soil from water erosion. Disasters such as floods disaster in El-Arish (2010) may not return to the floods alone but as a result of the random nature of the establishment of the buildings in the corridors of the floods and without the work of the previous geological study of the area where the various facilities will be installed on them.

Chapter 13 is titled "Flash Flood Risk Assessment in Egypt." It presents an assessment of flash floods in Egypt. The assessment of the flash flood risk in Egypt is classified in this chapter based on three main perspectives.

1. How to deal with the current situation since all catchments are draining toward urban areas, agricultural land, and other assets?

After assessing the causes of some previous incidents, it was clear that the lack of drainage structures (whether due to poor design or flood plain encroachments), and lack of maintenance of existing ones are the main source of these catastrophic incidents. The 100 year return period was selected for the peak discharge calculations, that is subjected to stakeholder decision based on the allocated budget for flood mitigation measures. Due to the large variance of the catchments peak discharge and runoff volume, the box plot technique was employed to eliminate the ranking outlier values.

A map of peak discharge standardized risk classified into five categories (Very High Risk, High Risk, Moderate Risk, Low to Moderate Risk, and Low Risk) is proposed to highlight the reassessment priorities of the flood mitigation measures to control the catchment outlets affecting the exposed human lives, agricultural lands, and any other assets.

2. How to prioritize the rainfall harvesting projects to support in current water stress problem?

A map of runoff volume standardized risk classification is also provided for the same five categories used to assess the peak discharge. The classification based on the runoff volume can guide the designer accounting for rain harvesting projects that would increase the rate of investment return from both flood mitigation and the reduction of freshwater stress.

3. What to do in future planning for unavoidable urban and agricultural expansion?

A two-dimensional HEC-RAS rainfall-runoff model is conducted for Ras-Gharib City by using 30 $\times$ 30 DEM files. The DEM files could not capture the effect of the levels of Ras-Gharib El-Sheikh-Fadl road on the flow directions. The DEM file has been updated based on the available road topographical survey data. The flood plain, flow depths, and velocities were obtained, and accordingly, the flood intensity was calculated for all streams affecting Ras-Gharib City. The model was verified versus aerial photos for the 2016 incident. In order to assess the effectiveness of the newly constructed culvert (16 vents, 3 m × 3 m box culvert) with attached two dikes, another updated two-dimensional HEC-RAS rainfall-runoff model has been conducted and the results showed significant improvement in flood intensity values in Ras-Gharib City.

In order to harvest and use the water of flash floods, it is necessary to identify the potential location. Consequently, Chap. 14 comes with the Determination of Potential Sites and Methods for Water Harvesting in the Sinai Peninsula by Application of RS, GIS, and WMS Techniques to handle this issue with application to Wadi Dahab. Wadi Dahab has very high importance in a new development in southeastern Sinai, for its touristic position and promising water resources. RS, WMS, and GIS techniques are modern research tools that proved to be highly effective in mapping, investigation, and modeling the runoff processes and optimization of the RWH. In the present work, these tools were used to determine the potential sites suitable for the RWH in W. Dahab. The performed WSPM for determining the potentiality areas for RWH depended on the hydro-morphometric parameters of drainage density, infiltration number, maximum flow distance, overland flow distance, basin slope, basin area, the volume of the annual flood, and basin length. The WSPM model was accomplished through three scenarios: equal criteria weights (scenario I), authors' judgment (scenario II), and weights justified by the sensitivity analysis (scenario III). The obtained WSPM maps for defining the RWH potentiality areas classified W. Dahab basin into five RWH potentiality classes ranging from very low to very high. There are good matches between the three performed WSPMs' scenarios in results for the very high and high RWH potentiality classes, which are very suitable for RWH applications.

There are good matches between the three performed WSPMs' scenarios in results for the very high and high RWH potentiality classes, which are very suitable for RWH applications. These classes are frequently represented generally by El-Ghaaib, Dahab Trunk Channel, Zoghra, Nassab, Saal, and Ganah sub-watersheds, which represent about 62.94%, 56.95%, and 73.83% of the total area of the basin for scenarios I, II and, III, respectively. RWH utility system has been proposed to store runoff water and reduce flash flood risks in identified optimal locations.

3.5 Prediction, Mitigation, and Management of Flash Flood

This theme is covered in Chaps. 15 and 16. Chapter 15 is titled "Prediction and Mitigation of Flood in Egypt." The chapter presented an overview of flash flood including flood definition, flood causes, and comprises types of floods and damages caused by the flood. The chapter also presented the application of prediction and mitigation methods to a real case study in Egypt (Wadi Sudr, Sinai). Egypt has alluvial (wadi) systems, formed during fluvial time of the Tertiary and Quaternary Periods. These wadis suffer from flash flood, consequent to heavy precipitations. Wadi Sudr, Sinai has selected a case study to study the prediction and mitigation of flood in this area. The runoff flow paths are detected across the study area and their flow magnitudes under different rainfall events of 10, 25, 50, and 100-year return periods that have been used for designing the flood mitigation measures. Rational and SCS methods are used to facilitate the simulation process during this study and used as tools to convert rainfall to runoff discharges to determine flood quantity throughout the study area.

Once the flash flood or rainfall pattern is predicted, it could be harvested or collected in different ways. Chapter 16 utilizes Alexandria as a case study to switch in stormwater management from gray to green infrastructure. The chapter is titled "Gray-to-Green Infrastructure for Stormwater Management: an Applicable Approach in Alexandria City, Egypt." The green infrastructure systems have recently found successful applications for stormwater management and flood control. This chapter aims at reviewing the recent applications of the management of stormwater drainage projects. The discussed green infrastructures include bioswales, retention basins, ponds, wetlands, rain gardens, permeable pavements, and urban green spaces. These stormwater infrastructures tend to control runoff volume and timing and promote ecosystem services. In addition, this work would provide a better understanding of the barriers and facilitate factors affecting the management of reclaimed stormwater.

Alexandria is the second-largest city in Egypt that has been suffered from periodic flash floods due to rapid urbanization and various infrastructure-related problems. Stormwater management can be extended to an Alexandria Governorate case study to demonstrate the impact of climate change and urbanization on the performance of a city's drainage system, subject to repeated periods of heavy rain, flash flooding, and strong winds. The combination of traditional drainage systems with green infrastructure could be a viable solution to mitigate the stormwater runoff in Alexandria city, Egypt. The outputs of this work can assist water resource managers, government, professionals, and private and public sectors in maintaining flood risk management, especially in Egypt.

The book ends with the 17th chapter of conclusions and recommendations. Chapter 17 contains an update of recently published research works on flash floods including references from Bruins et al. (2019), Vema et al. (2019), Vemula et al. (2019), Sörensen and Emilsson (2019), Shariat et al. (2019), Alves et al. (2019), Piro et al. (2019), Osti (2018), Abdelkarim et al. (2019), Saber et al. (2017), and Al-Momani and Shawaqfah (2013) among others.

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