APPLICABILITY OF RATIONAL FORMULA IN HYDROLOGICAL ANALYSIS OF HIGHWAY CROSS DRAINAGE STRUCTURES

Gimhani Anuruddhika Dissanayake

(138306K)

Dissertation submitted in partial fulfillment of the requirements for the degree Master of Engineering in Highway and Traffic Engineering

Department of Civil Engineering

University of Moratuwa

Sri Lanka

August 2017

DECLARATION

Declaration of the candidate

"I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text".

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: …… Date:

Declaration of the supervisor

The above candidate has carried out research for the Masters thesis under my supervision.

Signature of the supervisor: ……. Date:

Applicability of Rational Formula in Hydrological Analysis of Highway Cross Drainage Structures

Abstract

The peak flow estimation at Highway –Waterway intersects has substantial effects on Hydraulic design aspects of culverts and bridges. Fair and accurate estimation of peak flow would be the basis in deciding the size of cross drainage structures to ensure proper transfer of runoff collected at inlet towards the downstream.

The history of hydrology modelling varies from well-known Rational Formula to sophisticated computer aided models. Rational Formula has been used for over 150 years and still remains as the most widely used method due to its simplicity in approach. The present study considered five numbers of flood estimation techniques; Rational Formula, Fuller Formula, Snyder's Method, Flood transportation and HEC-HMS for catchments located in four road segments where area varies from 9 – 6663 hectares (ha). All catchments are ungauged and prediction of flood flows for ungauged basins is extensively discussed in past decades and still remains a question due to accuracy and validity of assumptions made in the analysis.

The study focused on different methods of time of concentration, runoff coefficient and design discharge estimations. Three empirical relationships along with Irrigation Department guideline (1984) were considered for the computation of Time of Concentration. Time of concentration results of Kirpich equation was substantially lower than other methods while UK Flood Studies Report equation was identified as the highest. Only the Bransby – William equation showed fair agreement with Irrigation Department Guideline.

Peak flow estimations of flood transportation technique is highly sensitive for the drainage area ratio and relatively low drainage area ratios correspond to culvert and bridge sites caused significant deviation from other methods. Fuller formula estimations were also considerably deviated from other methods.

The difference in peak flow estimation methods was not significant up to catchment area of 100 ha. Peak flow estimations of cross drainage structures in studied road segments revealed that Rational formula can be applied up to 770 ha. As a comparative assessment catchments larger than 770 ha to be modeled using Rational formula and alternative flood estimation methods.

Key Words: Time of Concentration, Rational Formula, HEC-HMS, Fuller Formula, Flood Transportation

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to the supervisor, Dr.H.R.Pasindu for giving earnest support, guidance and commitment extended throughout the study. I further express my appreciation for the Staff of Department of Civil Engineering, University of Moratuwa for their enormous guidance and support.

I am thankful to my employer Central Engineering Consultancy Bureau (CECB) for facilitating me to pursue studies leading to a Masters degree.

I take this opportunity to thank Eng. P.C.Jinasena (former Additional General Manager), Eng. W.A.D.D.Nandakumara (Additional General Manger - Northern Roads) and Senior Engineers of CECB for sharing their valuable expertise and experience in Hydrologic and Hydraulic design works and constant optimism throughout my carrier. The contribution of all CECB staff worked at North Road Rehabilitation Project and Local Bank Funded Road Project are gratefully acknowledged for their immense support in finding necessary information and data pertaining to the research area.

Finally my deep and sincere gratitude to my parents and my friends for their continuous support and encouragement throughout the process.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
A, F	Area
AMC	Antecedent Moisture Condition
ASTER	Advanced Spaceborne Thermal Emission and Reflection
BPR	Bureau of Public Roads
C	Runoff Coefficient
CAg	Catchment Area of gauged site
CAu	Catchment Area of ungauged site
CN	Curve Number
Cp	Peak Parameter
Ct	Time Parameter
d	Depth of rainfall
D	Duration of Unit Hydrograph
D’	Storm Duration
DDF	Rainfall Depth Duration Frequency
DEM	Digital Elevation Model
DRH	Direct Runoff Hydrograph
ESDAC	European Soil Data Centre
FAO	Food and Agriculture Organization of the United Nations
f_c	Final/Equilibrium infiltration capacity
FR	Ferralsols
GIS	Geographic Information System
GPS	Global Positioning System
GTOPO	Global 30 arc-second Elevation
ha	hectares
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling System
hr	Hour
HSG	Hydrologic Soil Group
HydroSHEDS	Shuttle Elevation Derivatives at multiple Scales
I	Rainfall Intensity
Ia	Initial Abstraction
ID	Irrigation Department ,Sri Lanka
IDF	Rainfall Intensity Duration Frequency

IL+ULS	Initial loss plus Uniform loss rate
IWMI	International Water Management Institute
K	Frequency factor
km	kilometer
km^2	Square kilometer
L	Length
Lca	Center of Gravity of a Catchment Length
LV	Luvisols
mi	Mile
NRCS	U.S. National Resources Conservation Services
P	Excess Rainfall
Q	Peak Flow
q_{pi}	Peak runoff of unit hydrograph
Qpi	Flood hydrograph peak
RBE	Reddish Brown Earth
S	Slope
SCS	Soil Conservation Service
SRTM	Shuttle Radar Topography Mission
T	Return Period
Tb	Time base
tc	Time of Concentration
tp	Time lag/Basin time lag
TR	Technical Release
UH	Unit Hydrograph
USGS	United States Geological Survey
V	Velocity
W_{50}	Width in hrs of unit hydrograph for 50% of q_{pi}
W_{75}	Width in hrs of unit hydrograph for 75% of q_{pi}
X	Mean
Yr/YR	Year
y_T	Reduced variate
σ	Standard Deviation

LIST OF APPENDICES