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Technical Evaluation of the Performance of River Groynes Installed in Sezar and Kashkan Rivers, Lorestan, Iran

Farzad Mohammadi*[1], Nazanin Mohammadi[2]

[1] Department of Water Sciences and Engineering, Shoushtar Branch, Islamic Azad University, Shoushtar, Iran
[2] Department of Architecture and Urbanism, Shahid Beheshti University, Tehran, Iran

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ABSTRACT

In this paper we aim to investigate the performance of River Groynes that have installed near the banks of Kashkan and Sezar rivers in Lorestan province of Iran. For this purpose we performed field studies, and collected information about these rivers. To predict depth of scour at groynes we used equations proposed by Khosla (1953), Garde et al (1961), Niel (1973), Zaghloul(1983), Ahmad (1953), Gill (1972) and Liu (1961).Our results showed that

The groyne constructed on both rivers had performed their performance properly in spite of their design and application. The spaces between groynes and their length had been determined suitably in Sezar river, but it was not suitable in Kashkan river. Using poor materials, poor pier foundation, and improper lateral wall angle were their negative aspects

Considering the armoring phenomenon, the river bed has reached a proper balance, and therefore, river protection and thus, erosion between two groynes was conducted properly.

KEYWORDS: Kashkan River, Sezar River, river groyne, performance, scour depth, flow pattern, groyne-fields

1. INTRODUCTION

Rivers are continuously changing under the influence of various factors including geology and topology of the region, properties of alluvial deposits in floodplain, hydrologic features of the basin, hydraulic condition of the flow, and human exploitations. Variability of the some of the above mentioned factors lead rivers to continuous changes in short-time and even in different intervals. These changes can be a threat for human societies. The changes and displacements which occur naturally or because of normal and abnormal expansion in the path, direction and geometry of the river, are the results of the river system reaction to a new balance. Changes in river occur in form of erosion and alternative sedimentation on the bed, destruction and widening walls and river banks, displacement of the spiral pattern and flow direction, change in the river form, and river diversion. Bank erosion and destruction are one of the most important issues of water and soil resources and are environmentally important. Due to the frequent occurrence of floods per year, a significant part of the fertile lands of floodplain are occupied by river, and may be flooded and damaged. The necessity of direct exploitation of the river and natural resources along with constructions on the river banks by human being, and also the necessity of sustainable protection of the vital river system for future has caused the issue of river control and determining their boundaries and limits to receive a considerable attention.

Until 1950, the science and technology of protecting river banks had no progress except in a few cases. The measures taken place in this regard are mostly in form of local protections in outer meander, eroded reach, or within water and coastal facilities. Previous damages or the possibility of future damages in near future have been the main incentive for controlling and protecting the river banks. Most of the protective methods have been structural, and in some cases, natural, and biological.

In recent decades, various methods and techniques have been introduced for river training. Training, modifying river path and protecting the river walls are not hampered to using a specific method alongside a reach or on two banks of the river, but include a combination of using different methods. Protection and river walls stabilization are generally done using direct and indirect methods (retarders and deflectors). River groyne is a kind of deflectors. The main function of the river groyne is to deflect the flow from the river banks and navigate it to the main channel of the river. The result of deflecting flow is the generation of eddy and roller zones downstream of the groyne. Hydraulic process of this flow is to create the scour around the groyne, and deposit the sediment load downstream and in river banks. (Uijttewaal 2005; Yeo et al. 2005; Yeo and Kang 2008; Kadota et al. 2008; Gu and Ikeda 2008; Teraguchi et al. 2008)

Groynes can cause severe erosion if poorly located and wrongly installed. Although the usage of groynes are reduced as the development of direct methods for bank erosion protection like as concrete revetment, the groynes are continuously installed to control the flow for navigation and improve the channel alignment.

* **Corresponding Author:** Farzad Mohamma, Department of Water Sciences and Engineering, Shoushtar Branch, Islamic Azad University, Shoushtar, Iran. Email: Email:farzad.m60@gmail.com

Recently groynes attract attention again because the natural bank form made by groynes is very beneficial to river ecosystem. If a groyne is correctly designed, then the amount of material it can hold will be hampered, and excess sediment will be free to move on through the system. However, if a groyne is too large it may trap too much sediment, which can cause severe beach erosion on the down-drift side. In this paper we aim to evaluate and investigate the groynes installed in *Kashkan* and *Sezar* rivers located in Lorestan province of Iran.

2. MATERIALS AND METHODS

2.1. River groyne

River groynes are one of the most important structures for river training. Groyne is a rigid hydraulic structure that interrupts water flow and limits the movement of sediment. It is usually made out of wood or concrete. The groynes are defined as a structure that was installed at the front of bank or revetment to protect bank or levee against erosion by controlling the flow direction and velocities. They are often constructed nearly perpendicular to the riverbanks in single or symmetrical form on one or two sides of the river, beginning at a riverbank with a root and ending at the regulation line with a head. They maintain a channel to prevent ice jamming, and more generally improve navigation and control over lateral erosion, that would form from meanders. (Yossef, 2002)

According to figure 1, the general structure of a river groyne includes the following parts:

(a). Head/ toe: which is constructed wider due to the resistance against the water flow and protection against scour;

(b). framework: which forms the main body of the groyne;

(c). Root: which is responsible for the stability of the framework through the locked connection of the groyne to the river wall;

(d). Toe protection: which is critical for groyne safety against the general and local scour on the head and around the body

(e). Blanket: this is a protection cover for groyne and river wall to avoid from destruction and erosion.

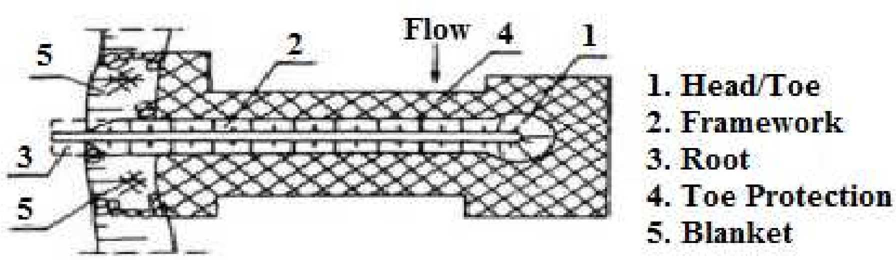

Figure 1. A general design of a groyne (Pirayesh, 2014)

2.2. Purposes of installation

The main purpose of installing groynes is flow control and bank protection; However, they are also widely used for modifying the flow direction in spiral rivers (protecting the walls of the main channel, and controlling the floodplains). Generally, the river groynes are installed for the following purposes:

- Modifying the river path for controlling the flood or reducing the risk of river precession to the coastal land, erosion and destruction of the walls, and other installations through reducing or modifying the river width and wall stabilization;
- Protecting the meanders by adjusting relative curvature of them, improving the bank line, and flow deflection from the bank toward the center of the river;
- Local protection of the river bank against destruction of the hydraulic structures, bridges and other critical lines (water, electricity, oil and gas) by improving the bank line and flow deflection;
- Increasing flow velocity to prevent sedimentary deposit
- Providing the possibility of shipping in the river by modifying the regular width and depth of water

- Restoration of the aquatic ecosystem;

2.3. Different Types of Groynes

Groynes can be classified according to their functions, objects, forms, and materials.

2.3.1. Materials

Groynes can be divided into two types of “impermeable” and “permeable” with completely different structure and hydraulic function. Technically, the term groyne refers to the impermeable or deflector type. The impermeable groynes are constructed using rock, gravel, gabions while the permeable groynes, are large rocks, bamboo or timber.

2.3.2. Flexibility

In terms of Flexibility, the groynes are divided into two types of “rigid” and “flexible”. Generally, flexible groynes are better than the rigid ones. A rigid groyne can easily and quickly get cracked, and some parts of it can be destroyed; but the flexible groynes can be regulated, displaced, and repaired. Rubble-mound, sand-filled bag or concrete tripod groynes are the significant examples of the flexible structures.

2.3.3. Submergence

Groynes can be submerged or not under normal conditions. Usually impermeable groynes are non-submerged, since flow over the top of solid groynes may cause severe erosion along the shanks. Submerged groynes, on the other hand, may be permeable depending on the degree of flow disturbance needed.

2.3.4. Effect on stream flow

Groynes can be attracting, deflecting or repelling.

- *Attracting/Declined groynes:* which point downstream, serving to attract the stream flow toward themselves, and not repel the flow toward the opposite bank. They tend to maintain deep current close to the bank. Their angle point downstream is 10-30°. These types of groynes in flood conditions may cause the destruction of walls.
- *Deflecting/Normal groynes:which* change the direction of flow without repelling it. They are generally short and used for limited, local protection.
- *Repelling/Inclined groynes:* which point upstream; they force the flow away from themselves. A single groyne may have one section, for example, attracting, and another section deflecting. Their angle point upstream can be 5-30°.

2.4. Shapes of Groynes

The most important groyne design are planview shape, length of the groynes, spacing between groynes, orientation to the flow, crest elevation and slope, cross-section, construction materials and scour (Alvarez , 1989; Richardson et al. ,1975; Przedwojski et al. , 1995). The most common planview shapes of the groynes are shown in figure 2 including: straight with or without round head, L-head, T-head as well as hockey, inverted hockey, wing/tail, and birds mouth groyne. [Ahmed, 1953; Freeman, 1929; Garde et al, 1961; Gill, 1972; Ibrahim, 1995)

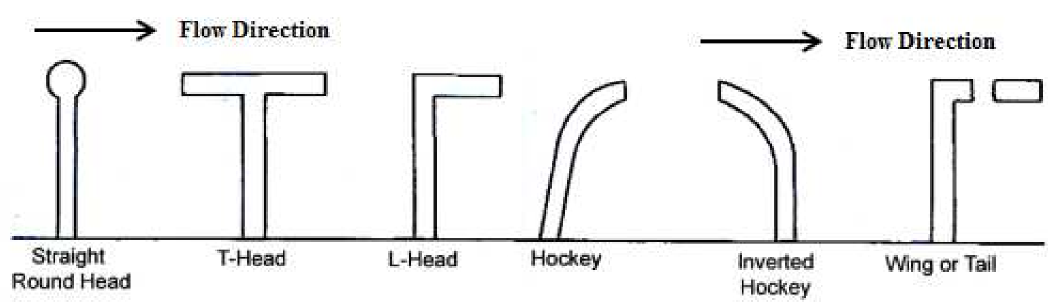

Figure 2. Different shapes of groynes (Przedwojski et al, 1995)

In terms of length, groynes rely on location, purpose, spacing, and economics of construction. The total length of the groyne includes the anchoring length, and the working length. Also in terms of cross-section, the crest widths range from 1to 6m and side slopes from 1:1.25 to 1:5. The minimum crest width of 1m is controlled by the equipment placing the groynes and wider crests make placing easier. (Yossef, 2002)

2.5. Function of Groynes

The main function of the impermeable groynes is to deflect the flow from the river bank to the center of the river. Flow deflection results in development of a recirculating flow area with high turbulence around the river groyne. A set of vertical and horizontal eddies are active in recirculating flow area which cause turbulence flow.

The hydraulic process of this flow is development of a Local Scour Hole, sediment deposition bar downstream and on the river bank and bed mobility downstream. While scouring is considered as serious local risk for the stability, strength and functioning of the groynes, sediment downstream causes natural development and stabilization of the river bank in desired direction.
The structure of recirculating flow area depends on the cross-section geometry, lateral slope along the groyne's body and head, the groyne's position (straight, inner or outer bank) and the groyne's angle to the bank line and flow direction, in addition to the length and spacing between the groynes. Topography of the bed around a single groyne and also in the field of sequential groynes on one side of the flow are summarized and presented below.

2.5.1. Flow pattern and bed topography near a single groyne

Flow area around a single groyne is different from the flow area around the groynes in series arrangement. In case of non-submerged groyne, the river width, and flow cross-section has been hampered which leads to changes in kinetic structure of the flow at the flow area of the river groyne. With upstream deflection toward the center of the river channel, the average velocity and cross-section flow increase in main channel. Increased average velocity results in the increase in velocity gradient and generation of eddies and highly turbulent flow around the groyne (Przedwojski, 1995). Figure 3 shows flow pattern in a single groyne

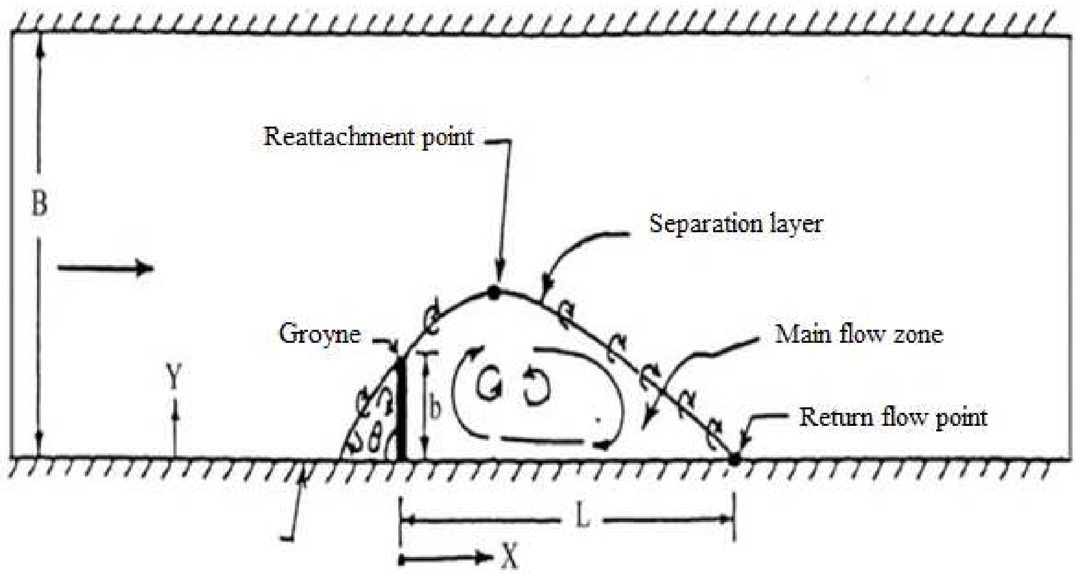

Figure 3. Flow pattern around a single groyne

2.5.2. Flow pattern and bed topography in sequential arrangement groyne fields

Under conditions where there are non-submerged groynes in series arrangement, the groyne fields are not considered as a part of wetted cross section of a rive; Therefore, the flow pattern of the groyne field does not directly depend on the flow intensity in main channel. In addition, stream velocity reduction in groyne field has no special effect on the flow pattern but reduction of water level in groyne field significantly affects it (Uijttewaal et al., 2001)
flow pattern inside a groyne field is affected by its geometry (length and the spacing between the groynes), groyne type, inclination angle, location along the river, water depth, submerging condition of the groyne, and angular orientation (inner curve, outer curve, or straight part), cross-section shape, lateral slope of the framework and head of toe. (Przedwojski, 1995).
Figure 4 shows a flow pattern a groyne-field between two groynes (with the space to length ratio of 4). In this figure, a large eddy is observed in three-quarters of the groyne-field. In addition, the center of the eddy is not in the center of the floe pattern but it is near to the tip of upnstream of groyne and dragged toward the main channel of the river. Further, downstream, the main current does enter the groyne-field, and leads to the increased effective flow width. The second eddy develops in smaller area upstream of the second groyne where the main outflow is hampered by this groyne. The flow condition in figure 5 indicates the proper functioning of the groynes in deflecting the main flow from the river banks.

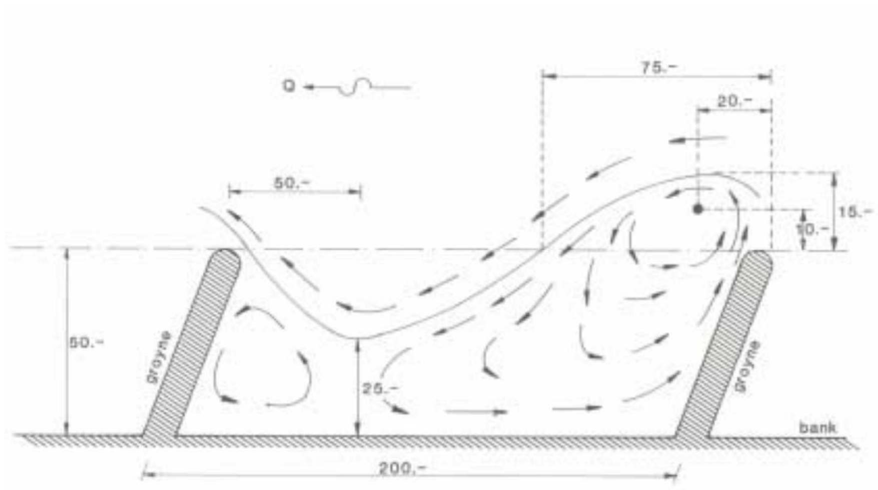

Figure 4. Flow pattern between two sequential groynes (Brolsma, 1988)

Based on the experimental studies on the physical model of groyne in series arrangement placement on the river bend, the effect of spacing between the groynes on recirculating flow pattern in groynes field has been shown in figure 13. In this study six recirculating patterns in groynes field have been recognized based on the increased spacing between the groynes.

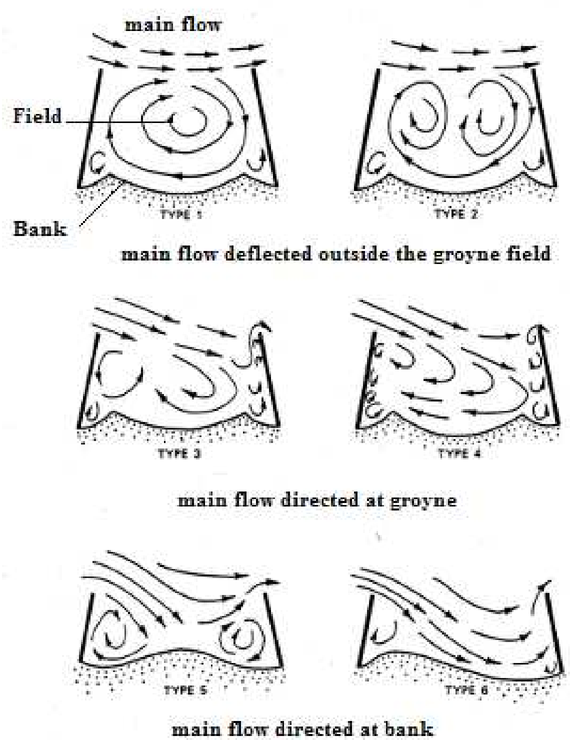

Figure 5. Types of flow pattern in groyne-fields (Przedwojski, 1995)

Based on figure 5, In type 1, the main flow has been deflected outside the groyne field and only one unit of the single recirculating flow develops between the groynes. This type can be applied for hipping purposes since the concentration of the main flow in the middle of the river supports and controls the required depth. In type 2, by a slight increase in the spacing between the groynes, the main flow is still deflecting outside the groyne field but the second vortex also appears in groynes field area. In Type 3, flow pattern develops by the increase in spacing between the groynes so that the main flow enters the groyne field and a stronger vortex is formed around the groynes and a more severe turbulence happens along the upstream and around the head of the second groyne. In type 4, a reverse current occur, and finally in the fifth type, the flow deflected by the first groyne (upstream), is directed to the river bank downstream. However, some eddies are formed on both sides of the flow line which reduce the main flow attack power and provide little protection for the bank. According to type 6, by more increase in the spacing between the groynes, the downstream eddy can not t protect the bank, and then the main flow lines directly attacks the bank. In this condition, the groyne is not efficient.

2.6. Case Study

Lorestan province with an area of 24532.4 $km^2$is located in 47 degrees, 1 minute, 24 seconds to 49 degrees, 56 minute, 52 seconds East length and 32 degrees, 50 minute, 42 seconds to 33 degrees, 39 minute, 42 seconds North width. Lorestan province area is located within two major basins of Karkheh and Dez. Two important rivers in these two basins include: Kashkan in the West and Sezar in the East of the province. Their locations are shown in Figures 6 and 7.

Figure 6. Location of Kashkan River in Lorestan, Iran

Figure 7. Location of Sezar River in Lorestan, Iran

Based on the available data and the data obtained from the Lorestan Regional Water Board Company for 35-year time interval, moment and daily debis statistics of the stations on the Sezar and Kashkan rivers were analyzed. Then, using the Smada 6.0 Software and various equations to determine the current return, log Pearson type III was used to estimate the probable debi with 35 years return period. Figures 8 and 9 show log Pearson type III for Kashkan and Sezar Rivers.

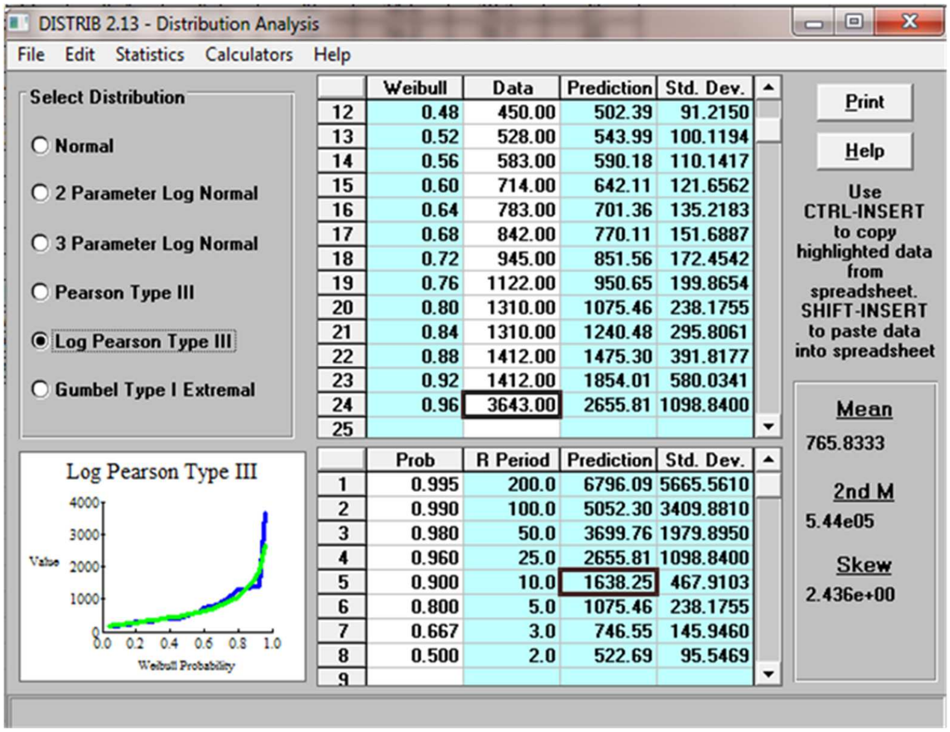

Figure 8. Maximum debi of Kashkan River with 35 years return period

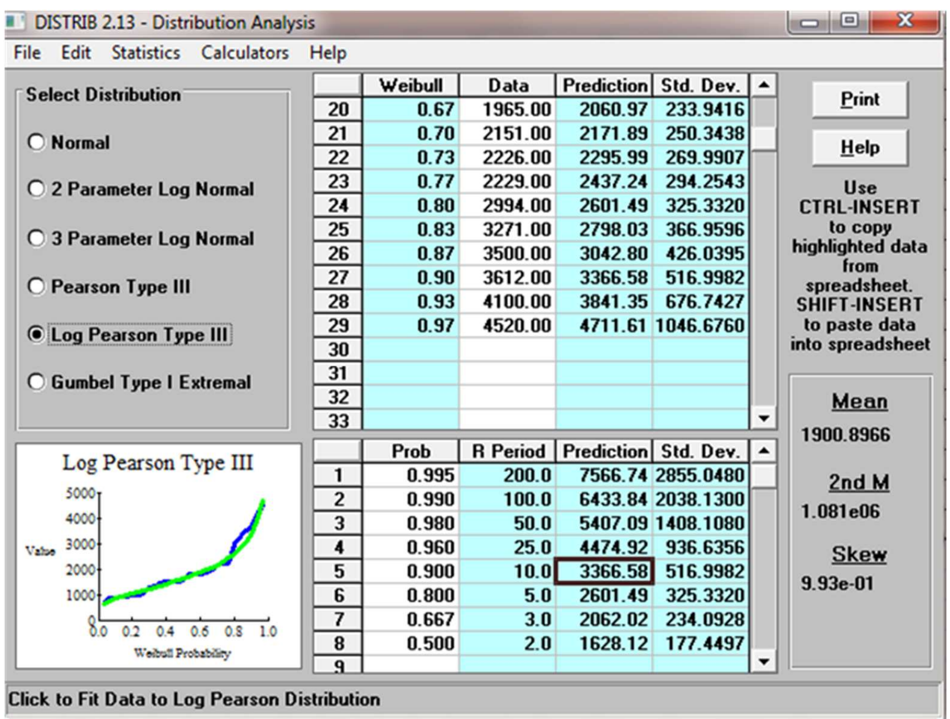

Figure 9. Maximum debi of Sezar River with 35 years return period

The maximum probable debi in Kashkan and Sezar Rivers are 3366 and 2655 m^3/s, respectively. Now, we study the behavior of the groyne-field pattern of groyne installed in these two rivers.

3. RESULTS AND DISCUSSION

3.1. Field visit

Characteristics of the groynes installed in Kashkan and Sezar Rivers are as below:

3.1.1. Sezar River

River width = 175 m
River average gradient= 0.00012
The average diameter of bed sediments= 10 mm
Maximum probable debiwith 35 years return period= 3366 m^3/s
Groyne type = impermeable- attractor 15 degree angle
Groyne length= 25 m
Spacing between the groynes= 85 m
Groyne height= 5m
The gradient of the groyne lateral wall = 0.5 horizontal – 1 vertical
The depth of the scourhole near the river depth= about 3.2 m
Groyne age= about 10 years
Based on the watershed on the river bank, the groyne series are submerged and this has happened while it is not recommended to place impermeable groyne in submerged condition since the recirculating layers toward the river bank causes the overpass to erode the banks.

3.1.2. Kashkan River

River width = 280 m
River average gradient= 0.00084
The average diameter of bed sediments= 8 mm
Maximum probable debi with 35 years return period= 2655 m^3/s
Groyne type = impermeable- vertical
Groyne length= 38 m
Spacing between the groynes= 50 m
Groyne height= 2 m
The gradient of the groyne lateral wall = 2 horizontal – 1 vertical
The depth of the eroded hole near the river depth= about 2.5 m
Groyne age= about 15 years

3.2. Calculations

There are some equations to predict the maximum depth of scour at groynes such as Khosla (1953), Garde et al (1961), Niel (1973), Zaghloul(1983), Ahmad (1953), Gill (1972) and Liu (1961). In this regard, their values were obtained for both rivers which are shown in figures 10 and 11. Relative error of each methods are presented in figure 12.

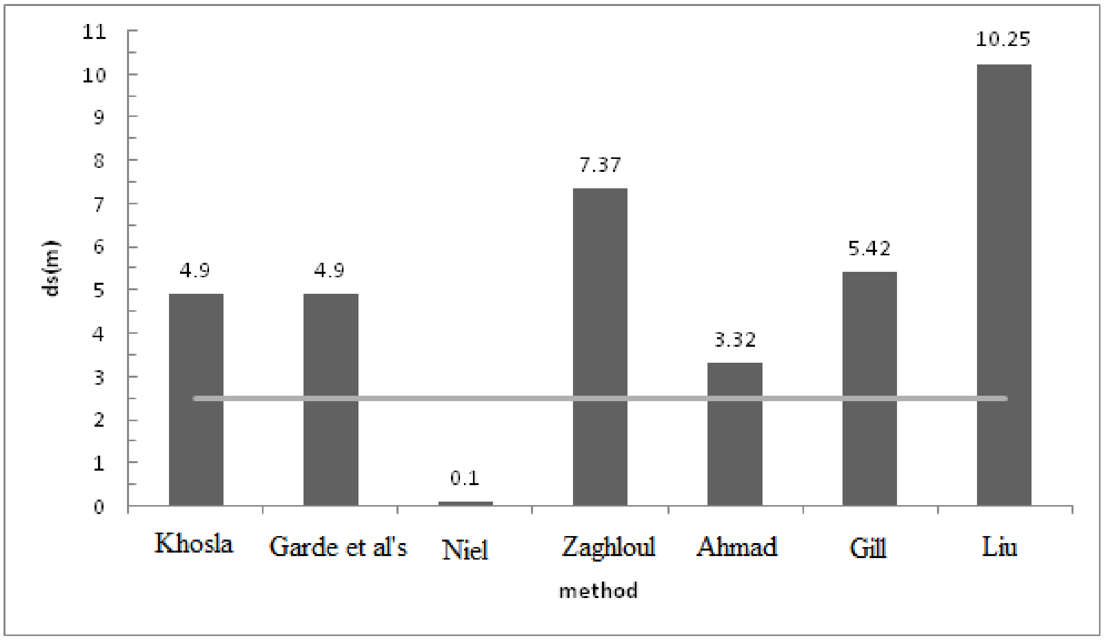

Figure 10. Scour depth Results of Kashkan River

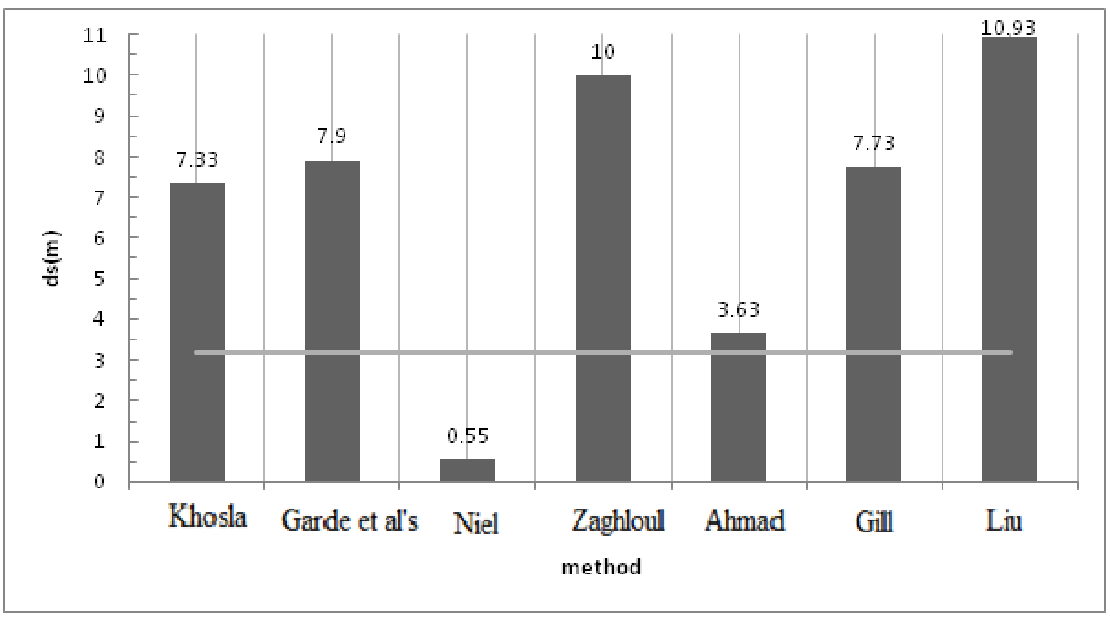

Figure 11. Scour depth Results of Sezar River

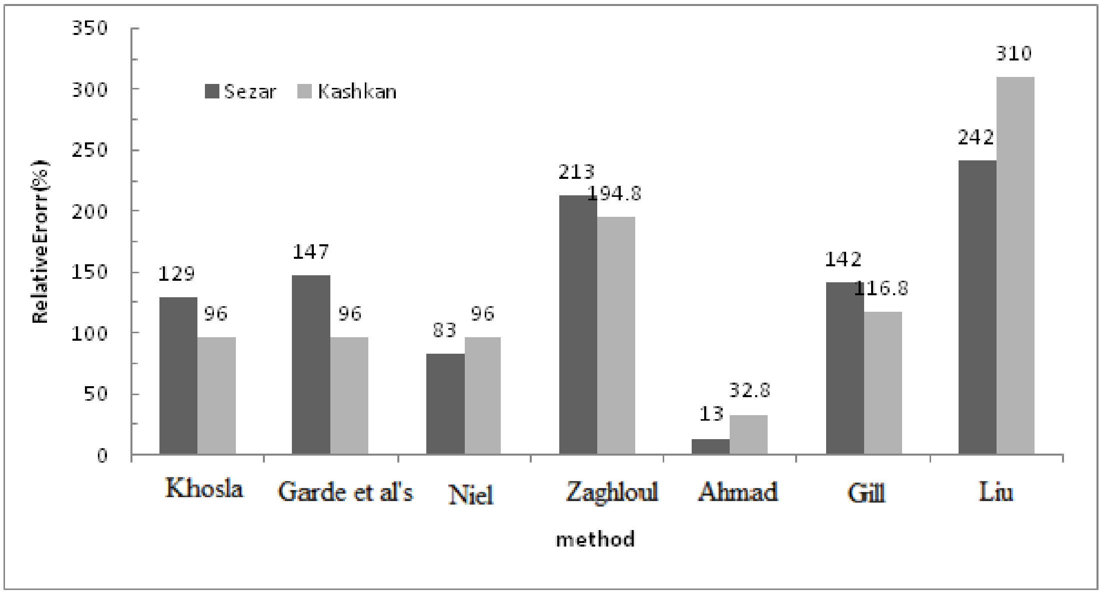

Figure 12. Relative error of each method for scour depth prediction

4. Conclusion

The present study, in addition to describing the function of the groyne in protecting the river banks, investigated the groyne's behavior in protecting the banks of two important rivers in Lorestan province, Kashkan and Sezar. The most important results of the study can be summarized as below:

- The groynes installed in both rivers have had proper function in their area despite of their improper design and implementation;
- In Sezar River the installed groynes's length and space with each other were determined properly, but they are not suitable in Kashkan River.
- It seems that the last groyne on Kashkan River was not able to protect the river bank. Therefore, there was the possibility of scouring in the pier of Murani village Bridge, and it would be destroyed due to sever local erosion.
- Using poor materials, poor pier foundation, and improper lateral wall angle are one of negative aspects of these structures.
- The equations provided by various researchers about the scour depth even with various coefficients and scope cannot properly calculate the scour depth.
- Considering the armoring phenomenon or bed processing, the river bed has reached a proper balance, and this has led to proper river protection and deposition in the spacing between the groynes.
- Ahmad's formula had the highest accuracy for estimating the scour depth due to the toe erosion.

In order to improve the efficiency of the groynes on both rivers, it is recommended to:

- Take required measures for repairing and retrofitting the groynes head;
- Take quick measures for repairing, retrofitting and extending the length of the last groyne (near Murani Village Bridge) on Kashkan River;
- Train the stone pieces of the groynes on Kashkan River;
- Simulate the hydraulic model of the structures in natural condition and using the software such as CCHE2D, HEC-RAS.

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