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The Effect of Base Map Scale on the Accuracy of Floodplain Zoning Using GIS

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Abstract: The present study examines the effect of base map scale on the accuracy of floodplain zoning using hydraulic simulation and GIS. The study area was the Bahookalat River located in the southeast of Sistan and Baluchistan Province. The river has a mild sloping and stretches over mountainous and plain terrains. The errors due to map scales are determined through floodplain zoning over various return periods using base maps with scales of 1/1000 (field surveying) and 1/25000 (topographic). In the present study, the Arcview environment was used for GIS analyses and the HEC-RAS software was used for hydraulic simulation. Hydrometric data and water level values were used to calibrate the hydraulic simulation model and the accurate Manning coefficient was estimated. The floodplain zone for various return periods and on the basis of the above base maps for different terrains have been determined. The analysis of the results was accomplished using relative error index and normalized floodplain zone. Comparison of overall and average relative errors for mountainous and plain terrains showed that the errors in these terrains were almost the same as those in the Bahookalatr River ranging over 19 to 35% for different return periods. The relative error showed a higher sensitivity within the dominant discharge but in mountainous terrains it showed a declining trend for floods with return periods of more than 10 years. In the case of return periods of more than 100 years, the relative error was lower for mountainous terrains than that for plain terrains.

Key words: Flood zoning, base map, GIS, Sistan and Balouchistan, hydraulic simulation

INTRODUCTION

Floodplain zoning is a non-structural method of alleviating flood damages. GIS is a tool that can be employed in developing floodplain zoning maps. The accuracy of these maps is affected by such basic data as hydraulic and hydrological data, base maps and computational methods employed.

A number of researchers have in recent years directed their attention to the effect of base map scale on the accuracy with which basin physiographic parameters are determined. Investigation of the base maps required for determining the physiographic parameters in Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) and Center for Research in Water Resources (CRWR-PREPRO) softwares showed that cell dimensions of less than 30 meters for level areas with slopes of below 0.0008 cause considerable errors in determining basin boundaries[1]. The study showed that base maps with a scale of 1/25000 used in the development of DEM (Digital Evaluation Model) with cell dimensions of 90 meters lead to gross errors and cannot be used in determining physiographic parameters. However, in addition to determining physiographic parameters, GIS has also been employed in determining geometrical characteristics of hydraulic sections.

In another study, the possibility for the application of two models of earth features DEM and Triangular Irregular Network (TIN) as the sources of river cross section data was investigated to obtain a horizontal error of 5-15 m and a vertical error of 0-20 m[2]. The study by Bates and Deroo[3] showed that a combination of hydraulic computations and raster-based models for determining floodplain inundation will contain an error of 0.15 to 0.37%. These researchers also recommended that it would be better to use raster-based data at higher magnifications when used in determining floodplain inundation.

Mason and Maidment[4] studied the accuracy of base maps and found out that the use of DEM at a scale of 1/250000 as related to a river network at a scale of 1/100000 would not yield satisfactory results in identifying basin hydrologic parameters and basin boundaries. Rather, they maintain that the use of DEM with a scale of 1/24000 and a river network at a scale of 1/100000 will provide better results even in the absence any further investigations.

As river floodplain zones in plain terrains cover considerable areas and with regard to the fact that the largest scale of topographic maps in the process of preparation by the State Mapping Organization is 1/25000, it is necessary to examine the error expected to result from

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the use of these maps in floodplain zoning. The present study aims to examine the error resulting from these maps while it also considers the variations in error ranges against floodplain inundation return periods in mountainous and plain terrains of rivers. For this purpose, part of the course of the Bahookalat River in Sistan and Balouchistan Province is also simulated.

MATERIALS AND METHODS

The study area is the Bahookalat River in the southeast of Sistan and Baluchistan Province. It extends from 61° and 15' to 61° and 30' longitudes and from 25° and 30' to 25° and 45' latitudes (Fig. 1). The three main tributaries of the Bahookalat River are the Bahoo, the Kajoo and the Gargaroo plus a number of other minor tributaries. It receives surface river flows of the Naalit, the Aman and the Sohli in the middle of the basin on its course southward. The slope of the river within the terrain under study is 0.0037%, which indicates a flat region. The Bahookalat Hydrometric Station has been in operation collecting statistical data since 1967. The recorded flood events obtained from hydrological analyses of this station are reported in Table 1. Other data used in this study include: numerical maps on a scale of 1/25000 published by the State Mapping Organization, 15 cross-sections of the river with a scale of 1/1000 and Landsat TM images. The TIN elevation model of the area was used for the morphological investigation of the study terrain. Field investigations and the data in Fig. 2 indicate that from a morphological point of view, the cross-sections 1, 2, 3, 7, 8 and 9 are located within the mountainous terrain of the river while other sections are located within its plain terrain. We will examine the relative error due to using numerical data of 1/25000 as compared to those due to data of 1/1000 over both mountainous and plain terrains. The HEC-RAS model will be used in the hydraulic simulation while for GIS analyses, the Arc-View software will be used.

HEC-RAS and Arcview were used for hydraulic simulation and RS and GIS analyses, respectively. Fig. 1 shows the computation and simulation processes in the present study. Three major stages are recognizable in the execution of this study:

- The preliminary stage and calibration of the hydraulic model;
- Hydraulic simulation stage; and
- The stage of floodplain inundation zoning and the identification of errors.

The preliminary stage and calibration of the hydraulic model: In this stage, the main course of the river and the boundaries of its right and left banks were determined using satellite images and Extension Geo-RAS in the Arcview environment. Then, using Extension Cad Reader, the location of ground cross-sections on the TIN elevation model was determined and different land uses were identified with the help of satellite images. The initial values for Manning coefficient for different terrains were estimated according to Chow method and the US Geological Organization method. Next, HEC-RAS was calibrated with the help of the existing discharge and flood contour data and the values for Manning coefficient were adjusted (Table 2). Initial estimation based on the empirical methods mentioned above is slightly higher than the calibrated value.

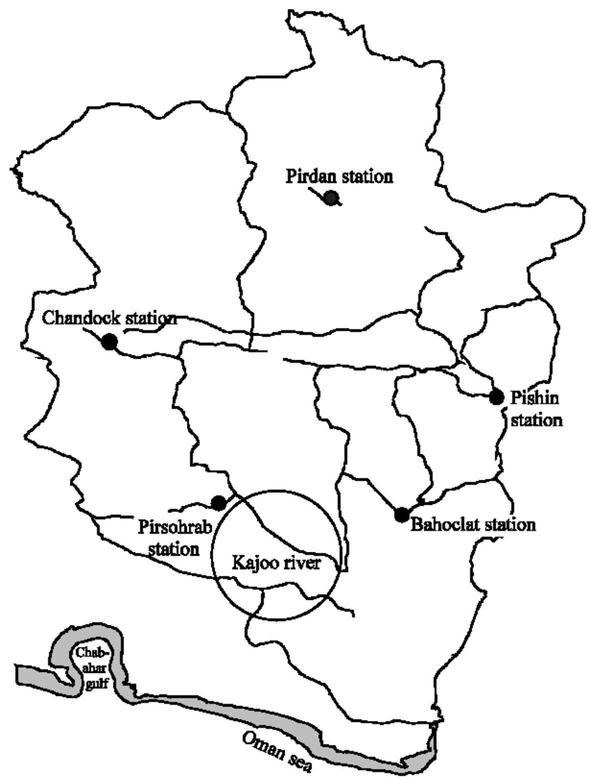

Fig. 1: The study area

Simulation: In this stage, the hydraulic simulation was calibrated for different discharge rates with different return periods (Table 1) and two types of cross sections were determined:

- Ground cross-sections with a scale of 1/1000
- Cross-sections determined by the TIN elevation model in the Arcview environment

The results from these two types of simulation will be used in the next stage as hydraulic

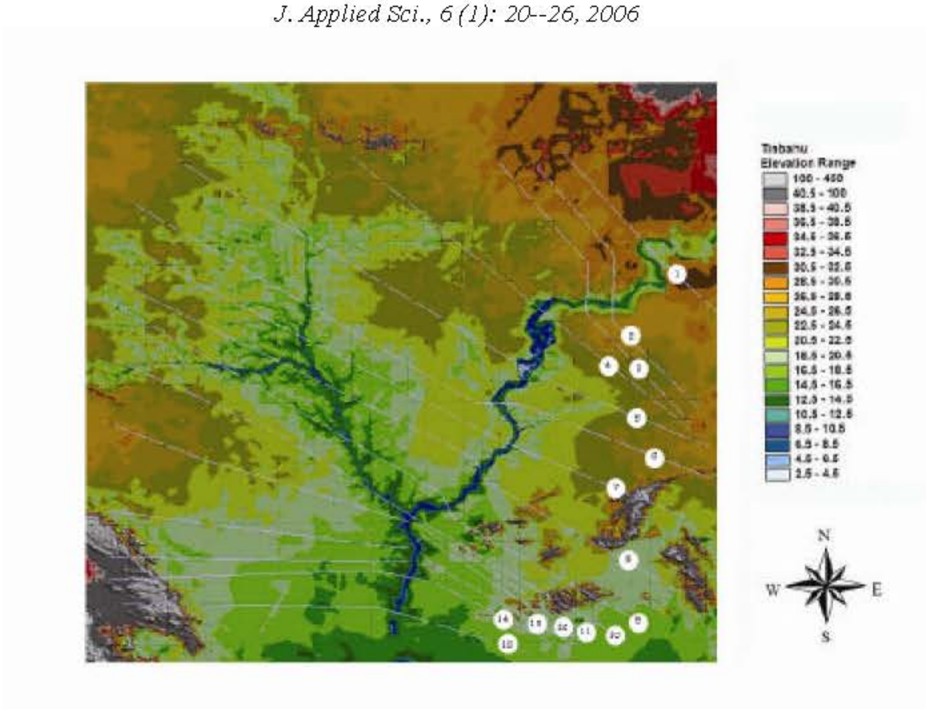

Fig. 2: The TIN elevation model of the study terrain

Table 1: Flood events with different return periods at Hookal at station

Return period	2	2/33	5	10	20	25	50	100	200	500
Discharge $m^3 sec^{-1}$	670	735	1815	3072	4240	4688	5706	6958	8279	965 0

Table 2: Values of Manning coefficient before and after calibration

Description	Discharge $m^3 s^{-1}$	Distribution coefficient obtained from the table	The corrected coefficient distribution	Height resulting from the distribution coefficient of the table	Corrected height of the water level
River calibration					
	11/59	0/0365	0/043	0/52	0/95
	15/6	0/0365	0/05	0/6	1/15
Flood plain calibration					
	496	0/055,0/06,0/04	0/051,5/07, 0/037	5/07	4/38
	1182	0/055,0/06,0/04	0/053, 0/059, 0/038	7/06	6/82
	2847	0/055, 0/06,0/04	0/053,0/06,2,0/044	8/81	11/82

characteristics in both the analyses and floodplain zoning (Fig. 3).

Floodplain zoning and determining the errors: The outputs from the hydraulic model were analyzed in Extension-Geo RAS in the Arc View environment and floodplain zoning was accomplished for each set of analyses to obtain the following maps:

- Floodplain zones for peak flood discharges with return periods of 2, 2.33, 5, 10, 20, 25, 50, 100, 200 and 500 years and on the basis of maps with a scale of 1/1000.
- Floodplain zones for peak flood discharges with return periods of 2, 2.33, 5, 10, 20, 25, 50, 100, 200 and 500 years and on the basis of maps with a scale of 1/25000.

The area of the floodplain zones for each discharge rate, in each terrain and according to each base map was determined using Extension-Xtools.

RESULTS AND DISCUSSION

Relative error index and normalized floodplain zone are defined as follows:

$$En = Ai/Amax$$

$$E = (A0-A1)/A$$

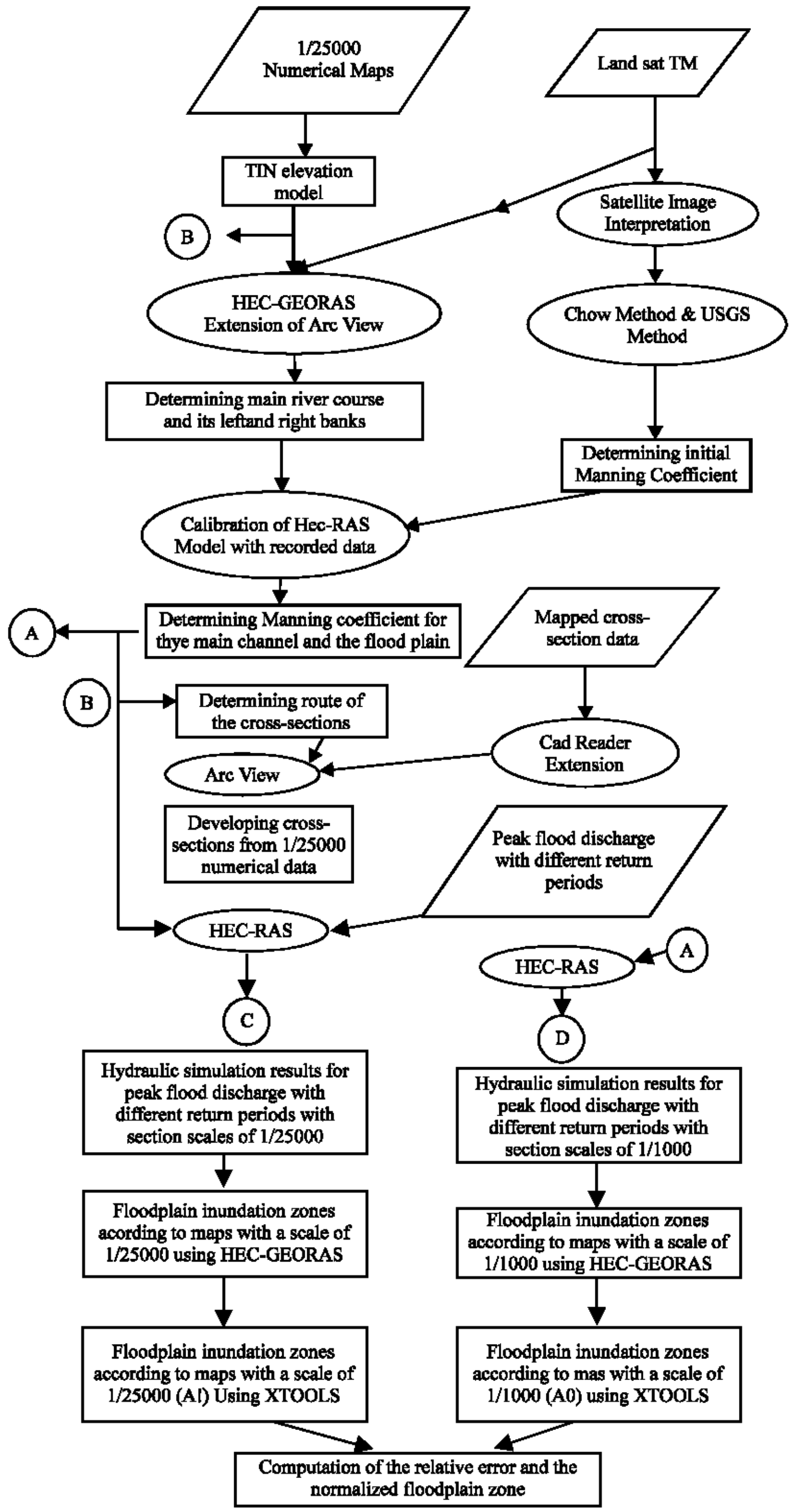

Fig. 3: Schematic view of computation and simulation processes in the present study

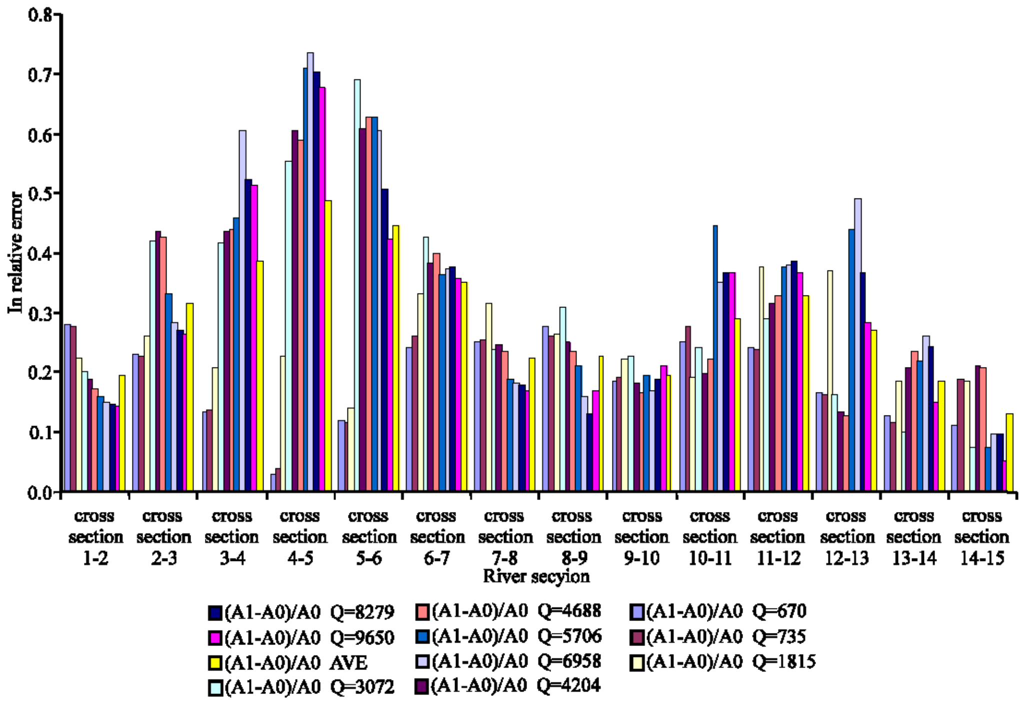

Fig. 4: The variations in relative error I n different terrains for different peak discharges over return periods of 2 to 500 years

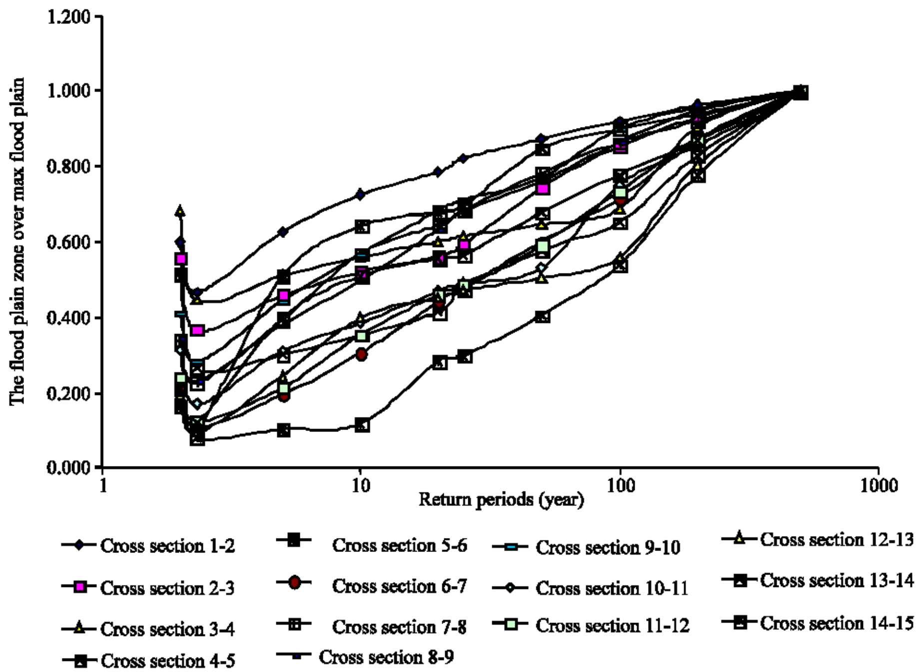

Fig. 5: The variations in the normalized floodplain zone according to map scales of 1/1000

Relative error index and normalized floodplain zone in different terrains: Figure 4 shows the variations in relative error in different terrains for different peak discharges over return periods of 2 to 500 years. The relative error increases from section 1 through 5 and then decreases onwards up to section 10. It resumes its increasing trend from there on to section 13 and decreases again toward the final terrain. The trend in error variation

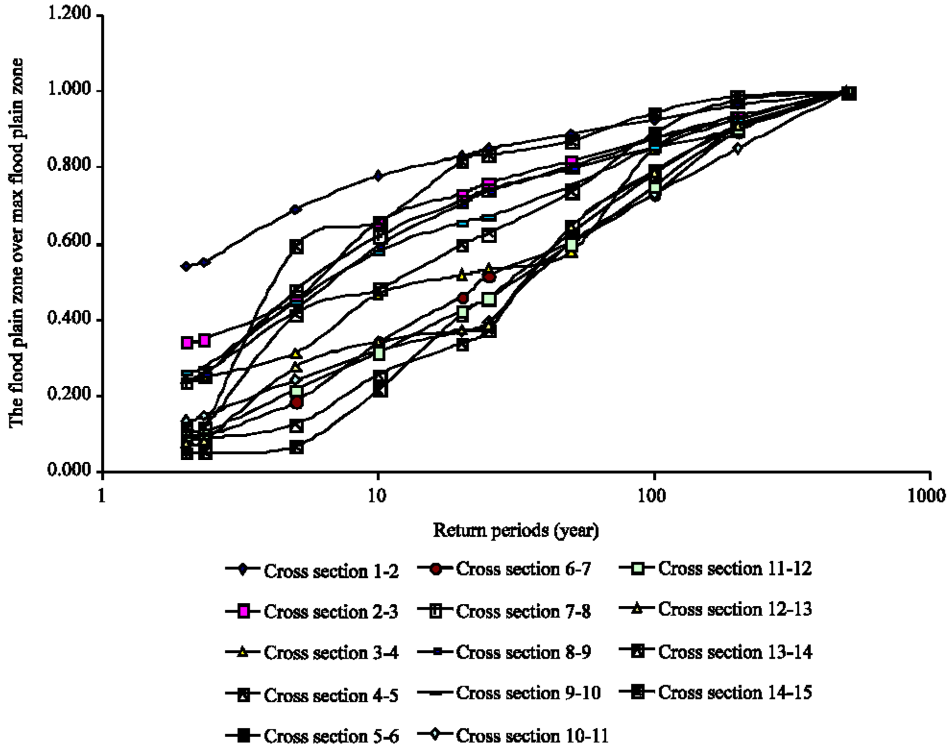

Fig. 6: The variations in the normalized floodplain zone according to map scales of 1/25000

in the mountainous terrains decreases with increased return periods but it has no definite trend in the plain terrains.

Figure 5 and 6 show the variations in the normalized floodplain zone according to map scales of 1/1000 and 1/25000, respectively. Comparison of these two figures indicates that the normalized floodplain zone developed from accurate ground maps always exhibit an increasing trend with increasing discharge and return period. However, when 1/25000 maps are used, they exhibit a decreasing trend for low discharges but an increasing trend for higher (beyond two-year) discharges. This indicates the sensitivity of floodplain zone variations in low return periods.

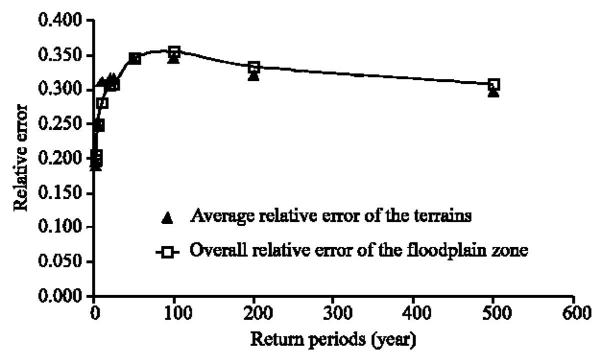

Fig. 7: The comparison of overall relative error of the floodplain zone (all the terrains) with average relative error of the terrains

Comparison of overall relative error of the floodplain zone with average relative error of terrains: Figure 7 shows the comparison of overall relative error of the floodplain zone (all the terrains) with average relative error of the terrains for return periods of 2 to 500 years. This indicates that the overall relative error has no significant difference from the average relative error of the terrains for different return periods but that the relative errors gain an increasing trend for discharges with return periods of 2 to 10 years. In such rivers, the predominant discharge has a return period of 2 to 5 years. Therefore, it can be concluded that the error variation within the dominant discharge is highly sensitive. The average and overall relative errors reach their maximum values for discharges with a return period of 100 years. The relative error for average or overall discharges with return periods of 2 to 100 years ranges over 19 to 35%.

Comparison of relative error in mountainous and plain terrains: Figure 8 is a comparison of relative errors for the mountainous and plain terrains of the Bahookalat River. It indicates that no significant differences can be observed in relative errors up to return periods of up to

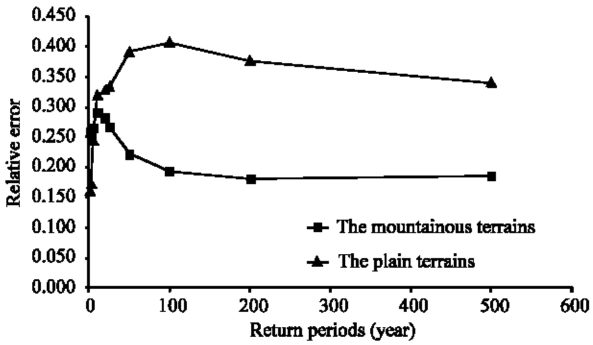

Fig. 8: Comparison of relative errors for the mountainous and plain terrains of the Bahookalat River

10 years in both mountainous and plain terrains. However, for return periods above 10 years, the relative errors in plain terrains maintain their increasing trend while those for mountainous terrains acquire a decreasing trend. Relative errors of mountainous terrains reach their maximum for return periods of 100 years while those of plain terrains reach a certain minimum and become constant onwards for the same return period. It can be concluded, therefore, that using large scale maps with large return periods for mountainous terrains will have a lower relative error than for plain terrains.

CONCLUSIONS

Hydraulic simulation and GIS and RS analyses were used in the present study on the basis of 1/1000 and 1/25000 maps of the Bahookalat River to determine the effect of map scale on the accuracy of floodplain zoning. The following results were obtained:

- The overall relative error of the floodplain zone and the average relative error of different terrains in the Bahhokalat River are almost the same and will range 19 to 35% in case 1/25000 maps are used. The sensitivity of error variation is higher within the dominant discharge.
- The trend in the relative error for mountainous terrains, especially for discharges with return periods of over 10 years, is decreasing and lower errors can be expected when large-scale maps are used for return periods of above 100 years in mountainous terrains.

ACKNOWLEDGMENT

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Symbols

A_0 : Floodplain inundation area on the basis of 1/1000 base map

A_1 : Floodplain inundation area on the basis of 1/25000 base map

A_i : Floodplain area in each terrain and for different return periods

A_{max} : Floodplain area in each terrain and for a return period of 500 years

E : Relative error of the floodplain zone

E_n : Normalized floodplain zone.

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