UNIVERSITI PUTRA MALAYSIA

GIS-BASED MODELING OF THE CHANGES IN WATER LEVEL DUE TO FLOOD WALLS

PARISA PARVANEH

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Master of Science
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GIS-BASED MODELING OF THE CHANGES IN WATER LEVEL DUE TO FLOOD WALLS

By

PARISA PARVANEH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Master of Science

August 2010

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DEDICATION

Dedicated

To my beloved parelltsJor their help alld support.

To my husbandJor his love and patience.

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

GIS-BASED MODELING OF THE CHANGES IN WATER LEVEL DUE TO FLOOD WALLS

By

PARISA PARVANEH

August 2010

Chair: Associate Professor Abdul Ralim Ghazali, PhD

Faculty: Engineering

Flood control structures may protect an area against flood; however, it may also induce inundation in another area at the same time. One of such structural projects is constructing flood walls along a river reach. This study investigated the effects of these flood walls on the upstream of the protected river reach using a GIS-based modelling approach. The framework developed in this study covered the problems encountered in the implementation of the GIS-based hydraulic models in the regions with insufficient integrated data. The study area covered the reach of Karoon River which is located between the Ahwaz and Farsiat hydrometric stations in Khuzestan Province, Iran. The area was selected primarily due to the current and future development of both the residential and industrial centres along this reach, as well as because of the availability of data for the study area. Ahwaz City, which is located at the upstream of this reach, is frequently subjected to flood and flood-related problems. The flood walls on both river banks at the selected reach were simulated in order to compute any changes in the water level and the flow velocity at the

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Ahwaz hydrometric station. This simulation approach integrated both the ArcGIS tools and HEC-RAS hydraulic model by interfacing the HEC-GeoRAS extension. The river reach and the required features of the HEC-RAS model were digitized and extracted from Triangular Irregular Network (TIN) in the ArcGIS. Meanwhile, the HEC-RAS model was applied for the existing condition with no flood walls and the model was calibrated with the observed data. The restriction on the widths of river cross sections was carried out for a length of I km using three different methods to represent the flood walls. Based on the findings of the study, the best method was subsequently selected, and this was to use flood walls for the whole reach. Flood walls were added to the model using two different designs. In the first design, the widths of the cross sections along the equal length of the river banks (10 km) were confined by the flood walls at three different distances from the Ahwaz station so as to investigate the effects of these distances. The second design incorporated 30 km continuous flood walls, beginning from 10 km downstream of the Ahwaz station. Changes in the water level and the flow velocity at the Ahwaz station, due to the different lengths of the flood walls and the various distances, were determined and analyzed for seven return periods. The increases in the water level for the first design were found to vary from 0.66 m to 1.44 m, and it reached 2.32 m for 100 years return period in the second design. The resulted charts can aid engineers to make judgments on such flood protection techniques. The framework developed in this study could be used as a prototype simulation method for other rivers and to be implemented for different lengths of flood walls at any distance from any upstream gauge.

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PERPUSTAKAAN SULTAN ABDUL SAMAD UNIVERSITI PUTRA MALAYSIA SERDANG

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMODELAN BAGI PERUBAHAN ARAS AIR YANG DISEBABKAN OLEH DINDING BANJIR BERDASARKAN GIS

Oleh

PARISA PARVANEH

Ogos 2010

Pengerusi: Profesor Madya Abdul Halim Ghazali, PhD

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Struktur tebatan banjir mungkin melindungi sesuatu kawasan daripada banjir, namun pada masa yang sama ia boleh mengundang banjir di kawasan lain, yang perlu dikaji. Salah satu daripada projek struktur ialah membina dinding banjir di sepanjang satu jangkauan sungai. Dalam kajian ini kesan dinding banjir ke atas kawasan di hulu kawasan yang dilindungi dikaji melalui pendekatan pemodelan berdasarkan GIS. Rangka kerja yang dibangunkan dalam kajian ini meliputi kaedah menggunakan model hidraulik berdasarkan GIS dalam kawasan yang tidak mempunyai data yang lengkap. Kawasan kajian ini adalah satu jangkauan Sungai Karoon yang terletak di antara stesen hidrometrik Ahwaz dan Farsiat dalam daerah Khuzestan, Iran, yang dipilih kerana pembangunan pusat penempatan dan industri di sepanjang jangkauan ini. Bandar Ahwaz, yang terletak di hulujangkauan ini, kerap dilanda masalah banjir. Dinding banjir pada kedua-dua tebing sungai yang dipilih ini disimulasikan bagi menentukan perubahan dalam aras air dan halaju aliran di stesen hidrometrik Ahwaz. Pendekatan simulasi ini menggabungkan alatan ArcGIS dan model hidraulik HEC-RAS dengan mengantaramuka lanjutan HEC-GeoRAS. Jangkauan sungai itu dan

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rupa bentuk yang diperlukan bagi model HEC-RAS didigitkan dan maklumat dikeluarkan daripada satu rangkaian berceranggah segitiga (TIN) dalam Arc-GIS dan model HEC-RAS digunakan bagi keadaan semasa tanpa dinding banjir dan hasil model dikalibrasi dengan data yang dicerap. Kekangan ke atas lebar keratan rentas sungai bagi jarak sepanjang 1 km sungai dilakukan dengan tiga bentuk simulasi dinding banjir. Kaedah yang terbaik dipilih untuk digunakan bagi menambah dinding banjir di sepanjang jangkauan itu. Dalam bentuk yang pertama, lebar keratan rentas di sepanjang jarak yang sarna di sepanjang tebing sungai, iaitu 10 km, dikekang dengan dinding banjir dalam tiga jarak yang berbeza dari stesen Ahwaz, untuk menilai kesan jarak. Bentuk yang kedua melibatkan penambahan dinding yang berterusan sepanjang 30 krn, bermula dari 10 km di hilir stesen Ahwaz sehingga ke penghujung jangkauan. Perubahan aras air sungai dan halaju aliran di stesen Ahwaz, disebabkan oleh panjang dinding banjir yang berlainan dan pelabagai jarak itu ditentukan dan dianalisis bagi tujuh nilai kala kembali. Pertambahan aras air sungai bagi bentuk pertama berubah daripada 0.66 hingga 1.44 m dan bagi bentuk kedua pertambahan aras air sungai mencapai 2.32 m bagi kala kembali 100 tahun. Carta yang dihasilkan boleh membantu penilaian kejuruteraan bagi teknik perlindungan banjir seumpama itu. Rangka kerja yang dihasilkan dalam kajian ini dapat digunakan sebagai satu kaedah simulasi prototaip bagi sungai lain dan boleh digunapakai bagi panjang dinding banjir yang berlainan pada sebarang jarak dari sesuatu stesen di hulu.

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I am grateful to my precious unique gentle husband, Sirous, whose shoulders give me a reliable back for ever. He stands a very long time far from me and just encouraged me kindly during this time. His love and supports were what made me strong in difficulties of living alone in Malaysia. His essence and peacefulness are sensed anywhere, anytime.

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I certify that a Thesis Examination Committee has met on 16 August 2010 to conduct the final examination of Parisa Parvaneh on her thesis entitled "GIS-Based Modeling of the Changes in Water Level Due to Flood Walls" in accordance with the Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Master of Science.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously and is not concurrently submitted for any other degree at UPM or at any other institutions.

PARISA PARVANEH

DATE: 16-8-2010

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LIST OF ABBREVIATIONS

I-D	One-dimensional
2-D	Two-dimensional
3-D	Three-dimensional
ARI	Average Recurrence Interval
DEM	Digital Elevation Model
DTM	Digital Terrain Model
Existing condition	Condition with no flood wall
FW	Flood wall
LOB	Left OverBank
N	Manning roughness coefficient
NS	Not Significant
Phase=PH	Distance from first added flood wall to the Ahwaz station varying as 10,20 and 30km
ROB	Right OverBank
RS = River station	Distance from downstream end of reach
S	Significant
TIN	Triangular Irregular Network
Vel Total= Total velocity	Average velocity of flow in total cross section
WS	Water Surface
Yr	Years

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CHAPTER 1

INTRODUCTION

1.1 General

Flood that is caused by storms is among the most devastating natural disasters in almost any country. Although, heavy falls either in the form of rain or melting snow or ice layers are considered as the main causes for this phenomenon, it is undeniable that it can be induced by poorly managed constructions along riverine areas. Due to the development along rivers or throughout the catchments, studies are needed to simulate current and future hydrologic and hydraulic characteristics of the catchments to determine, prevent and solve the flood induced problems and also to plan future developments. Rivers under such conditions are mostly interfered by humans through changes made in their stream regime or natural bed conditions by silt removal, restricting their width and construction of different water control structures.

Hydraulic simulation of a river is necessary to detennine the rate of discharges and current and future levels of water surface profile specially after the effects of performing the river engineering designs on flood distribution at the upstream and downstream (Scott Wilson Piesold and Mahab Ghodss, 2005). Flow behavior for rivers is determined under hydrologic processes and geologic variations during different time periods. Due to natural changes as well as artificial modifications along the river and its adjacent floodplain, the behavior can always be influenced.

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A category of tools utilized for hydraulic analysis of flow is mathematical modeling. These models solve the differential equations to bring about flow regime and flow characteristics as their results. Ultimately, the model outputs would be analyzed and interpreted to be applied to engineering designs (Water Research Center, 200Ib).

1.1.1 Flood

Flood is a natural disaster that should be expected to take place anywhere. If no control is imposed, it brings damages to cultivations, crops, properties, human welfare and in critical situations, it endangers human life as well. Obviously, it is impossible to prevent the damage completely. However, the purpose of floodplain management is to minimize such disasters as much as possible.

To reduce damages to properties along a river, predicting the hydraulic response of a river, such as changes in the water levels, to probable floods, has considerable importance ın societies. **In** addition, before conducting any hydraulic structures planning on river, a reliable overview of the river response to such plans should be taken into consideration.

1.1.2 Effect of Flood Control Structures

Changes in the hydraulic parameters of a river should be considered as anthropogenic impacts. Such changes can be made in different hydraulic structures by preventing the natural flow path, storing its energy in dams and bunds, or restricting the river width by levees or flood walls. The presence of some structures

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itself can affect the current water level and stream velocity of a river. These effects contribute to changes in inundated areas. The functionality of a flood control structure must be mutually satisfactory. In other words, it should reduce the severity of flood in one region meanwhile it does not increase the flood risk in other regions or at least this risk should be compensable (Lever and Daly, 2003; Remo and Pinter, 2007). Where flood control in a region brings about undesirable effect in another area, the non-structural methods for flood mitigation are proposed.

1.2 Study Area

The study area is located in the Khuzestan Province, Iran. The area is drained by Karoon River, one of the main rivers in southern Iran. It flows through Ahwaz City in its journey to the Arvand River to join Persian Gulf.

Khuzestan Province ranks second in Iran among the 28 provinces in the number of flood events in a period of 25 years with 117 events and it ranks first in damages to properties (Sabzab Arvand, 2006), even though it is believed that the reported financial losses are highly underestimated.

1.3 Problem Statement

Flood is one of the most detrimental phenomenon in Khuzestan Province, Iran. The rise of water levels in the most populated city of this province, Ahwaz, is making the damages more often. The area usually experiences many flood events either due to runoff or when the river overflow its banks.

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Many studies have been done before and some structural measures had been constructed to protect the city and the river banks from flood, like designs and plans for silt removal, bunds, levees or flood walls. However, changes in river bed in a reach would affect the water level or velocity in this reach and others. It may also cause problems such as more sever floods beyond the protected reach. This effect has been implied hypothetically that the levees are expected to protect a reach from flood by conducting the additional flow to other districts (Water Research Center, 2001a; Remo and Pinter, 2007).

Confining the river cross sections by flood walls on both sides of the river downstream of Ahwaz is one of the proposed solutions against flood at riverine banks. This constriction may cause a rise in water level upstream of the protected reach, where Ahwaz City is located. Regarding the natural topography of Ahwaz which is flat, the extra elevated water levels will spread horizontally which means more areas would be flooded throughout the city. Consequently, other problems should be expected such as inundation of more roads and highways and subsequent difficulties in traffic and transportation and so on. Hence, it is vital to investigate the effects of flood walls construction on water surface profile and consider the raised water level in Ahwaz hydrometric station.

Insufficient data to run some hydraulic models, especially in a developing country such as Iran, is responsible for using improper hydraulic models which lead to inaccurate results. Thus, it is necessary to integrate a modeling approach to use the available data to run a valid model. In this area, due to lack of aerial photography and field survey which includes both floodplain and river bottom, it is not easy to run a

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GIS based hydraulic modeling in which all the required geometric data can be extracted from an incessant and reliable Triangular Irregular Network (TIN) map. The approach in this thesis is to prove the capability of such discrete data to produce a complete geometric outcome and river scheme.

1.4 Objectives

The main objective of this research is to investigate the effects of flood walls on Karoon River downstream of Ahwaz City on the river water level in the city using HEC-RAS model and GIS facilities. The other specific objectives are:

1. To develop a method for the preparation of geometric data file for hydraulic modeling by utilizing individual topography measurements.
2. To assess the effect of different lengths of flood wall and its distance from Ahwaz station on the water level at this station using HEC-RAS model.
3. To determine the effects of cross section constriction downstream of Ahwaz city on the flow velocity before the constricted reach.

1.5 Scope of the Study

An integrated approach was introduced in this study to produce a continuous TIN in ArcMap for river bed and floodplains by using different groups of data formats for the Karoon River in Khuzestan Province, Iran. Digitizing river features and preparation of the imported file of geometric data required by hydraulic model was done by interfacing an ArcGIS extension called HEC-GeoRAS. Using these

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geometric data extracted from continuous TIN and other flow data, HEC-RAS hydraulic model was run to calculate the water surface profiles along the river. This model was calibrated by comparing the simulated water levels at Ahwaz City gauge and the observed water levels at the same gauge. Floods of different return periods were computed from 44 maximum annual discharges at the gauge by HYFA software. After assessing the accuracy of the HEC-RAS model for the existing condition, flood walls were added on both sides of the river in ArcMap and were modified in HEC-RAS to constrict the width of the cross sections. This constriction was simulated in three different methods. The best method to model the considered restriction was then selected and used in all of the modeling processes in which flood walls were added in one kilometer stretch along the river in two different designs. All of the simulating processes were done repeatedly for each segment of I km flood wall to determine the water level changes at upstream gauge as a result of constriction in the widths of the river cross sections. In short, both GIS and hydraulic models were run 51 times to achieve the comparative chart of such changes. Factors such as different lengths of flood walls and different spacing between the first flood wall from the upstream gauge were studied.

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