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The New Method for Simulating of Flow Pattern in Water Intake Using Numerical Model-
A Case Study of the Mianab Irrigation Network and the Old Darioun Channel in Iran

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ABSTRACT

Diversion of optimum water from the main stream line is emerging an important consideration in managing renewable water resources of arid and semi-arid regions. Various factors have to be taken into consideration by major stakeholders in order to achieve the above objective. The aim of present paper is to investigate flow pattern in the intake structures at the Mianab irrigation and drainage network and old Darioun channel using Numerical Model.

This package was used for modeling 3D unsteady flows with free water surface in complex geometry. Two scenarios were considered; one with a rock on the intake of Darioun stream and the other without it. Results indicated that by entering a specific water level in the software program; the secondary flows are generated which is linked to the presence of obstruction in the flow direction that in turn caused eddy flow and increased drop in water level. Under such circumstance irregular velocity-height curve was observed. This is considered to mean that water abstraction and intake under such circumstances would not be appropriate. Moreover, the pressure-height curve could be seen under this circumstance, where at the beginning with a given height range, the cure will have a descending tendency and from a specific height the pressure curve approaches to zero. Results also indicated that when there was no rock at the intake along the flow direction, and where the data on water level is fed into the software, there would be very less secondary flow in the region, making this more appropriate for water abstraction and intake. The underlying reason for that is the removal of rock from the flow path. Based on the observations from the velocity and pressure with the height the curve indicates that at a given height range, first there will be a regular shape inverse parabolic after which the pressure closes to zero. On the pressure- height curve, first at a given height the pressure increases, and at a specific height pressure shows decreasing trend which ultimately closes to zero.

KEYWORDS: flow pattern, unsteady flow, Darioun channel.

1. INTRODUCTION

Diverting water from its original route for agricultural, domestic, hydro-electrical and industrial needs can be met by proper functioning of the water intakes. Abstraction from the surface water resources such as the rivers can be possible by two methods including pumping and gravity.

Abstraction by pumping is normally used for domestic water supply. Abstraction of water by gravity method does not require energy because of the flow continuity and for this reason is preferred to pumping.

Various studies and experimentations on flow hydraulic around the intakes have been carried out. Taylor (1944) for example, focused his on the point by which the canals merge and based his analysis on the upstream and downstream flow depths at that point.

The outcome of [1]' work was provision of an equation for estimating the upstream flow depth. Thus the scope of applying [1]' equation was limited by the Froude Numbers of lower than one [1].In this line researchers elsewhere [2] expanded [1]'work by considering various degree for angles δ (angle for the merge of the three diversion branches) in their study. By considering the effect of canal side curve they proposed an equation for estimating the upstream flow depth. Results indicated that under smaller angle than δ and q (ration of upstream flow to downstream flow) there was a close correlation between the results of equation and the observed experimental data [2]. [3] Investigated the formation conditions of hydraulic jump in combined flow in three canal branch. His experiments for three branches with 90 º and 17 º. In his study flow in the secondary branch was observed to be subcritical and in the main branch it was observed to be weak critical with Fr ranging between 1.5-2.

He proposed an equation for conditions of hydraulic jump with different flow ratios and presented the results in a range dividing the areas with and without hydraulic jump.

The dynamic model was used by Shabayek, Steffler and Hicks (2002) under sub-critical flow condition in the channel confluence. This model is capable of estimating the upstream depth with downstream discharge and downstream depth. The parameters used in this model included the shear forces between two control volumes,

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resisting boundary forces, and the shear forces in the separation zones. Larry et al (2001) investigated various flow parameters in each confluence for three branches with similar width and 90 degree diversion angle under 3D state. The velocity equation at various depths in meshed points in the confluence using Ecostic Dopler velocity meter. These were complimented by velocity time series in various zones to estimate average velocity and turbulence.

Governing equations:

The equations governing the three-dimensional flow were the Navier-Stocks, which represent the flow velocity which are derived at by equilibrium of the forces exerted over a small volume of water under steady flow conditions. Then the Reynolds average method is used to convert these equations for the turbulent flow. The governing equations of flow are continuity and momentum respectively:

$$\frac{\partial u_i}{\partial x_i} = 0$$

$$u_j \frac{\partial u_i}{\partial x_i} = -\frac{1}{\rho}\frac{\partial}{\partial x_i}(P\delta ij + \rho \overline{u_i u_j})$$

Mianab and Darioun stream irrigation and drainage scheme:

Mianab plain consists of some fertile lands on the left banks of the Shatate river and those on the right banks of the Gargar river. The irrigation and drainage scheme commands an area about 43,000 ha but only 36000 ha are actually catered for. The total water requirements of this command area are about 40 m^3 /sec. There are various reasons for selecting an appropriate point of intake for this scheme[8]which include placing the intake at the scheme's high point, appropriate depth of the river during the minimum flow period(minimum of 5 m)[9] . The present study includes a comparison between the flow pattern at the intake with and without the rock using the Numerical Model.

Chart 1: Geometrical specifications of the Darioun water intake.

Height of water (h)	Height of Darioun stream (z)	width of Darioun stream (y)	Length of Darioun stream (x)
8.8 m	0.01-12.5 m	0.01-33 m	0.01-39 m

MATERIALS AND METHOD

The methodology used here involved two states. First to investigate the flow pattern under a vertical vector on the rock where all the points have x and y constant whereby the Z was variable at a specific t , the V and P relative to height Z can be drawn. Second to investigate the flow pattern under a vertical vector without a rock with the same X, Y, Z and T the velocity and pressure curves relative to Z can be drawn. Then the flow pattern under two conditions is compared. X, Y, T are constant whereby Z , P and V are variable.

First case: with a rock on the intake of the Darioun stream

In the first case by considering a vertical vector at the point of intake having a rock (with x and y as constants and z is variable) at a constant time, it would be possible to draw the ratio of velocity and pressure to height curve.

Table 3-3: the specifications on the vertical vector with a rock around the water intake structure

Z(m)	V(m/s)	P(pa)
3.1325	0	45931.92
3.548833	1.0546014	45931.92
3.965167	0.779688	41871.8
4.3815002	0.74354	37763.85
4.797833	0.704226	33636.06
5.214167	0.658609	29494.75
5.6305	0.606592	25344.45
6.046833	0.552287	21187.5
6.463167	0.502405	17023.62
6.8795	0.46382	12852.58
7.295834	0.441564	8672.364
7.712167	0.439438	4477.742
8.1285	0.457521	235.4213
8.544834	0	0
8.961166	0	0
9.3775	0	0
9.793833	0	0
10.21017	0	0
10.6265	0	0
11.04283	0	0
11.45917	0	0
11.8755	0	0

Vertical vector

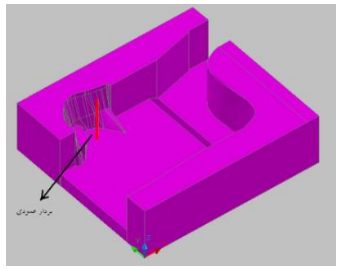

Figure 1: Having a rock on the intake of Darioun stream

Velocity vectors in X-Y direction with the rock on the Darioun intake:

It is crucial importance to investigate the velocity components for their effects on the flow direction towards the intakes.

Sediment and eddy flow

Sediment and eddy flow

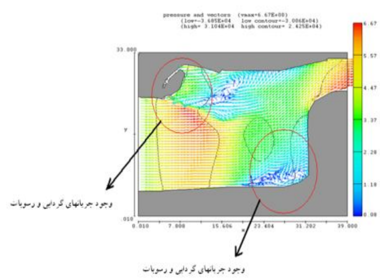

Figure 2: fluctuation of velocity vectors at Darioun water intake in the first case at X-Y direction.

It can be interpreted from the figure 2, that water flow has relatively low velocity where the rock is located at the intake. This causes sediment formation and sediment accumulation just around the rock before the intake.this also causes the generation of the vortex flow. On the other hand the mindering feature of the river along the stream flow on the left and right sides of the intake causes vortex flow at that point.

Velocity and pressure curves with a rock on the intake:

What can be observed from the velocity and pressure curve indicates that under the circumstances where the rock is located on the intake which is shown in figures 3 and 4, by inputting a certain water level in the software vortex flow are generated which is caused by the obstacle along the water flow nearby the intake structure. Under these conditions, the velocity-height curve was observed to be irregular, which renders the water abstraction and system operation inappropriate and undesirable. Furthermore, at a certain height range the pressure decreases and from a certain height onward, it tends to approach zero pressure.

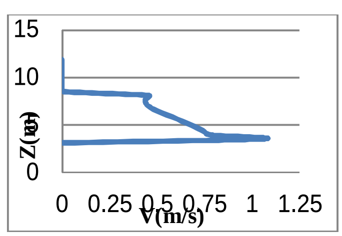

Figure 3: velocity - height curve

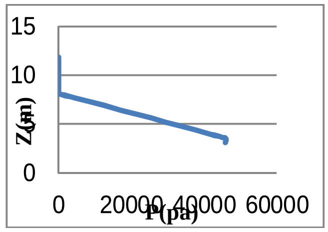

Figure 4: pressure - height curve

Second case: without a rock on the intake of the Darioun stream

In the second case, considering a vertical vector in the former location with the same X, Y, Z and T, the velocity and pressure curve relative to height are drawn.

Table 3-3: the specifications on the vertical vector without a rock around the water intake structure

Z(m)	V(m/s)	P(pa)
3.1325	0	8168.959
3.548833	0	49870.29
3.965167	0.138026	49870.29
4.3815002	0.20284	45765.22
4.797833	0.257319	41667.49
5.214167	0.313283	37578.61
5.6305	0.369337	33492.7
6.046833	0.41395	29403.2
6.463167	0.436248	25306.43
6.8795	0.433343	21197.65
7.295834	0.412816	17072.81
7.712167	0.384627	12926.33
8.1285	0.35435	8749.572
8.544834	0.313264	4528.93
8.961166	0.218071	378.0637
9.3775	0	0
9.793833	0	0
10.21017	0	0
10.6265	0	0
11.04283	0	0
11.45917	0	0
11.8755	0	0

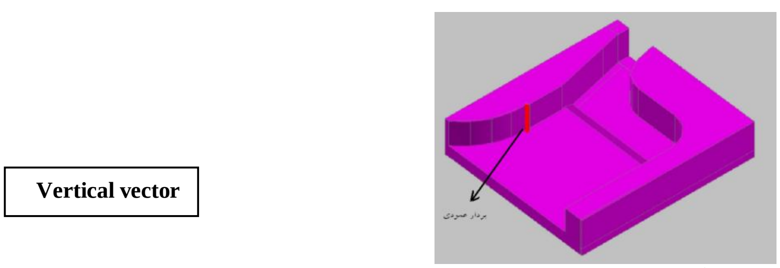

Figure 5: without a rock on the intake of the Darioun stream

Velocity curve at the X-Y direction without rock:

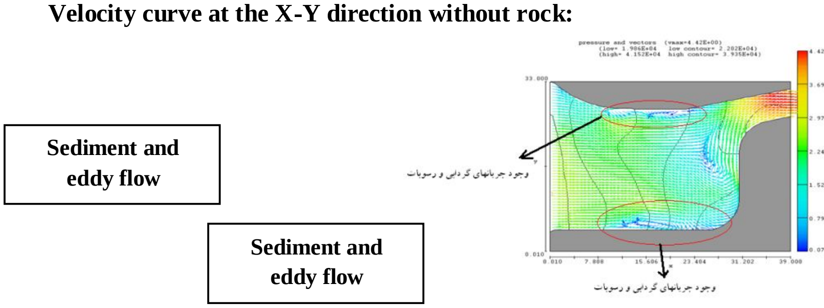

Figure 6 : velocity vectors fluctuation at the intake entry

From what can be observed from the data, it can be interpreted that at the location where the rock has been removed the flow has a higher velocity than other case and the sedimentation formation and sediment accumulation shows a decreasing trend. Furthermore, without the rock along the stream flow, the flow vortex generation is lower than other case. What is important to note is that although removal of the rock causes less vortex nonetheless due to the meandering of the stream course the flow vortex still remain in the flow regime. What can be observed from the velocity and pressure curve indicates that under the circumstances where the rock is removed on the intake which is shown in figures 7 and 8, by inputting a certain water level in the software, considerably much less vortex flow are generated within the water intake structure. This makes a better condition for water abstraction and system operation. The reason for that is the removal of the rock as an obstacle. From what can be observed from the pressure and velocity curve relative to height, first at a constant height pressure increases and then pressure decreases at a certain height range. This trend continues until the pressure approaches to zero. Furthermore, at a certain height range the curve has a regular shape and an inverse parabolic and after a certain height it approaches zero. The regularity of the curve suggests a desirable conditions caused by the removal of the rock from the vicinity of the intake structure.

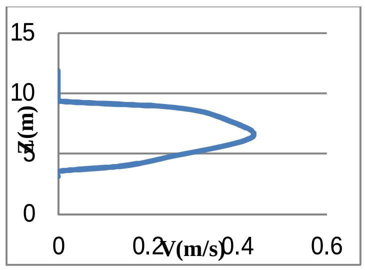

Figure 7: velocity - height curve

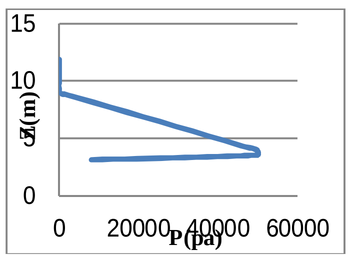

Figure 8: pressure - height curve

RESULTS AND DISCUSSIONS

Results indicated that the water intake is among the hydraulic structures with a very complex flow condition. Results of the modeling suggest that having a rock located on the entry of the water intake structures and with inputting a certain water level in the software, the vortex flows are generated. These are caused by flow obstacle attributed to the rock being on the vicinity of the water entrance into the intake structure. This in turn causes the emergence of the vortex flows and decreasing the water level. All these create a condition for sediment accumulation around the rock.

What can be interpreted from these data is that water abstraction and system operation under these conditions would not be appropriate. Results further indicated that under the circumstance where there is no rock along the stream flow of the intake structure, with inputting a certain water level into the software, considerably less vortex flows are generated. This makes the water abstraction more appropriate and system operation desirable. The reason for this is the removal of rock from the stream flow and water course. Thus by removing the rock, much of the operational challenges can be overcome and sustainability of the system is ensured. The figures substantiate the results of this study under two conditions of having rock on the entry of the intake and not having one.

The mathematical models are emerging as the most effective and economically feasible tools for design and implementation of wide-ranging engineering works. However their applications should be considered upon their merits and should be careful not to consider them as a fix blueprint for project feasibility studies.

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