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Calibration of Channel Roughness for Lower Mahi River, Using HEC-RAS

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ABSTRACT-*Channel roughness is the most sensitive parameter in development of hydraulic model for flood forecasting and flood plain mapping. Hence, in present study it is attempted to calibrate the channel roughness coefficient (manning's 'n' value) along the river Mahi, Gujarat through simulation of flood using HEC-RAS. The requirement of multiple channel roughness coefficient manning's 'n' values along the river has been spelled out through simulation of floods, using HEC-RAS, for year 2001 and 2003 , supported with the photographs of river reaches collected during the field visit of the lower Mahi river. The calibrated model, in terms of channel roughness, has been used to simulate the flood for year 2005 and 2011 in the river. The performance of the calibrated HEC-RAS based model has been accessed by capturing the flood peaks of observed and simulated floods; and computation of Root Mean Squared Error (RMSE) for the intermediated gauging stations on the lower Mahi River.*

KEYWORDS: *Manning's "n", Hydraulic Model, Mahi River, HEC-RAS.*

I. INTRODUCTION

With rapid advancement in computer technology and research in numerical techniques, various 1-D hydrodynamic models, based on hydraulic routing, have been developed in the past for flood forecasting and inundation mapping. The discharge and river stage were chosen as the variables in practical application of flood warning [1]. The discharge, river stage and other hydraulic properties are interrelated and depend upon the characteristics of channel roughness. Among various hydraulic parameters, the channel roughness plays very important role in the study of open channel flow particularly in hydraulic modelling. channel roughness is a highly variable parameter which depends upon number of factors like surface roughness, vegetation, channel irregularities, channel alignment etc. It also depends on such factors as: bed material, vegetation, channel irregularity and alignment, scour and deposition, obstructions, channel size and shape, stage and discharge, seasonal changes, suspended material and bed load [2].
Photographs of Panam and Mahi river bed are taken for the study in variation of channel roughness along the river, which represent that the river bed characteristics at Panam, Mahi at Wanakbori, Mahi at Sindhrot and Mahi At Expressway bridge is different. In this study manning's 'n' value for Panam and from Sindharot weir to the end study river reach taken as 0.028, calibration from Kadana Dam to Sindhrot Weir.

Figure 1. Channel characteristics at Panam

Figure 2. Channel characteristics at Wanakbori Weir

	
Figure 3. Channel characteristics at downstream of Sindhrot Weir	***Figure 4. Channel characteristics at Expressway Bridge near Vasad***

II. MODEL DESCRIPTION

HEC-RAS is capable of performing one-dimensional water surface profile calculations for steady gradually varied flow in natural or constructed channel. Subcritical, supercritical and mixed flow regime water surface profile can be calculated.

2.1. Equation for Basic Profile Calculation

Water surface profiles are computed from one cross section to the next by solving the Energy equation with an iterative procedure called the standard step method. The Energy equation is written as follows [3].

$$Z_2 + Y_2 + \frac{a_2 V_2^2}{2g} = Z_1 + Y_1 + \frac{a_1 V_1^2}{2g} + h_e$$

Z_1, Z_2=elevation of the main channel inverts
Y_1, Y_2=depth of water at cross section
V_1, V_2=average velocity (total discharge/total flow area)
a_1, a_2=velocity weighting coefficient
g=gravitational acceleration, h_e=energy head loss

III. STUDY REACH

Mahi River is one of the major west flowing river in the country, that originates from the Vindhya range and drains into Gulf of Khambhat. Major parts of basin area lies in the elevation zones of 100-500 m. Total length of Mahi river is 583km out of which167km in Madhyapradesh 174km in Rajsthan and 242km in Gujarat. The total drainage area of Mahi river is 34842 square kilometre out of which 6695km^2 lies in Madhyapradesh, 16453km^2 lies in Rajasthan and 11694km^2 lies in Gujarat. Mahi basin id divided in two sub basin namely, Mahi upper basin and Mahi lower basin.

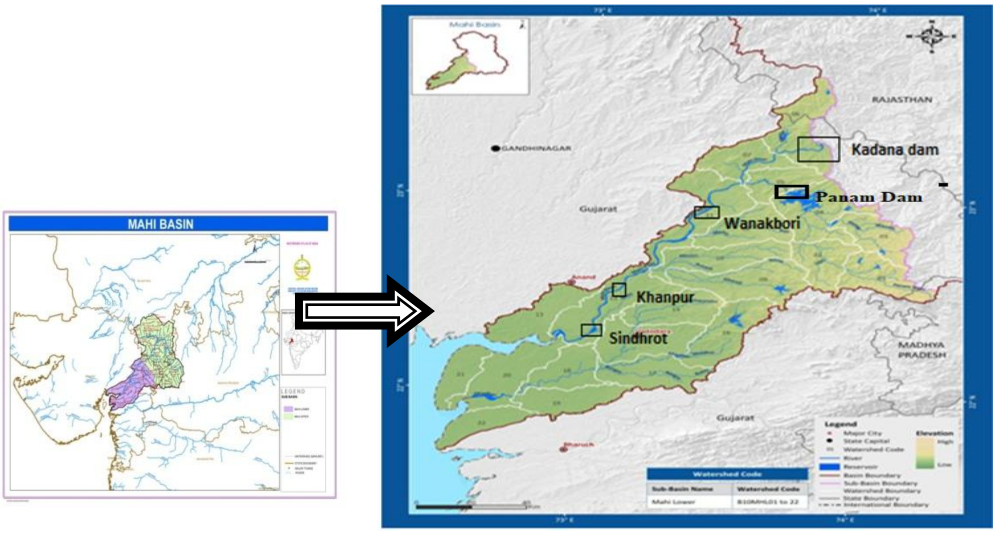

Figure 5 Lower Mahi River from Kadana dam to sea
(Source: www.india-wris.nrsc.gov.in)

IV. GEOMETRIC AND HYDROLIC DATA

The Channel geometry, boundary conditions and channel resistance are required for conducting flow simulation through HEC-RAS. River cross section data are extracted from DEM (USGS SRTM 30m resolution) with help of HEC-GeoRAS in Arc-GIS which has been imported in HEC-RAS model. In study reach 249 numbers of cross sections are taken. The cross-section data approximate at 980 meter intervals from Kadana dam to Gulf of Khambhat extending over a length of 236 km, from which length of river Kadana to Wanakbori and Wanakbori to Sindhrot are around 72.55km and 92.32km respectively. Length of Panam River from Panam Dam to Mahi river is around 21.77km.. Discharge data are collected from Kadana Reservoir Project at Diwda Colony and Panam Irrigation Circle at Godhra. Wanakbori and Sindhrot Weir data were collected from Mahi Right Bank Canal Project and Vadodara Irrigation Project respectively. Khanpur gauging site used for calibration and validation of the Project. Yearly peak discharge and water surface elevation data collected from India Waris. Crest width of Wanakbori Weir and Sindhrot Weir are 4.2m and 8.5m respectively. River cross section derived from DEM (USGS SRTM 30m resolution) with help of HEC-GeoRAS in Arc-GIS then it extracted in HEC-RAS model.

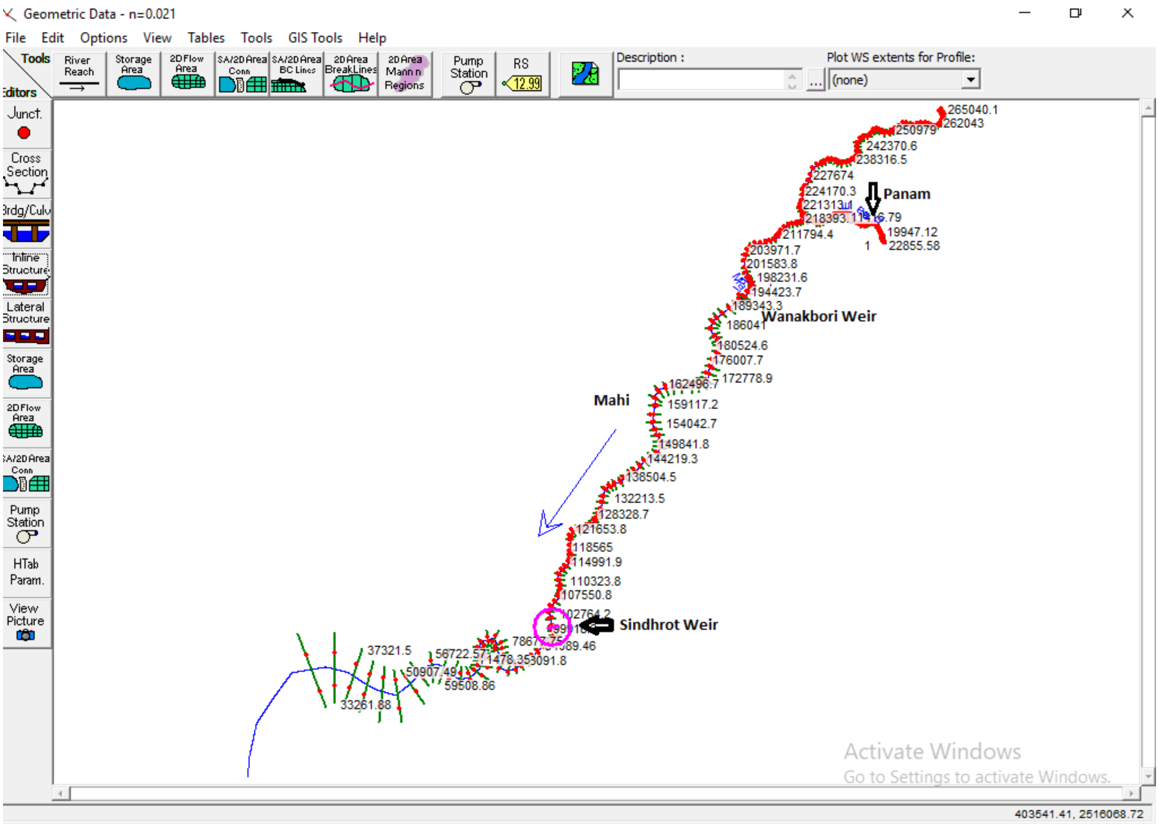

Figure 6: Plan of lower Mahi River in HEC-RAS

V. CALIBRATION AND SIMULATION OF MODEL FOR DIFFERENT VALUE OF MANNING'S "n"

The data pertaining to the floods for years 2001 and 2003 have been used for calibration of Manning's roughness coefficient "*n*". In the present study, effort has been made to calibrate Manning's roughness coefficient for single value using aforesaid data and subsequently, different values of "*n*" have been used to justify their adequacy for simulation of flood in the study reach along the channel.
HEC-RAS model for lower Mahi basin simulated for water surface elevation for different manning's 'n' value for flood year of 2005, 2006, 2007 and 2011 by steady flow analysis. Simulated water surface elevation compared with Wanakbori Weir, Khanpur gauging site and Sindharot Weir.
Root Mean Square Error (RMSE) has been used for comparison of observed and simulated water surface elevation.

$$RMSE = \sqrt{\frac{\sum_{i}^{n}(W_o - W_s)^2}{n}}$$

Where w_o is observed water surface elevation, w_s is simulated water surface elevation and n is total number of reference data point.

VI. PERFORMANCE OF MODEL

In the above context, it shall be pertinent to mention that the Manning's "*n*" value as detailed by Chow [4] lies between 0.025 to 0.035 for flood plains. In simulation of steady flow analysis year of 2005, 2006, 2007 and 2011 are used, from which comparison of 2005 and 2011 flood year shown in following table2.

Table1. Channel Roughness value

Location for "n" value	Manning's "n" value		
	Case 1	Case 2	Case 3
Kadana Dam to Wanakbori	0.026	0.025	0.028
Wanakbori to Khanpur	0.03	0.033	0.035
Khanpur to Sindhrot	0.025	0.027	0.03

Table2. Comparison of water level (flood Year 2005 and 2007)

			Manning's 'n' value		
			Case 1	Case 2	Case 3
Year	Location	Computed water level (m)	Observed water level (m)	Observed water level (m)	Observed water level (m)
2005	Wanakbori	62.19	62.20	62.21	62.33
	khanpur	19.02	18.87	19.06	19.34
	Singhrot	11.65	11.31	11.66	11.68
	RMSE		0.21463	0.02645	0.2024
2011	Wanakbori	63.71951	62.61	62.80	62.93
	khanpur	21.235	19.49	19.70	20
	Singhrot	13.50	12.01	12.40	12.39
	RMSE		1.2599	1.2126	1.0651

The simulated and observed stages at Wanakbori Weir, at Khanpur Gauging site and at Sindhrot Weir for flood year 2005 and 2011 for manning's value according to case2 (Table1) are compared in Fig. 7.

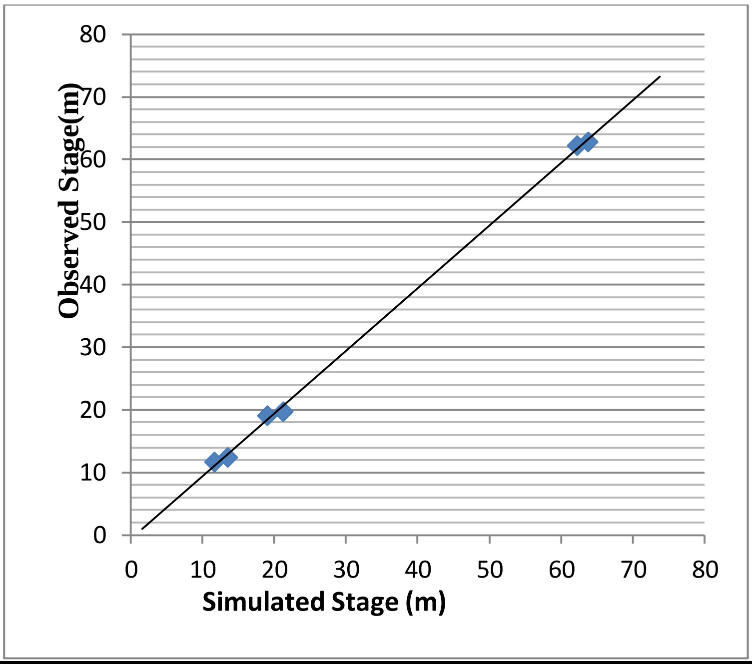

Figure 7: simulated stages Comparison

From Fig. 7, it is evident that the calibrated HEC-RAS model performs well under the steady peak discharge of flow events 2005 and 2011.

VII. CONCLUSION

Channel roughness is a sensitive parameter in development of hydraulic model for flood forecasting and flood inundation mapping. Topographic assessment of river bed features and simulation of past floods of year 2001 and 2003 for multiple value of manning's roughness coefficient, it become evident that different manning's coefficients are required for lower Mahi river simulation of flood. The most effective manning's roughness coefficient calibrated on flood data of the years 2001 and 2003 and validate on flood data of the year 2005, 2006, 2007 and 2011. Further, simulation of flood model for multiple values of manning's roughness coefficient along the river reach has revealed that a value n=0.028 for Panam river and Kadana dam to sea **.**Close agreement have been arrived between simulated and observed flows for Khanpur Gauging site and Wanakbori Weir. Based on river bed condition manning's roughness coefficient according to case2 (Table1) may yield best result for flood forecasting and flood plain mapping.

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