URBAN FLOODING AND WATERLOGGING IN THE NORTHERN PART OF KABUL CITY

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DEDICATION

This project report dedicated firstly to my parents who put their hands together and sacrificed their lives to make me grow and develop. Secondly to my wife that really helped me during my work on this project report. Finally, this project report is dedicated to all researchers and students who work in the field of hydraulics and hydrology.

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ABSTRACT

Urban flooding and waterlogging are the big challenges in urban areas of Afghanistan especially in the northern part of Kabul city. Such flooding during monsoon become common in recent years. Urban flooding occurs due to unsustainable urban expansion, change in catchment topography, and increase impervious surface, poor link between catchment drainage structures. Obstruction of the drainage structures leads to waterlogging so that stormwater overspills and blocks the roads against traffic and businesses. Over a decade, drainage systems had been undesirably upgraded in proportion to population growth, caused an increase in frequency of urban flooding and waterlogging. However, very few studies have been conducted to address this issue. Therefore, the objective of the study was to evaluate pre and post-development land-use changes and delineate flooding prone area, identify the factors causing urban flooding and waterlogging and finally, to identify catchment discharge from the rainfall using HEC-HMS. For this purpose, land-use changes over 45 years of pre and post-war periods (1964-2009) were evaluated using CORONA 1964 imagery with new update 2009 imagery 10x10cm resolution of Kabul city. Climate Hazard Group InfraRed Precipitation with Station (CHIRPS) and the ministry of energy and water (MEW) rainfall data set were used to estimate discharge from rainfall. The land-use changes scenarios were analysed by using geographical information system (GIS) under the causes of the increase of urban flooding. The results revealed that unsustainable development activities in the natural water flow path are the major cause of increasing flood in the study area. There are other factors as a poor link between Wazerabad canal and existing drainage structures, catchment characteristic, undesirable combined drainage structures law enforcement and less attention to maintenance which contribute to urban flooding and waterlogging. The study suggest that the sub-drainage structure should be linked to Wazerabad canal by considering sufficient slop, segregation of sewer system where applicable, public awareness, structural and non-structural approaches for urban flood mitigation , law enforcements, sediment and solid waste trap at each drainage inlet as well as system cleaning and maintenance after each rainfall are recommended.

ABSTRAK

Banjir dan penebangan air bandar adalah cabaran besar di kawasan bandaraya Afghanistan terutamanya di bahagian utara bandar Kabul. Banjir seperti semasa musim hujan menjadi biasa pada tahun-tahun kebelakangan ini. Banjir bandar berlaku akibat pengembangan bandar yang tidak lestari, perubahan topografi tangkapan, dan meningkatkan permukaan yang tidak tahan, hubungan yang tidak baik antara struktur saliran tangkapan. Halangan struktur saliran membawa kepada penyaliran air supaya pemercikan air hujan dan menghalang jalan raya daripada trafik dan perniagaan. Lebih sedekad, sistem saliran telah dinaikkan ke tahap yang tidak sesuai dengan pertumbuhan penduduk, menyebabkan peningkatan kekerapan banjir bandar dan pengairan air. Bagaimanapun, sedikit kajian telah dijalankan untuk menangani isu ini. Oleh itu, objektif kajian ini adalah untuk menilai perubahan penggunaan tanah sebelum dan selepas pembangunan dan menggambarkan kawasan rawan banjir, mengenal pasti faktor-faktor yang menyebabkan banjir bandar dan pengairan air dan akhirnya, untuk mengenal pasti hujan dari hujan menggunakan HEC-HMS. Untuk tujuan ini, perubahan guna tanah selama lebih dari 45 tahun sebelum dan selepas perang (1964-2009) telah dinilai menggunakan imejan CORONA 1964 dengan resolusi baru 2009 imejan 10x10cm resolusi Kabul city. Kumpulan Hazard Iklim Iklim InfraRed dengan Stesen (CHIRPS) dan set data hujan kementerian tenaga dan air (MEW) digunakan untuk menganggarkan pelepasan daripada hujan. Senario perubahan penggunaan tanah dianalisis dengan menggunakan sistem maklumat geografi (GIS) di bawah sebab-sebab peningkatan banjir bandar. Hasil kajian menunjukkan bahawa aktiviti pembangunan yang tidak lestari di laluan aliran air semulajadi adalah punca utama peningkatan banjir di kawasan kajian. Terdapat faktor lain sebagai hubungan yang tidak baik antara terusan Wazerabad dan struktur saliran yang sedia ada, ciri tadahan, gabungan struktur saliran yang tidak diingini penguatkuasaan undang-undang dan kurang memberi perhatian kepada penyelenggaraan yang menyumbang kepada banjir bandar dan pengairan air. Kajian menunjukkan bahawa struktur sub-saluran perparitan harus dikaitkan dengan terusan Wazerabad dengan menimbangkan cerun yang mencukupi, pemisahan sistem pembetung yang mana berkenaan, kesedaran awam, pendekatan struktur dan bukan struktur bagi tebatan banjir bandar, penguatkuasaan undang-undang, sedimen dan perangkap sisa pepejal di setiap salur masuk salur serta pembersihan dan penyelenggaraan sistem selepas setiap hujan dicadangkan.

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LIST OF ABBREVIATIONS

GIS	-	Geological information system
HEC-HMS	-	Hydrologic Engineering Centre, Hydrologic Modelling System
DID	-	Drainage and irrigation department (Malaysia)
MASMA	-	Manual Saliran Mesra Alam (Urban storm water management for Malaysia)
UD	-	Urban drainage
BMPs	-	Best Management Practices
USW	-	Urban Storm Water
WL	-	Waterlogging
MEW	-	Ministry of engineering and water (Afghanistan)
CHIRPS	-	Climate Hazard Group InfraRed Precipitation with Station
USWL	-	Urban storm water-logging
GSOD	-	Global Summary of the Day
NOAA	-	National Ocean and Atmospheric Administration
AMD	-	Afghanistan Meteorological Department
CMS	-	Cubic Meter per Second (cms)
GW	-	Ground Water
CSTP	-	Centralized Sewage Treatment Centre
RMSE	-	Root Mean Squire error

LIST OF SYMBOLS

T_c	-	Time of Concentration
Lc	-	Length of the sub-catchment
Sc	-	Slope of the sub-catchment
K	-	Time passing of the wave in reach length
$\sum$	-	Summation
Pi	-	Predicted data
Oi	-	Observed data
n	-	Number of data
Q	-	Discharge
V	-	Velocity
R	-	Hydraulic radios
s	-	Slope
n	-	Manning roughness coefficient

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CHAPTER 1

INTRODUCTION

1.1 Background

Kabul city, the capital of Afghanistan has experienced a rapid urban expansion in order to accommodate more than 4 million people. Urban development in Kabul city consists of industrial, commercial and residential places. The study catchment area comprising of 4 districts (4, 10, 11, and 15) of Kabul city. This catchment was not developed in a sustainable and balanced way which causes urban flooding and waterlogging even for less intense rainfall event. The debate on the improvement of existing urban infrastructure (drainage system network) is apathy for the government. However, the improvement of the urban road and drainage systems is an important and vital artery to be focused on.

Kabul which belongs to a semi-arid climate, receives an average of 350 mm rainfall per year. This amount of annual rainfall seems to be less and cannot cause directly urban flooding. However, most of the rainfall occur during the months of March to May. The rainfall during these three months is often very intense. The volume of surface runoff generated by the rainfall is often more than the drainage capacity of the area. Besides, reduction of the design capacity of the combined sewer and storm water drainage networks due to human activities like littering in drainage, eroded sediments from sub-catchments causes urban flooding even for less intense rainfall. Due to catchment slope (flat), undesirable drainage structures (undersized drain), poor drainage links, bared soil surface, the rainfall generates a significant amount of surface muddy runoff which blocks the drainage network and causes a flash flood. The land surface of the city is mostly bared soil. Besides, roofs of most of the houses are constructed conventionally using raw soil instead of concrete or steel sheet covers. Therefore, the amount of soil erosion is much higher in the city which often blocks the sewer network and causes overflow and floods.

Intense rainfall may cause a flood level up to 80 cm in some parts of the catchment. For instance, the flood that occurred in Prodae Jadid locality due to a heavy rainfall on 16th March 2014 as shown in Figure 1.1. The rainfall caused flood with an inundation level of 60 to 80 cm which lasted for almost 24 hours.

Figure 1.1: A rainfall of 16-March-2014 caused a flood with an inundation level of 60 to 80 cm in the catchment.

Furthermore, during snowfall time, most of the roofs are cleaned by owners of the properties. Therefore, snow melts do not erode the bare soil in the winter months of December, January and February. However, snow starts melting quickly after winter (mid-March) for the meantime, the precipitation also changes its form from snowfall to rainfall. The soil particles slowly detach from bared surfaces and sediment being added to the stormwater. The worst-case scenario happened when the wastewater from residential and commercial areas collectively meet stormwater which changes the quality of water into highly toxic (Figure 1.2). This indicates that many geographical factors such as soil type, slope, land use, and imperviousness of the land surface, poor and undesirable drainage structures (stormwater & wastewater combined system) can affect the quantity and quality of surface runoff.

Figure 1.2 Stormwater mixed sewage overflowing on the roads

Another aspect of the catchment area is the topography. The topography of the catchment area directs the generated runoff on certain paths and then accumulated runoff need to be conveyed directly to the main canal with adequate slope and velocity. However, the surface runoff completely stagnant at some points due to catchment slope, poor linkage of the sub-drainage structures to the main canal. These phenomena cause urban flooding in most of the flood-prone areas of the catchment. Urban flooding normally occurs with the duration of an average of (10 to 24) hours (Figure 1.3).

Figure 1.3 Flash flood, muddy flood inundation in sub-district streets

The present study was conducted with the purpose of analysing the situation of urban flooding and waterlogging by gathering the meteorological an hydrological data for urban flood modelling, to assess pre and post-development land-use changes between year 1964 and 2009, to develop hydrological model for determining catchment discharge, and to analyse the factors causing urban flooding and waterlogging in Kabul city with in this catchment. This method will also be used for other catchments that are experiencing the same issue.

1.2 Problem Statement

Rapid urban expansion (land-use change), limited and undesirable combined drainage structures, a poor link of sub-drainage network, bared soil surface (impervious surface), catchment characteristic are the main reasons for urban flooding and waterlogging. Water inundates low lying area. The Kabul city frequently experiencing urban flooding and waterlogging in monsoon seasons annually which disturbs social life and damage properties of residents who lives within the affected area of this catchment. Despite the large economic losses and social consequences, studies related to floods in Kabul city is still very limited. The scarcity of hydrological data is considered a contributing factor in this regard. Therefore, the major challenge is to use the available secondary data from different sources for modelling of floods of Kabul city in order to recommend the effective mitigation measures.

1.3 Study Objectives

The general objective of this study is to investigate the factors causing urban flooding and waterlogging in the most vulnerable sub-catchment of Kabul city during monsoon and recommend the optimal achievable solutions for flood mitigation. The specific objectives are

1. To gather physical, meteorological and hydrological data required for flood modelling from different sources.
2. To evaluate pre and post-development land-use changes between (1964 and 2009) by using geographical information system
3. To develop a hydrological model (HEC-HMS) of the catchment for simulation of run-off for different rainfall events and using numerical equation for determining wazerabad canal capacity
4. To analyse the results for understanding the factors causing urban flooding and water logging in the Kabul city and recommend the possible structural and non-structural measures for flood mitigation.

1.4 Scope of the of the study

Assess and evaluate the pre and post land-use changes with the period of 45 years by using GIS to create digital elevation model DEM, Hillview, flow direction maps and also digitizing of pervious, impervious and bared soil on old and new maps.

Validating of MEW and CHIRPS rainfall data set in order to identify the catchment discharge by using hydrological model HEC-HMS.

Fewer studies and limitation of land-use and rainfall data made me to start investigation on finding the factors causing urban flooding and waterlogging in the northern part of Kabul city.

1.5 Significance of the study

This is part of pioneer studies aimed at modelling urban flood in Kabul. The model developed in this study can be used forecasting floods in Kabul city and warning people which would certainly help in reducing economic losses and public suffering.

The model can be used to understand the effect of different structural and non-structural measures on flood peak control and thus, may help to identify the mitigation measures.

The recommendation made based on the finding of this study can be adopted by urban planners for mitigation of flood in Kabul city.

The methodology used in this study for modelling floods in a data-scarce region can be replicated in other similar region for flood modelling and identification flood mitigation measures.

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