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ORIGINAL ARTICLE

Determining the Flood zoning based on the Satellite image and roughness coefficient in composite channels (Case study: Nekarood of Mazandaran Province-Iran)

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ABSTRACT
Land use is one of the most important factors affecting the increase of flood plains at margin of streams and cause the discharge to increase with different return period. So, determining the flood plain is important in managing and predicting hydraulic manner of flow. In this research the land use of Neka watershed was determined in GIS and ENVI software using landslide imagery of sensors of ETM+ and IRS1D. Then, roughness coefficient in HEC-RAS software was used to simulate the flood plain of composite channels with different return periods and two statuses with and without land use parameter. Results showed that the depth of water and the area of flood cover increased 14.60% and there was significant relationship with land use change. Finally, with integrating the achieved data from satellite imagery and flood plain simulation software are the suitable tools in determining the flood plain area and flood awareness system.
Keywords: Composite channels, Flood, Land use, Nekaroo

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INTRODUCTION

The reducing operation of flood risk are defined as the activities which are done to reduce damage of flood in region of flood plain and usually the socio-economic considerations and technical capacity in approach selection are the suitable method to control flood. The map of flood plain is used in studying flood management [10, 23, 30, 15, 16]. Nowadays, these maps are one of the basic and important data in studying construction plans in the world and must be investigated by organizations before the investment and operation of construction plans [4]. Therefore, the determination of the flood plain by different softwares especially HEC-RAS and its extension in GIS is developing daily for different streams and flood plain in the world. HEC-RAS software integrating with GIS can use the different return periods to simulate the water level in natural and artificial channels and the effects of stream buildings such as bridge, culvert to prepare three dimensional of flood plain [2, 9]. The determination of the land use and its role on flood area has been considered in recent decades and the managers attempt to use different environmental maps beside the simulation to prevent flood [25]. In recent years the cities at the margin of stream was developed and neglecting to environmental potential and unsuitable usage of sources cause the damage to mentioned community [27] and this is necessary for managing flood plain [19]. Many studies was conducted about the determining land use and land coverage and the satellite data such as SPOT, ETM and IRS was used to produce these maps by experts [1]. Oyli (2010) and Daneshfaraz et al. (2010) achieved to appropriate data about calculation of maximum discharge of flood with different return period and simulation by HEC-RAS [8, 23]. Results showed that to prevent flood occurrence and reduction of its consequences and damage several comments has been suggested. Kotrolois and Tesanis [18] in their research reported that empirical indices used in flood measurement and lack of simulation for stream direction are the factors which cause the maximum discharge and flood volume not estimated precision.

Hou and Yomitsou (2011) compared the flood damage by HEC-RAS software before and after the simulation to determine the stream right of way and the reduction of the volume of field survey through satellite image were the most important findings of them [17]. So, in this research the flood plain was simulated using HEC-RAS software and extension of HEC-Geo-RAS as well as map of Neka stream in Auto CAD shape with scale of 1:1000 and taking 2004 elevation points at 2 kilometer distance of stream. Moreover, the role of satellite imagery in determining roughness coefficient in composite sections was determined.

MATERIAL AND METHODS

The watershed of Neka stream is one of the Caspian Sea watersheds and is located in eastern longitude from 53° 17′ to 54° 44′ and northern latitude from 36° 28′ to 36° 42′. This watershed from northern aspect is limited to Gharehsoo and small watersheds of Gorgan gulf, from western aspect is contacted to Tejen watershed and from east is contacted to Gharehsoo watershed in Gorgan and from southern is contacted to Tejen watershed and watersheds of Semnan province. The area of this watershed is equal to 1922 km^2 and its surrounding is 406 kilometer [12]. The elevation of the highest point in the watershed was 3500 meter (elevations of Shahkooh) and the elevation of the lowest point in external region (Ablou station) was 50 meter and in connection to Caspian Sea it reaches to -20 meter. 61% of the watershed is located in Mazandaran province and 39% is located in Golestan province. The Gorgan plain is located between two main fracture of Alborz and Mazandaran-Caspian with have completed row of sedimentary, igneous and metamorphosis stones with thickness of 2.5 km. the direction and general aspect of the structures in region was north western and south eastern. Figure 1 shows the geographical position of the study area.

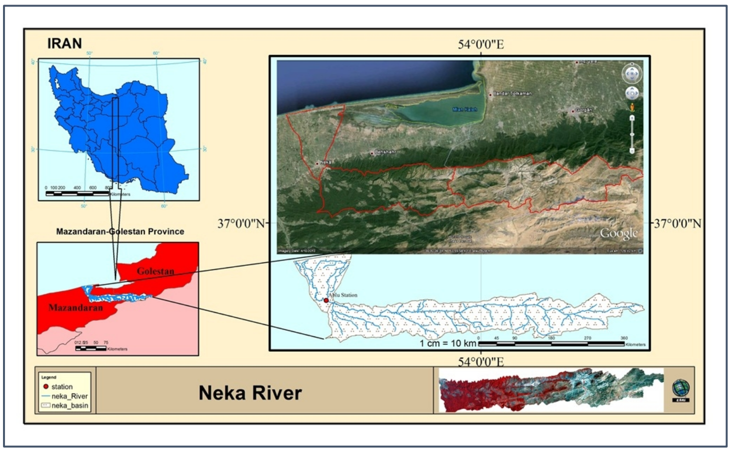

Fig. 1. Study area

SPSS, EasyFit and SMADA software were used to investigate the probability of discharge with return periods of 2, 5, 10, 25, 50, 100 and 200 years [11] and the predicted results was compared to statistics of ground stations (Table 1) in study area (Ablou station). The correlation coefficient of 93% in three softwares was observed in Pearson statistic distribution. Pearson type 3 was used to insert maximum momentary discharge to model (Figure 2).

Table 1: Characteristics of hydrometric station

Station	Stream	Code	Elevation (meter)	X	Y
Ablou	Neka	150321025	50 at sea level	53°41′17′′	54°36′38′′

Zoning Procedure

The benefits of the Arc GIS in hydraulic modeling are its potential to collect accurate topographic data for sections from digital and elevation model. Pistochi and Mazoli (2002) predicted the effects of flood in watershed of Romagna stream in Italy using HEC-RAS and ARC View software [24]. This research used these software and methods and had field survey similar to other study.

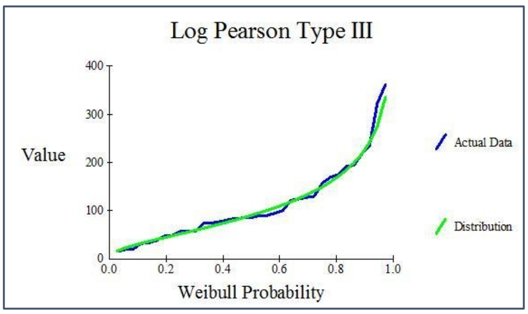

Fig. 2: Correlation coefficient of data using Pearson Type 3

The data which HEC-GeoRAS is saved in internal file are layer of central line of flow, Stream coast, cross section, boundaries of stream and flood plain at right and left of stream. This program was used to analysis of the results of calculation of the flow hydraulic with HEC-RAS [31]. The following stages were done in GIS to provide digital data after simulation and inserting data to HES-RAS software [21]:

1. Providing plan and cross sections of stream network [11] with maps of regional water company [20].
2. Evaluation of the Maning roughness coefficient
3. Determining boundary condition at upwards and downwards of the stream
4. Program operation
5. Model verification
6. Flood plain

In this research the field survey around the stream direction was done based on the table of Chow and then the roughness coefficients was determined through following equations to prepare best simulation for stream.

Chezy Equation

More than 240 years has been passed the first researches on the roughness coefficient and most of them were the empirical equations and curve fitness on measurement data of discharge [5, 6]. Chezy recommended an equation in 1768 which had general application in description of relationship between the velocity and flow properties [7]:

$$V = C\sqrt{RS} \qquad (1)$$

Where R is termed the hydraulic radius of the channel (m), S is slope of the river determined by measuring the change in elevation over a measured distance. C is the Chezy parameter (m S^{-2}).

Weisbach equation

Weisbach equation is a phenomenological equation, which relates the head loss or pressure loss due to friction along a given length of pipe to the average velocity of the fluid flow [7].

$$h_f = f \times \frac{L}{D} \times \frac{V^2}{2g} \qquad (2)$$

h_f is the head loss due to friction (SI units: m); L is the length of the pipe (m); D is the hydraulic diameter of the pipe (for a pipe of circular section, this equals the internal diameter of the pipe) (m); V is the average velocity of the fluid flow, equal to the volumetric flow rate per unit cross-sectional wetted area (m/s); g is the local acceleration due to gravity (m/s^2); f_D is a dimensionless coefficient called the Darcy friction factor. It can be found from a Moody diagram or more precisely by solving the Modified Colebrook equation. Do not confuse this with the Fanning Friction factor, f.

Manning Equation

The Manning formula is an empirical formula estimating the average velocity of a liquid flowing in a conduit that does not completely enclose the liquid**:**

$$V = \frac{k}{n} R_h^{\frac{2}{3}} \times S^{\frac{1}{2}} \qquad (3)$$

Where V is the cross-sectional average velocity (L/T; ft/s, m/s); k is a conversion factor of ($L^{1/3}$/T), 1 $m^{1/3}$/s for SI, or 1.4859 $ft^{1/3}$/s U.S. customary units, if required. (Note: $(1\ m)^{1/3}/s = (3.2808399\ ft)^{1/3}/s = 1.4859\ ft^{1/3}/s$); n is the Gauckler–Manning coefficient, it is unitless; R_h is the hydraulic radius (L; ft, m); S is the slope of the water surface or the linear hydraulic head loss (L/L) ($S = h_f/L$).

The coefficient of without dimension velocity

The velocity coefficient is defined as (Assistant of scheduling, 2003):

$$\Phi = \frac{V}{U_s} \qquad (4)$$

Where U_s fractional velocity and equal to $\sqrt{gRS}$(m/s). V is the velocity (m/s) and Φ is the velocity coefficient and is without dimension. Finally the achieved data was compared to Cowan method table. The Cowan method was later selected as the standard method by the soil conservation and the geology organization of USA. Manning coefficient is considered as the sum of factors and used the composite of the equations and empirical tables to determine the Manning coefficient for stream. This method can appropriately estimate the Manning coefficient for the composite sections and is important and had more precision compared to Chow table.

Cowan method

In this method the general Manning coefficient in main channels and flood plain is calculated as follow [3] which have tables [33]:

$$n = (n_b + n_1 + n_2 + n_3 + n_4)m \quad (5)$$

Where:

n_b =a base value of *n* for a straight, uniform, smooth channel in natural materials
n_1 =a correction factor for the effect of surface irregularities
n_2 = a value for variations in shape and size of the channel cross section,
n_3 =a value for obstructions
n_4 =a value for vegetation and flow conditions
m=a correction factor for meandering of the channel

Digital elevation model and satellite imagery

The determination of the cross section in direction of stream is as required data to evaluate hydraulic properties of stream flow. This file includes geographical properties required to calculate HEC-RAS. Geographical information of sections was extracted from digital terrain model in framework of three-angulated irregular network. Maps with scale of 1:1000 were used to provide three-angulated irregular network. Figure 3 shows the preparation of the GIS and HEC-RAS layers.

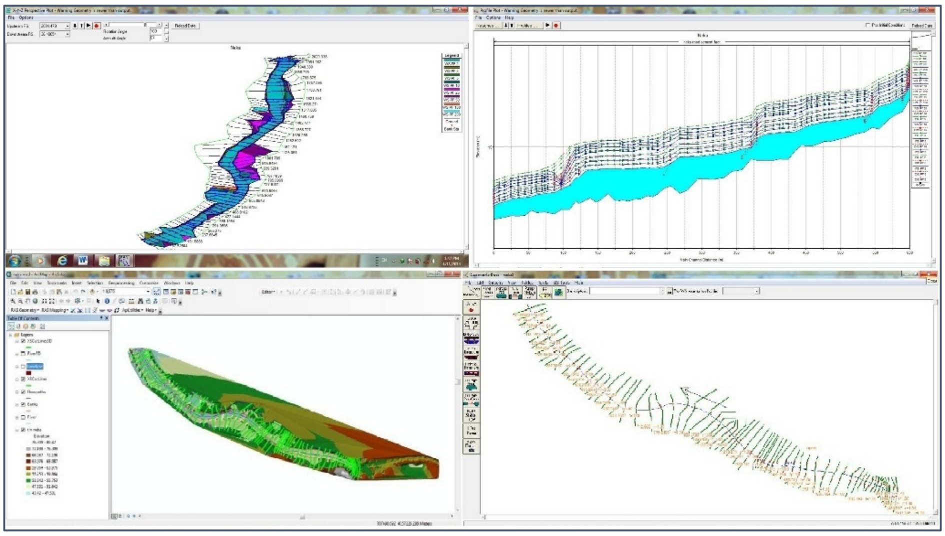

Fig. 3: The stages and the methods of layer processing in GIS and simulation process in HEC-RAS

Two satellite images ETM+2000 and IRS-1D 2012 was used to investigate the land use changes. The stages of pre-processing such as atmospheric, elevation and geometric corrections was done in user team of ENVI and the preparing GIS layer and processing in HEC-geo-RAS to inserting in HEC-RAS software was done in GIS group. Also, the field survey was done to determine required roughness coefficients in HES-RAS software and calibration of required discharges values with return periods of 2, 5, 10, 25, 50, 100 and 200 year. The Ablou stations in the region was used to calibrate and evaluate the roughness coefficient and observed discharges. The Maximum likelihood with 132 training region was used to classify the 5 land use in watershed including agricultural lands, forest, city, rangeland and unusable area. This method is the most precision method to classify basic pixel [1]. Then the accuracy of the evaluation was controlled through operational team in the field and the layers were sent to GIS to apply in HEC-geoRAS to calculate flood plain. Finally the based on the criteria of general accuracy, the Kapa coefficient, user precision, precision of the producer, the precision of the image classification was calculate and the digital elevation of flood and the precision of the application of roughness coefficient in composite sections. All stations can be observed in Figure 2.

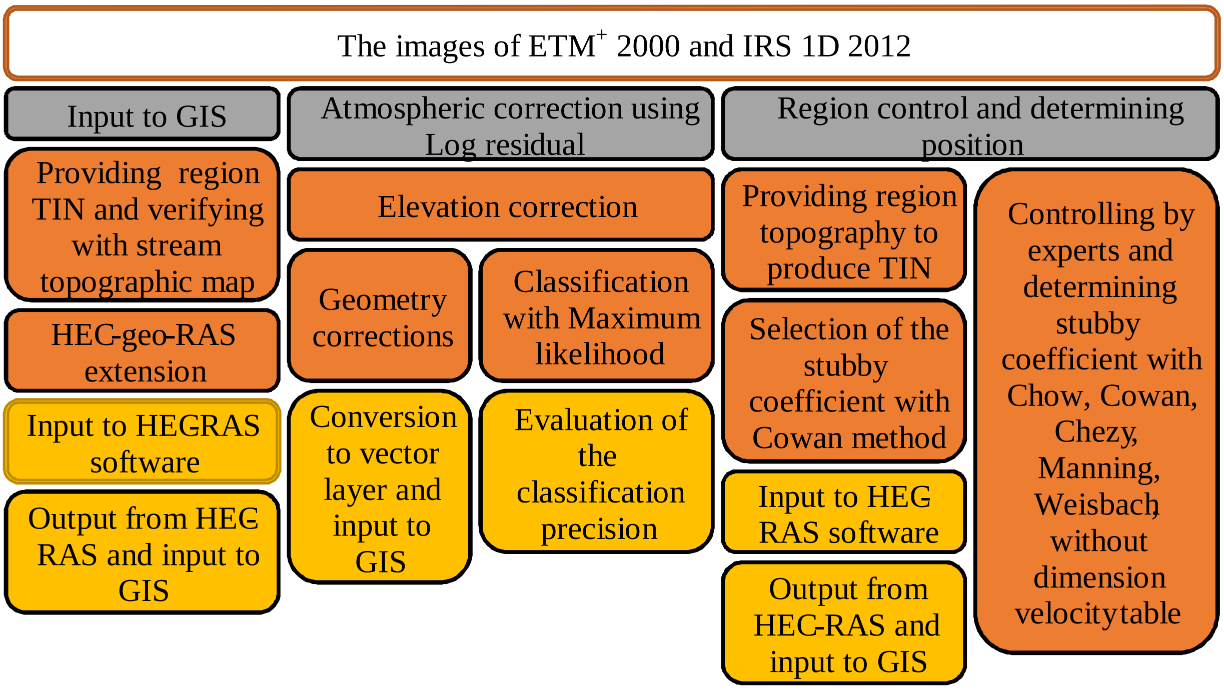

Fig. 3. All of the stages and the method of determining of land use and flood plain

RESULTS AND DISCUSSION

Results showed that the general precision of images was acceptable (Table 2) Then by using coarseness coefficients equations in composite water channel, flood area with different return periods was simulated by HEC-RAS software, in two states of existence or not existence of lands use change parameter. There was significant relationship between flood area and intensity with land use change.

Table 2: General result of classification precision in IRS images (2012) and Landsat (2000)

Row	Image	Image (year)	General precision (%)	KAPA coefficient
1	Landsat	2000	90.8121	0.8470
2	IRS	2012	94.0027	0.8908

The results of image and user precision were assessed to investigate the precision rate in determining of land use (Table 3) and the percentage of each land use was determined (Table 4).

Table 3: The precision of image and user in the images of IRS (2012) and Landsat (2000).

IRS			Landsat		
Precision of user (%)	Precision of image	Class	Precision of user (%)	Precision of image	Class
76.56	73.67	Agriculture	86.51	80.66	Agriculture
88.50	89.56	Unusable	86.23	99.76	Unusable
65.67	69.56	Rangeland	89.85	67.75	Rangeland
96.56	90.07	Forest	95.85	99.07	Forest
82.45	69.45	City	80.50	78.98	City

Table 4: The procedure of land use change in the images of IRS (2012) and Landsat (2000)

Difference of variations in percent(+increasing) and (-reducing)	IRS (2012)		Landsat (2000)	
	Sum of class (%)	Class	Sum of class (%)	Class
+8.39	14.15	Agriculture	5.76	Agriculture
+3.14	43.62	Unusable	40.48	Unusable
-1.44	5.50	Rangeland	6.94	Rangeland
-13.24	31.35	Forest	44.59	Forest
+3.15	5.38	City	2.23	City

Results of the map of land use in GIS was related to years of 2000 and 2012 and shows that the agricultural lands was 8.39%, unusable lands was 3.14%, the city 3.15% increased and the forests 13.24% and the rangeland 1.44% decreased. Among different equations the Cowan equation has the most precision (98%) in calculation of discharge with return periods (Table 5).

Table 5: Discharge of flood from coefficient of equations in cubic meter per second

Estimation method	Chow	Cowan	Manning	Without dimension velocity	Chezy	Weisbach	Estimated discharge
Precision(%)	R^2=0.92	R^2=0.98	R^2=0.96	R^2=0.91	R^2=0.92	R^2=0.93	R^2=0.100
2	60	98.2	40.01	136.3	65.3	57.4	90.8
5	52	175.2	192.3	134.4	124.2	193.5	167.3
10	201.6	218.3	202.1	173.3	169.5	202.4	222.1
25	267.4	281.5	260.2	203.5	184.3	256.4	293.2
50	399.1	333.3	331.2	294.4	199.4	303.9	346.8
100	400.7	390.9	375.4	333.3	202.4	306.2	400.4
200	440.5	438.2	402.6	397.4	245.6	386.4	454.2

According to the results of above Table, the Cowan method shows the maximum correlation at probability level of 98% in SPSS software as compared to other equations.
After input of roughness coefficients the plod plain was determined in stream analysis software with return periods of 2, 5, 10, 25, 50, 100 and 200 years. The maximum of these return periods didn't increase because it causes the error increasing. After inserting the file of land use change to GIS it was concluded that if these values are used the flood level shows increasing and/or increasing status in some points as compared to condition which the land use change are not used and only the roughness coefficient was is considered.

Table 6: Flood plain area in 2000 and 2012

Return period	Flood area (2000)	Flood area (2012)
2 year	604 m^2	705 m^2
5 year	685 m^2	791 m^2
10 year	725 m^2	819 m^2
25 year	765 m^2	854 m^2
50 year	791 m^2	894 m^2
100 year	812 m^2	926 m^2
200 year	830 m^2	956 m^2

According to these results the effects of each one on flood plain was separately investigated in HEC-geo-RAS software and it was observed that the land use dramatically changed from 2000 to 2012 (Table 6). Table 7 shows the variation of the flood areas. Results showed that the depth of water and the area of flood cover increased 14.60% and there was significant relationship with land use change. Figure 4 shows the flood zoning in first and last return period. Results shows that 101 m^2 of region in year of 2012 with 2-year return period, 106m^2 of region with 5-year return period, 94m^2 of region with 10-year return period, 89m^2 of region with 25-year return period, 103m^2 of region with 50-year return period, 114m^2 of region with 100-year return period and 126m^2 of region with 200-year return period will more go under the water as compared to year of 2000. Findings of this research shows that the most of the land use change was done in direction of reducing forest area and converting usable area to unusable regions.

Table 7: Conversion percentage and the mean of flood change

Return period	Conversion (%)
2	**16.72**
5	**15.47**
10	**12.97**
25	**11.63**
50	**13.02**
100	**14.04**
200	**15.18**
Mean of conversion (%)	**14.60**

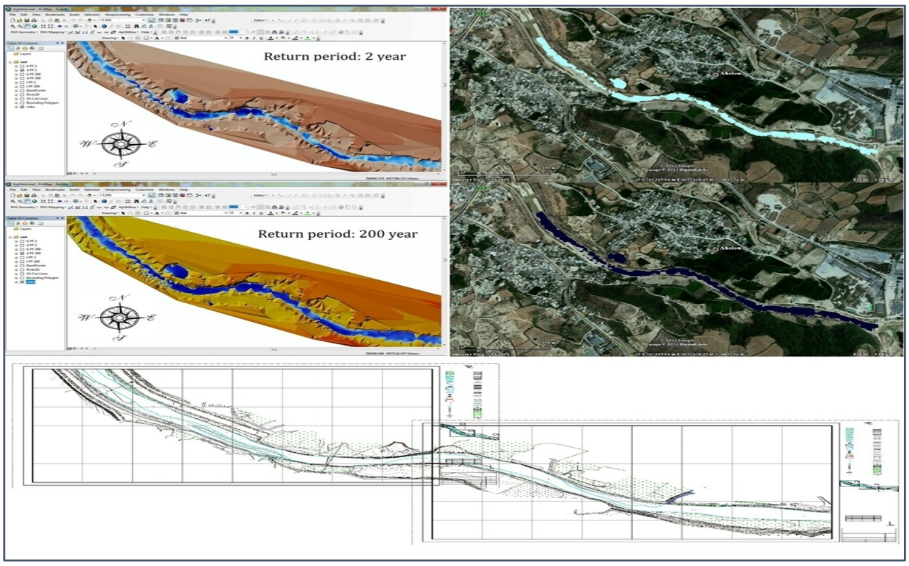

Fig. 4: flood zoning with return period of 2 and 200 year using land use change (left) and without land use (Right)

CONCLUSIONS

Flood zoning in Nekarood showed that the field survey had ever more confidence and precision. With use of the satellite image it can be possible to reduce the field survey in flood zoning [28]. But, the prediction of the flood is one of the problems which had not been yet solved completely ant it is required to field survey and use of the softwares such as HEC-RAS. According to our findings the researches about flood zoning didn't consider to land use and they had low precision and they didn't show the properties of plod plain. With integrating satellite image and simulation softwares of flood plain it is possible to determine the strategic aims especially determining risk zone [29] and/or financial scheduling and providing flood insurance when critical phenomena is occurred[26]. This map with overlapping flood area and susceptible area with different return period can do prediction activities and determination of stream boundary.

Field survey has defects such as: unsuitable temporal and spatial scale in determining stream right of way, statistical shortage or defects in watersheds which cause to unsuitable calibration and conversion coefficient of rainfall to runoff [22]. So, it is recommended that the flood zoning is done by determining stream right of way [13], insurances of insurance company, return periods of flood, structure age and many of the alarm system after integrating the results of this research with satellite image. The results of this research confirms the findings of Sarhadi et al. (2012) to do basic and important application in operating continues management to protect life and property of people [28]. Also it is recommended that the updated technologies of the world are used to prepare plans of urbanization adjacent of Neka stream.

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