Project Title: Disaster risk assessment and reduction for the flood prone UNESCO World Heritage Sites in Middle East and North Africa Archaeological Wadis

(中東および北アフリカの考古学的ワジ流域の世界遺産の洪水リスクアセスメントと対策)

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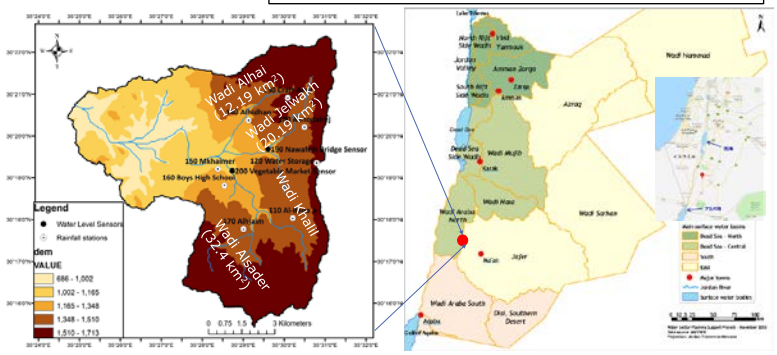
Recently, extreme and frequent wadi flash floods have occurred in most of MENA arid zone, resulting in significant economic and property loses. For instance, flash floods hit Egypt, Jordan, and Saudi Arabia, 39 times over the period of 1900–2016 causing life losses of 1,508 and significant damages exceeding 1.8 billion US dollars. In 2018, Wadi flooding trapped tourists and forced 3,000 tourists to evacuate to safe places within 1 hour before the peak flood reached to the historic site of Petra, Jordan. Sirens blared minutes before extreme flash flood after heavy rainfall approached the Petra. The last fatal flash flood struck Petra in 1963 when 22 French tourists and a local guide were killed by rapidly rising waters. The flash flood on 25 Oct. 2018, which happened at Wadi Zarqa-Maeen and discharging its water to the Dead Sea, caused 21 deaths including 16 schoolchildren.

Petra, the rock city carved by the Nabateans, is one of the Seven Wonders, and one of the major tourist attractions

Field Surveys

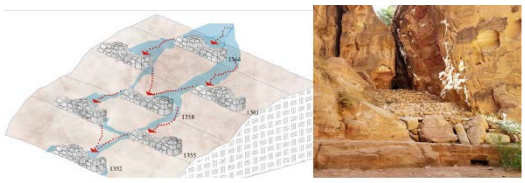
Within the framework of the UNESCO WHS we have selected Petra in Jordan and Valley of King in Egypt as two potential sites for investigations. A group of researchers of Kyoto University in collaboration with Nippon Koei company conducted a preparatory field surveys and meetings for facts findings and establish of cooperative research project. Three field surveys in Jordan have been conducted the 1st survey on 3-9 August, 2nd survey 24-28 August, and the 3rd 24-27 October, 2019. We have visited 7 weather stations and water level stations as well. The warning system is based on one station located at Wadi Mousa having monitoring devices such as automatic weather observation apparatus (AWS), automatic rain gauge and siren equipment, etc., which are installed on the roof top of the Petra Development Tourism Region Authority (PDTRA) main office. PDTRA is currently undertaking a study of “Water Harvesting and Flood Management Project in Petra”, which covers diversified subjects such as hydrological analysis, environmental assessment, structural measures, etc. by hiring a in-country private consultant firm aiming at completion in January 2020. Based on our field investigations we have proposed two new dams to be constructed in Wadi Alsader and Wadi Alhai.



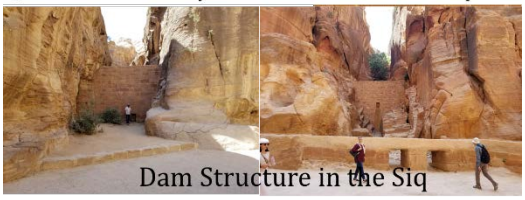
Confluence of 3 Major Tributaries at Upstream of Wadi Mousa

Wadi Mousa Channel conditions before the entrance to the Archeological site

The terraces, as shown in Figure 5 have been one of the main measures to reduce the runoff and sediment. During an extreme event, the terraces trap the runoff water from the nearby hill slopes would flow to the terraces fields along the wadis. Each terrace captures and holds a certain amount of runoff water, which infiltrates into the ground after. Even if the infiltration rate is law, it raises the volume of capillary water available for the growth of the plants.



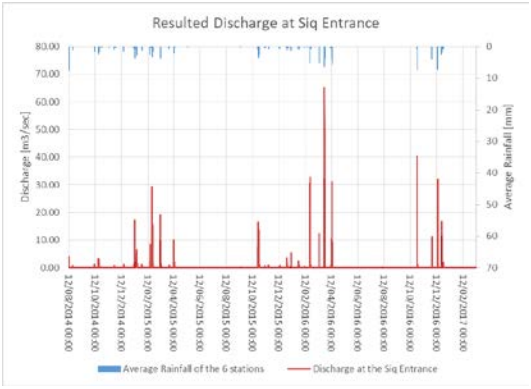
Terraces for sediment yield and control of sediment transport

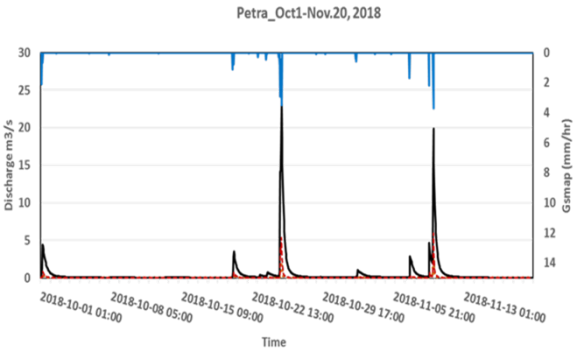


Dam Structure in the Siq

Modelling

Flash flood analysis model was developed and calibrated for Petra basin using the Rainfall-Runoff-Inundation (RRI) model. The calibration and the validation procedures were done based on observed data in the region collected from published paper and Petra authority. Moreover, the model was applied on different recent flash flood events using Satellite data such as PERSIANN, GSMaP, and GPCC. Furthermore, a synthetic rainfall analysis was applied on the calibrated model to estimate the scenarios of different extreme events and to understand the physical behavior of the catchment. Moreover, the model is going to be used to estimate the behavior of different events with different return periods. Subsequently, some mitigation measures are proposed and analyzed using the calibrated model. The calibration and validation were conducted based on the 1970 and 1974 events reported by published paper at ASCE 1999. The simulated peak flow results from the events 1968 and 1970 are similar to the observed peak flow. However, the simulated peak flow result for the event in 1974 is much higher that the observed peak flow. Further analysis should be made. At the moment, the procedure is made to calibrate the other 2 events and test their result until making sure of the water level recorded data so that calibration can be made more properly based on the hourly data. The hydrological model (RRI) was applied using the rainfall data (3 years) to estimate the long-term behavior of the catchment. The discharge was calculated at the downstream, more precisely, at the entrance of the Siq. Figure 5: The preliminary flood runoff simulation from the RRI model by using three years hourly rainfall from PDTRA stations.





Conclusions

The single management strategy is not enough to reduce the flash flood risk; nevertheless, a combination of flood risk management approaches is required in the Wadi system. The proposed management approach focuses on developing a strategic methodology for evaluating wadi flash flood potential, mitigation, and floodwater resource management as well as a rainfall-runoff simulation model. The lack of complete information archive of pre and post WFF events across the Petra obstruct the efforts to mitigate the flooding risk. There is a need to upgrade the installed rainfall and water level stations by PDTRA. Moreover, various existing infrastructures (culverts, bridges, canals, etc.) required an urgent intervention through restoration, removal, and reconstruction. There is an urgent need to mitigate and utilize floodwater as a new supply to sustain a minimum water resources base in rural desert areas.