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Hydraulic Impact of Intake Slope and Entrance Level on Flow Uniformity

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ملخص البحث :

تعتبر القنوات المفتوحة إحدى الوسائل المهمة لنقل المياه وجزء أساسى فى معظم المنشآت الهيدروليكية ومشاريع الموارد المائية. وغالبا ما يتطلب الأمر إنشاء قنوات فرعية لنقل وتوزيع جزء من التصرف. هناك أنواع مختلفة من تحويلات الأنهار التي تعتمد على حالة النهر وكمية المياه المحولة وان مأخذ النهر الجانبي هو أحد هذه التحويلات .

ابحاث عديده تم اجرائها لدراسه المآخذ فى القنوات المكشوفة وأجمعت معظمها علي أن كمية المياه بها غير منتظمة والتدفق مضطرب نتيجة لزياده أو نقص المياه خلال القناة فعند دخول المياه الى المآخذ تكون سريعة نتيجة لسحب المياه من أخر المآخذ .

فيما يلي الهدف من الدراسه التي ناقشت الترسيب والتصرفات وميل القاع فى المآخذ تأثيرها على سريان وتدفق المياه وكيفية التصميم المناسب ليقلل من مشاكل المآخذ والتى من أهمها نقل الرواسب حيث ان الرواسب تنقل من المنحنى الخارجى للمآخذ التى يحدث بها نحر نتيجة لسرعه المياه فى هذه المنطقة وتتجمع فى المنحنى الداخلى للمآخذ الذى يحث به اطماء و تكون سرعه المياه بها قليله مما يتسبب فى العديد من المشاكل ويحدث دوامات ورجوع المياه. وقد تم التوصل الى

1 Abstract:

Lateral intake is a structure created next to a main channel to distract part of the flow within the channel. Lateral intakes are used by hydraulic engineers for flow diversion in irrigation grids and water source systems. A 90-degree branching is the easiest method to distract water from main channels. With impending of the flow to the intake, the flow hurries in the sloping way and is divided into two portions. Part of the flow is directed into the lateral intake and the remain quantity goes into the main channel. Intake in an open channel has a non-uniform flow along the main channel. Velocity and direction change in the lateral intake lead to non-uniform flow, sediment transport, whirlpools and/or swirls. Intake abstraction efficiency decreases due to circulation and non-uniform flow. High maintenance cost is regularly paid in order to dredge the sedimentation areas and to guarantee abstraction efficiency. Sediment movements usually cause corrosion to the turbine blades, which consequently will increase maintenance cost. River flows at main channels and diversions are geometrically similar and belong to the same class of gravity-driven flows that divided into two directions and two flow ratios. Therefore, related to all these points and problems, the aims of this study were to improve the design of the lateral intakes and reach the most effective design by collecting most effective previous studies.and is has been

Key words: Diversion, Open Channel, reached that Intake, Intake Slope, Flow Uniformity.

2 Introduction

Rivers are considered as one of the providers of pure water for the nature and human. The delivery of water has been the most important cost-effective part of the rivers and the right design of river intakes is one of the most subjects in hydraulic engineering (Raudkivi, 1993) [13]. The water diversion method depends on flow conditions, topology and morphology of river. Flow diversion study in open channels (intakes) is much used to distract stream from the main channel or from a river into an irrigation or hydropower channel as shown in Figure 1.

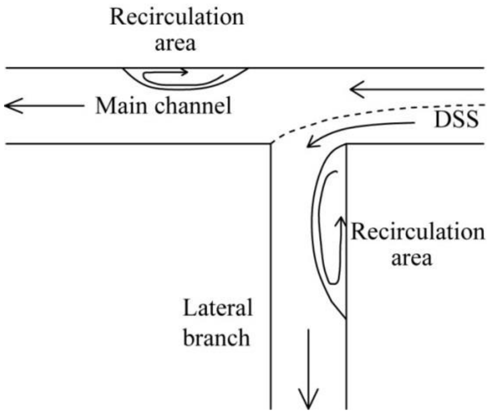


Figure 1: General flow patterns of a diversion (Raudkivi, 1993) [13].

There are different kinds of river diversions that depend on river condition and quantity of water diverted; lateral intake is one of these diversions. Flows through this lateral intake are turbulent (Hamid, 2008) [5]. Intake in an open channel has a non-uniform discharge resulting from the abstraction of water through the channel. As the flow enters the intake, it hurries by the suction forces at the end of intake. The flow may be to divide into two portions as a reason of last process, one incoming to the intake and the other flow in the downstream path in the main channel.

3 Applications Studies

3.1 Flow Characteristics in Intakes

Chung et al., (2002) [4], performed numerical and experimental model for a sub-critical, right-angled, equal-width, and open-channel dividing flow over a horizontal bed. The reduction constant at the supreme width of the contracted section in the recirculation is inversely related to the ratio of discharge at upstream to that at downstream. Under the statement that the velocities were nearly uniformly distributed at the considered boundaries, the depth-discharge relationship follows the commonly used energy equation. The predicted results relate fairly to the experimental data. For practical engineering applications, the maximum possible discharge in branch channel at a given upstream discharge could be determined with a prescribed downstream Froude number or the maximum possible downstream Froude number.

Rashwan et al., (2004) [12], developed a theoretical model for a junction at 90_o over a horizontal bed for subcritical steady flow through main, extension, and branch channels of equal widths. The developed model was derived essentially based on momentum, energy, and continuity equations. The model was verified with experimental data from the previous studies and give a good accordance with them. It was also found that a linear relationship between the experimental data of the inflow water depth and the branch water depth was valid. The specific heads upstream and downstream the junction was found to be practically equal.

Amin, (2005) [2], investigated experimentally the velocities distribution at diversions using a fixed-bed model. He defined the effect of the diversion angles on minimizing sediment deposition in intake channels, as shown in figure 2. The experimental results showed that the recommended range of the diversion angles of the channel intake needed to enhance the flow pattern inside the channel intake is in the range of 100_o to 112_o. In addition, he developed two empirical formulae to help the designers of intakes. His formulae were verified in the predictions of sedimentation problems at two locations along the Nile River which were in accordance with the measured quantities. It was recommended that the influence of the sediment exclusion measures such as bottom vanes upstream the entrance of the channel intake should be further investigated.

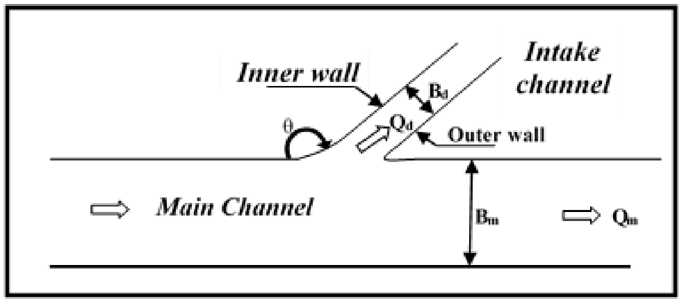
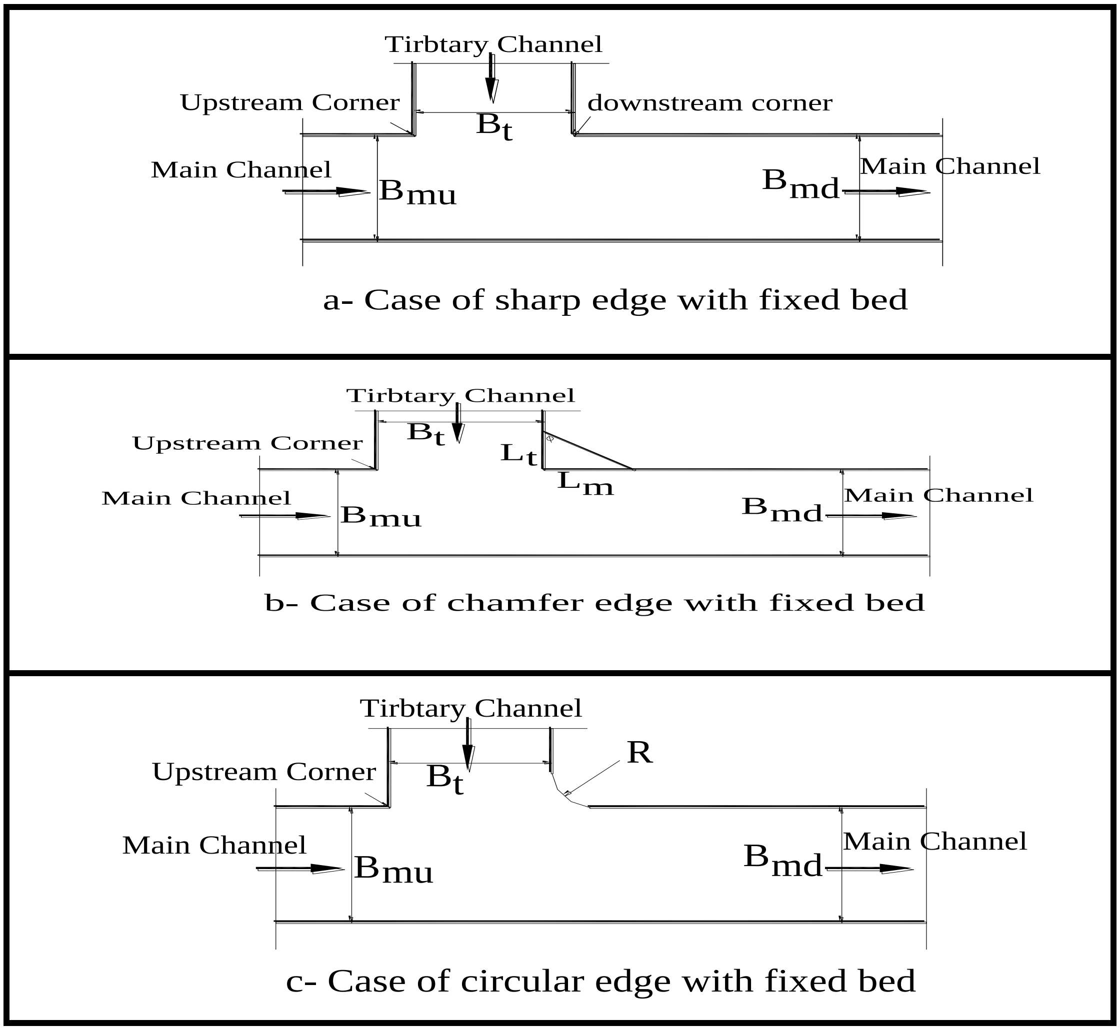


Figure 2: Layout of the intake, (Amin, 2005), [2]

Helal, (2006) [6], investigated numerically and experimentally how to minimize the effect of the separation zone at open channel junction. This could be achieved by changing the downstream edge of the junction from sharp to chamfer to circular edge. Experimental runs were categorized according to the junction and bed types. He measured the water depths, velocity along the profile, maximum scour depths, and scour-hole lengths. In the numerical study, the finite element technique was implemented in order to determine the velocity distribution downstream the junction with different dimensions, using ANSYS software program. The main factors, that were considered, were the main and branch channel velocities and radius of circular edge. The numerical runs were categorized into two groups, the first one was a sharp-edged junction, and the others were circular edge radius as shown in figure 3. It was concluded that the circular edge radius reduced the scour depths and the separation zone width with a reduction factor of 85% and 47%, respectively compared to the case of a sharp-edged junction. No separation zones downstream the junction occurred when a circular edge radius of 1.33 of the main channel bed width was used.



a- Case of sharp edge with fixed bed

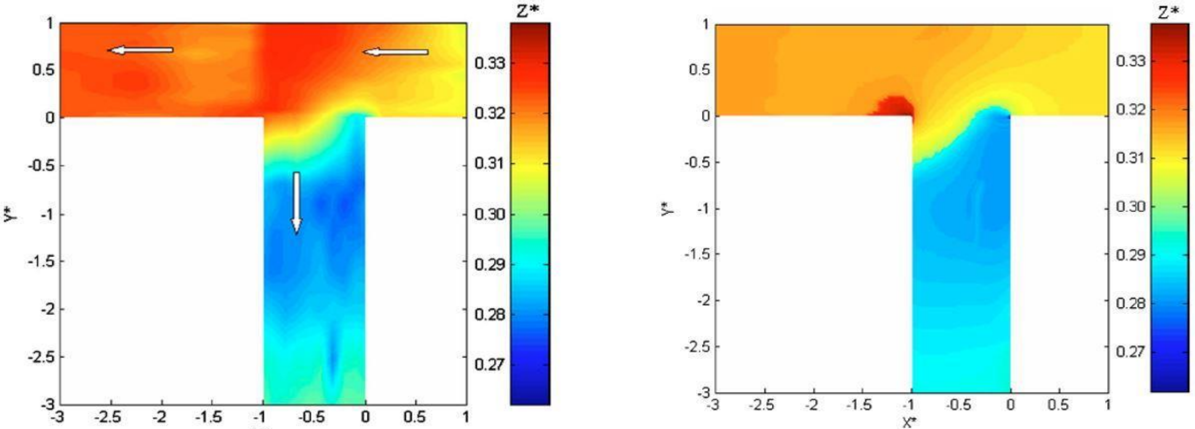
b- Case of chamfer edge with fixed bed

c- Case of circular edge with fixed bed

Figure 3: Layout of junction edge types (Sharp, chamfer, and circular), Helal, (2006), [6].

3.2 Water Depths and Water Surface

Discharge ratio and the Froude number are the key factors that affect water depths of the branch channel system. In the main channel, the lowest water level occurs on the branching side in the first half of the crossing, and the lowest water level occurs just off the downstream edge of the river (Hsu et al., 2002) [7]. Ramamurthy (2007) [11] also celebrated that the depth of water rose at the downstream edge of the lateral channel and in the downstream area of the junction region on the conflicting side of the lateral channel (about 2% higher than the water depth in the stagnation zone). In the branch channel, the water surface drops at the upstream corner at the entrance of the branch channel. In the contraction zone, the lowest water depth in the lateral channel happens and rises with the decreased separation zone. Figure 4 displays experimental water depths and a three-dimensional (3D) volume of numeric turbulent fluid (VOC) estimation.



(a) (b)

Figure 4: Water surface profiles (a) Experimental data, (b) Numerical model [11].

3.3 Separations Zones

Due to the low flow rate and the reverse of water at the same location, separation areas are occurred. These zones enclose the recirculating flow (Ramamurthy et al., 2007) [11]. There are two main separation zones, as shown in Figure 5.

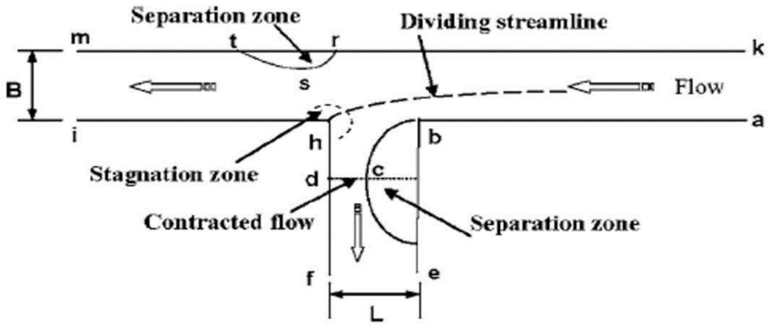


Figure 5: Zones of separation and stagnation point in the branching channel system

(Ramamurthy et al., 2007) [11].

This zone appears due to the high momentum of the water flow into the branch channel in the downstream main channel flow. The location and size of this region depends on the discharge ratio. An increasing discharge ratio leads to this region decreasing.

Ashok S. and Keshava, (1997) [3], developed a two-dimensional numerical model for the prediction of flow in open channel diversion. The model employed the depth average form of momentum and continuity equations. The model performed well in forecasting the distributions of discharge and computed water surface profiles, depth- average velocity distribution in the main channel, and size of separation zone that matched fairly with the experimental observations. Fig. 6 presents a view of the simulated water surface profile when such a flow condition prevails. These jumps generally occupy about half of the channel width and the other half will be occupied by recirculating flow.

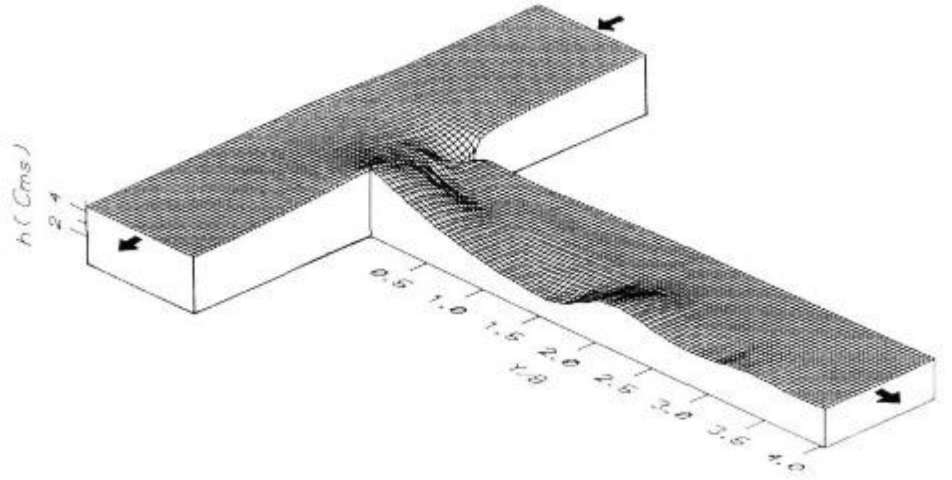


Figure 6: Water surface profile showing formation of hydraulic jump in the branch channel.

A two-dimensional numerical model for the prediction of flow in the open channel divisions is developed. The model employs the depth-averaged forms of continuity and momentum equations along with k-£ turbulence closure scheme. Second-order accurate. The model performs well in predicting discharge distribution and computed flow features like water surface profile, depth-averaged velocity distribution in the main channel, size of separation zone matches fairly well with the experimental observations. There is certain amount of error in the prediction of velocity distribution in the branch channel. The results of the model are used to calculate the energy losses at the right-angled junctions. Model studies show that the energy losses in open channel divisions are similar to those observed in closed conduits, when the submerged flow condition in the branch channel prevails. The study appears to be adequate for analyzing the How in open channel divisions for the engineering design purposes.

3.4 Velocity distribution and streamlines

The velocity in the branching junction is 3D, towards the main flow (Vx), towards the branch flow (Vy), and normal to the flow (Vz). After a lot of studies, it was found that an increase of the main mean velocity (Vr) in the branch leads to a reduction in the size of the separation zone in the branch channel and extension of the dividing streamline farther into the main channel. In addition, the strength of the secondary circulation (δ) (velocity near the surface – velocity near the bed) near the upstream wall at the beginning of the branch channel increases as (Vr) increases. This secondary circulation starts to appear at a threshold velocity ratio of 0.03. In the junction region, the flow is divided into two regions: towards the branch channel and towards the downstream main channel. The width of the separating flow towards the branch channel at the bottom are more than their width at the surface (Lama, Kudoh, & Kuroki,2003) [8], which rulers to the diversion flow taking more discharge from the lower layers than the upper layers. This difference between the widths in terms of diversion from a trapezoidal main channel is less than the diversion from a rectangular main channel (Moghadam et al., 2014) [9]. Thus, the high momentum in the upper layer navies the flow to continue towards the downstream end of the main channel (Omidbeigi et al., 2009) [10]. Figure 7 shows the streamlines pattern in the branching channel junction.

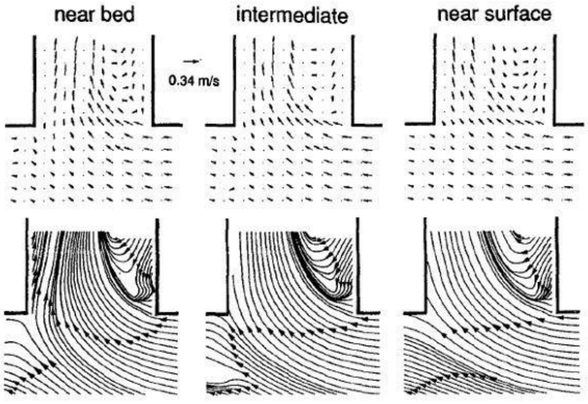


Figure7: Streamline patterns in smooth branching channel junction bed.

Tarek, (2019) [15] studied the study of branching flow in open channels that lateral channel flow labels any side water removals from main channels. Lateral intake channels have extensive application in numerous projects, such as irrigation, and many water resources projects. The flow diversion to the branch channel leads to a decrease in water depth downstream of the main channel. In addition, the study showed that the highest discharge rate was obtained when the angle of branching was equal to 45^o and then an angle of 60^o. While the lowest discharge rate was obtained at an angle of 90^o.

3.5 Numerical models vs. physical models

Rodriguez & Castro, (2003) [14] studied the fundamental difference between the two types of hydraulic modeling lies precisely in the requirement for the level of knowledge or experience surrounding the phenomenon. In the case of physical modeling, it is sufficient to identify the most relevant acting forces and hence to formulate the parameters and the criterion of dynamic similarity. There are areas of civil engineering science where the development of numerical modeling is effectively feasible and very important. Such is the case of the problems around the flow under pressure, the estimation of the flow profile in channels and collectors with free surface, in the use of groundwater, among others more related to environmental sanitation. The alternative use of numerical modeling has much in common with the use of efficient physical models. The following Table 1 summarizes the development process in the solution of a problem, with the help of hydraulic modeling, either physical or numerical, which allows to highlight the fundamental differences between the two types.

Table 1 Differences between physical and numerical models

	Physica	Numerical model
1	Definition of the problem. Identification of the essential acting forces	
	Definition of the objectives of the experimental treatment	
2	Definition of similarity criteria	Definition of the system of equations
3	Formulation of edge or boundary conditions	
4	Construction of the model	Development of the scheme for the solution
5	Model calibration using	
6	Measurements → Solution	Calculations → Solution
7	Optimization of the solution according to the objectives of the model	
	Construction variants in the model	Variants in the input data
8	Calculation for the real conditions of the prototype and verification of the	

4 Conclusion and Recommendation

Branching channel flow is considered a very complex flow, as this flow depends on many factors such as controlling gates at the end of the main and branch channel, velocity, Froude number and momentum in both of the main and branch channels, and the geometry of the branching channel system. This review paper highlighted the flow and physical characteristics of the branching flow. In addition, it reviewed many of the diversion flow physical and mathematical model's properties.

Regarding flow characteristics, the branching discharge decreases as velocity, Froude number and momentum in the upstream main channel flow increases. Moreover, it increases by increasing the upstream main channel water depth and branch channel bed slope. In subcritical flow, water depth in the main channel rises downstream diversion area. On the other hand, it decreases in its depth in the branch channel. There is a stagnation point that occurs in the downstream corner of the branch channel entrance. Two separate zones form in the branching channel system: one in the downstream main channel, in front of the branching junction, which occurs when a branch channel takes an important amount of water, and another at the beginning of the branch channel.

Lastly, from this review, it is important to study the effect of the different branching channel geometries, such as branching angle, and movable bed on the branching water.

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