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Local bed morphological changes due to oriented groins in straight channels

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Contraction ratio;
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Scour;
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Abstract This research investigates the effect of implementing oriented groins on the scour and silting processes in a straight channel. Combined physical and numerical models were used. Twenty-seven (27) runs were conducted in which the geometry of scour and silting associated with model groins was evaluated. Groin models were angled at 60°, 90°, and 120° to the downstream channel side wall with contraction ratios of 0.10, 0.15 and 0.20. The main goals of this paper were to evaluate the effect of the three angles on the scour geometry on minimizing erosion adjacent to the stream banks. Results were analyzed and were graphically presented and the percentages of errors between the obtained results from the used models were reported to define the sufficient compatibility between the used models. Simple formulae were derived to evaluate the scour and silting parameters.

1. Introduction

Groins may be defined as a structure extending outward from the bank of a stream for the purpose of deflecting the current away from the bank to protect it from erosion. Groins have also been used to enhance aquatic habitat by creating stable pools in unstable streams, Klingeman et al. [1]. Groins cause pools to be created and maintained, and have been found, in general, to be more beneficial to aquatic habitat resources than other types of bank protection. The magnitude of the benefit to the habitat in a disturbed stream is related to the volume of scour hole. Shields et al. [2] documented significant increases in fish numbers, size, biomass, and number of species in an incised stream following modification of groins to enlarge scour hole sand increase the percentage of pools in the reach. Designers of bank stabilization structures should, where possible, select groin geometry which stabilizes the bank and provides the largest scour volume subject to cost constraints. The initiation of local scour is associated with the increase in shear stress caused by the accelerating flow around the obstruction. The volume of local scour in the vicinity of a spur dike is difficult to estimate accurately, therefore, this research was initiated with the objective of investigating the influence of groin length, orientation angle and discharge on the characteristics of local scour and silting with in order to determine the optimum characteristics according to groin usage with

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Nomenclature

U	longitudinal surface velocity (m/s)	W_{sl}	silting width (m)
V	transverse surface velocity (m/s)	L_{sl}	silting length (m)
P	mean pressure (kg/m^2)	$Fr_{avr.cont}$	average Froude number at the contracted section (–)
F_X	body force in X direction (kg m/s^2)	Q	discharge (m^3/s)
F_Y	body force in Y direction (kg m/s^2)		
g	gravity acceleration (m/s^2)	*Greek symbols*	
d_{sc}	maximum scour depth (m)	ν_e	kinematics eddy viscosity (kg/m s)
y	depth of approaching flow (m)	ρ	fluid density (kg/m^3)
L	groin length (m)	τ_{fx}	turbulent frictional stresses in X-direction (kg/m^2)
B	channel width (m)	τ_{fy}	turbulent frictional stresses in Y-direction (kg/m^2)
d_{sc}	scour depth (m)	θ	orientation angle (°)
W_{sc}	scour width (m)	σ_g	geometric standard deviation (–)
L_{sc}	scour length (m)		
h_{sl}	silting depth (m)		

minimum side effects. The investigation phases are presented in this paper under the following headlines.

- Reviewing the literature
- Executing experimental work
- Modeling the problem in hand
- Analyzing and presenting the results
- Deducing formulas to evaluate the scour and silting parameters

2. Reviewing the literature

Many factors affecting the geometries of scour and silting around groins (i.e. length, alignment, flow intensity, shape, sediment size, and flow depth) are evident. Few studies have been made which investigated the morphological bed changes associated with oriented groins. Many researchers have studied the hydraulics of groins. Studies to date have predominantly investigated, local scour (Kuhnle et al. [3], Ohmoto and Hirakawa [4], Elawady et al. [5,6]), flow structure (Tominaga et al. [7], Uittewaal and Berg [8]) and the mass exchange in the groin fields (Uittewaal et al. [9]).

Abdelmageed [10] developed a relationship between the maximum and minimum velocities before and after installing oriented groin. Moreover, he reported that the maximum scour length and depth occurred for groin with 20% of aspect ratio. Ibrahim [11] used 2D flume model for measuring the velocity distribution associated with spur dikes and scour holes to define the influence of groin length and orientation angle. He indicated that the groin length is directly proportional to velocity at the groin field. Vaghefi et al. [12] investigated the geometry of the scour hole and topography of the bed around a T-shaped non-submerged spur dike located in a 90° bend. They developed a new equation for scour parameters at a T-shaped spur dike. Jamieson et al. [13] performed a series of laboratory flume experiments to study the effect of groins on flow field dynamics and sediment erosion in a 135° mobile-bed channel bend. They concluded that the outer bank region (particularly between groins) may still be at risk of erosion. Jamieson et al. [14] studied experimentally the flow field and sediment dynamics in a mobile-bed channel bend with and without the presence of stream barbs (upstream-angled submerged groins). They found that the vortices increased in the outer bank scour zone for all runs with and without barbs. Huthoff et al. [15] proved that the wing dike construction leads to water level lowering for in-bank flows and to water level increases for outer-bank (flood) flows. Ali and Uijttewaal [16] carried out experimental study to estimate and parameterize the form drag due to vegetated groin obstacle. They measured the energy head losses for a range of discharges and downstream water levels covering submerged and subcritical flow conditions. Uijttewaal [17] studied experimentally the effects of groin layout on the flow near the groin field For different types (i.e., standard reference groins, groins with a head having a gentle slope and extending into the main channel, permeable groins consisting of pile rows, and hybrid groins consisting of a lowered impermeable groin with a pile row on top). The study demonstrated that the turbulence properties near and downstream of the groin can be manipulated by changing the permeability and slope of the groin head. He also observed that for submerged conditions the flow becomes complex and locally dominated by three-dimensional effects. Fang et al. [18] used the large eddy simulation (LES) to investigate the influence of groin parameters (i.e., head shape, aspect ratio L/D, and length L) on the flow properties. They indicated that the rectangular groin generates higher turbulence intensities and larger vortices than a round-headed groin. Also, Eddies are formed at the groin tips and transported downstream. Sukhodolov et al. [19] studied the sediment distributions in a groin field. They found the concentration of suspended particulate matter reduces with distance from the shear layer toward the internal parts of the groin field. Maleki et al. [20] studied numerically the three-dimensional simulation of flow and vortex patterns around L-shaped impermeable groins at five different angles. They found that the maximum and minimum erosion are located at angles of 75° and 90° respectively. Naghshine et al. [21] studied the effect of groin angle on controlling the sediments entering the intake branching from a 180° bend. They deduced that groin with angle 90 degree showed the best potential for reducing sediment movement into division. Attia et al. [22] used 2D hydrodynamic model to investigate the effect of oblique spur dikes on the local study at Naga Hammadi Barrage. The study found that, the scour depth and length were directly proportional to orientation angle.