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ORIGINAL ARTICLE

Investigation of the two-dimensional model of water flow in the Gorgan Bay under the influence of various hydrodynamic factors using *Mike 21* software

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This research aims at studying the field and the nature of the flow pattern within the Gorgan Bay. The sandstone slabs of Miankaleh and Gorgan Bay openings under the hydrodynamic factors are constantly changing. Various factors such as wind, sea level fluctuations and flow are affected by this deformation.

In this paper, the two-dimensional hydrodynamic model of Gorgan Bay is presented using the Mike 21 hydrodynamic model software to calculate the flow velocity. Changes in water level at the only open boundary of the model (Ashuradeh - Turkmen port), Gulf primary water level, Meteorological parameters including precipitation, evaporation, wind speed and direction, time step, ambient heat exchange, and coefficient of roughness of the floor in the appropriate range to the model Applied. Using flow velocity data, the hydrodynamic model was accurately calibrated and verified. The results of the model state that the average direction of flow in a year in the Gorgan Bay is clockwise. The average water flow rate is 0.029 m/s, and the flow pattern calculated by the model is compared with the continuous measurements of flow through float tracking in two stages and the results are confirmed.

Key words: Gorgan Bay; Water Flow Velocity; Hydrodynamic model; Mike 21 sofftware

Introduction

The status of water bodies in human life is undeniable. Gulfs are important water bodies and very sensitive and fragile ecosystems in arid and semi-arid world, including Iran. Gulfs have a valuable role in the development of their marginalized communities and their vital effect is also visible to remote areas indirectly. Gorgan Bay and Miankaleh peninsula has been registered as one of the world's biosphere reserves of wildlife refuge due to have a great biological importance. Ecology of Gorgan Bay is affected by the Caspian Sea, adjacent rivers and the peninsula of Miankaleh which is important in the growth and reproduction of aquatic animals, fish and fish bones, cartilage and attraction of winter migratory birds. Research conducted in Gorgan Bay indicated that this water body is a good place for different aquaculture (Javani, 2012). In the current situation, facing with water shortage caused by drought and reduction of rainfall in the country, the preservation and management of water bodies such as gulfs and lagoons is essential. In order to carry out qualitative studies, locating and it is required that state of motion and flow in the body of water is known. So, one of the important requirements in water bodies' studies are performing of hydrodynamic study. Mathematical modeling of hydrodynamics simultaneously is possible and can provide the chance to measure and determine the pattern of changes in water flow velocity in the considered range. So far, many studies on hydrodynamic modeling is performed in water bodies, also, in several studies, Mike 21 software was used to design the hydrodynamic modeling. So, in any case in order to study accurately first of all the comprehensive investigation and accurate insights from studies of similar projects which was related to the topic is essential. Therefore, we will review some similar studies.

David et al. (2003) performed the hydrodynamic model MIKE 21 in the river channel in an area of 2 km and 14 km from the Gulf of Teignmouth in England. The result of sensitivity analysis after calibration program indicated the very low error in the model simulation and data analysis (David et al., 2003). Babu et al. (2005) studied modelling of tide-driven currents and residual eddies in the Gulf of Kachchh located in southwest India using Mike21 numerical hydrodynamic model. In this modeling, wind friction coefficient was equal to 0.002, Manning number was 38 and rotational viscosity was 0.5 and was calibrated. This study revealed that wind power has an important role in determining the hydrodynamics and sediment transport in the region so as to increase the southwest winds during January and July the tidal flow speed is about 20 percents and the rate of flow decrease equally (Babu et al., 2005).

French and Kerper 2004 using Mike software control the salinity of seawater in the Gulf of Ted and using the available data, the control of salinity was considered as a factor in improving the plant environment of Ted Gulf (French, Kerper, 2004).

Petersen and Rasch, 2005 with Modeling of seismic waves resulting tsunami off the coast of northern Sumatra in Indonesia examined how to create waves of ground motion and three-dimensional simulation software and how the waves took using Mike 21 software and its approach to these shores (Petersen, Rasch, 2005)

Materials and methods

Area of study: Gorgan Bay is located in the southeast of the Caspian Sea with an area of approximately 521 square kilometers and is considered as the largest Bay in the shore of Caspian Sea. The only open border of this Bay is Ashuradeh border in the northeast part which connects the Bay to the Caspian Sea (Fig. 1). The average length is about 40 km and the average width is about 10 km. its geographical coordinates are of 30°53′ to 03°54′ E and 36°46′ to 36°54′ N respectively. Part of the Bay is located in Golestan province and other parts of Mazandaran province. Gorgan Bay has a level-polling station digital which is located in Ashuradeh region and flush the water every 10 minutes once picked (Fig. 2).

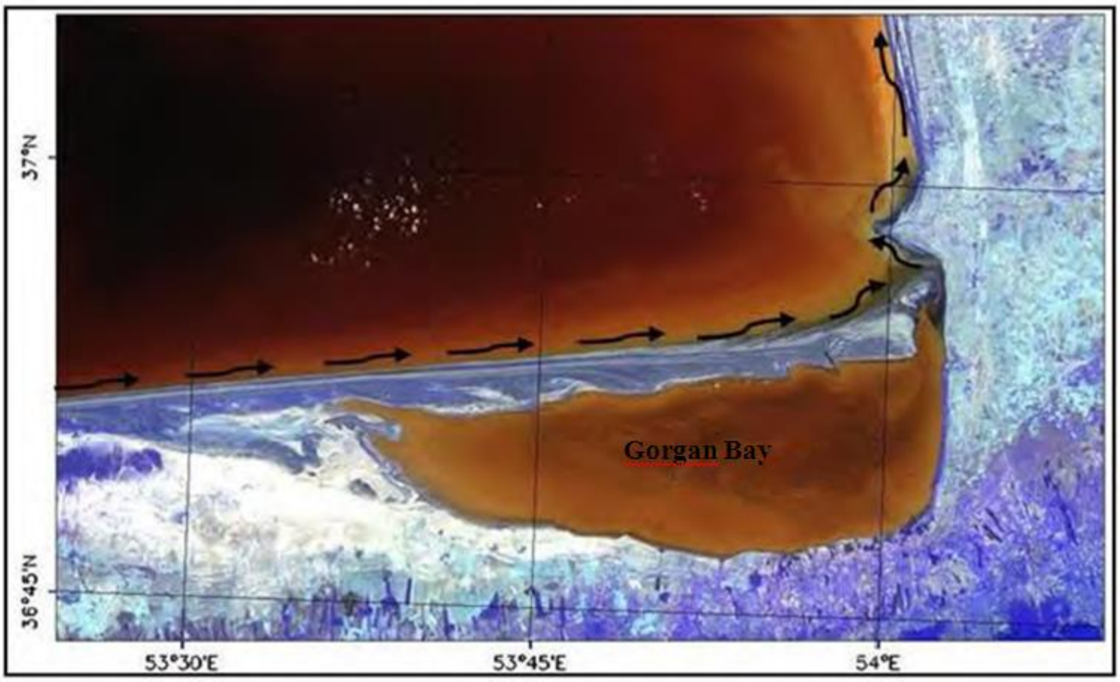

Fig. 1. The study area.

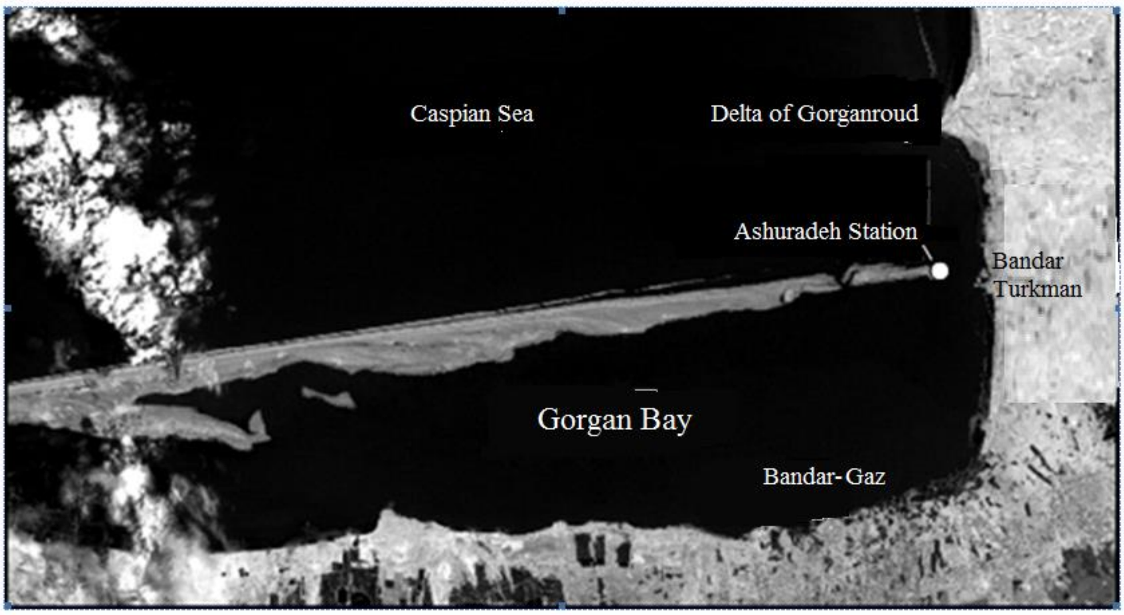

Fig. 2. Regional level gauge stations of Ashuradeh

The governing equations in the software Mike21. Mike 21 is a two-dimensional model (longitudinal and transverse) which has been developed by a Danish Hydraulic Institute (DHI) which is one of the most important and most prominent research institutions in the world in the field of hydrodynamics. This software supports hydrodynamic modeling for the kinematic wave, reflective and is quite dynamic. In this model, the assumption is made that there is no change in the vertical dimension this assumption seems reasonable because in Gorgan Bay the water depth is very small compared to its level. Mike21 hydrodynamic model is worked based on discrete finite difference method for the equations of continuity and momentum. Therefore, in this study, according to the capabilities Mike 21 model, the model for hydrodynamic simulation is used to calculate the water flow velocity. The governing equations of hydrodynamic model (Table1) are presented. The parameters used in the equations of hydrodynamics are presented (Table2).

Table 1. Hydrodynamic equations of the model Mike 21.

Formula	Equation
$\frac{\partial \zeta}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = \frac{\partial d}{\partial t}$	Conjunction
$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial x} + gp\sqrt{\frac{p^2+q^2}{c^2h^2}} - \left[nu_x\frac{\partial^2 p}{\partial x^2} + nu_y\frac{\partial^2 p}{\partial y^2}\right] - \Omega q = 0$	Momentum in the direction of x
$\frac{\partial p}{\partial t} + \frac{\partial}{\partial y}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial x}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial y} + gp\sqrt{\frac{p^2+q^2}{c^2h^2}} - \left[nu_x\frac{\partial^2 p}{\partial y^2} + nu_y\frac{\partial^2 q}{\partial x^2}\right] - \Omega q = 0$	Momentum in the direction of y

Table 2. Parameters used in the equations in the model Mike 21.

Parameters' definiton	Parameters' Mark	Parameters' definiton	Parameters' Mark
Water depth	h	Coefficient of viscosity	nu
Water level	(x,y,t)ζ	Chezy coefficient	C
water depth changes	d(x,y,t)	Coriolis parameter	Ω
Flux density in the direction of x and y	p,q(x,y,t)	Gravitational constant	g
Time		t	

Research Algorithm

According to the measured and collectd information modeling was considered for a period of one year, 2011, this period was intended to do modeling. Research algorithm (Fig. 5) is presented. Then, the steps shown in (Fig. 5) are described briefly in Fig. 5. In order to access the information of water border, Mark Line and deep-water of Gorgan Bay hydrographic modeling and geodetic field operations in the area was performed. Water harvesting and Mark Line were performed using Nivo Total Station and took a handheld GPS device, the base is used for all harvested areas land surveying and hydrographic operations, BM Precise Leveling wast the balance equal to -23.32 meters from the high seas (Yarinasab, 2012). The input data includes the following models: Time changes of Gorgan Bay in 2011 when the water level open border with Digital level gauge stations of Ashuradeh occurs each 10 minute (Fig. 3).

Fig. 3. Time changes in the water level of Ashuradeh station in the period when modeling

The wind changes for 10 minutes of synoptic station in Bandar Turkmen were picked due to its proximity to the Gulf was harvested. Regarding to (Fig. 4), windrose of synoptic station in Bandar Turkmen in the period plotted model.

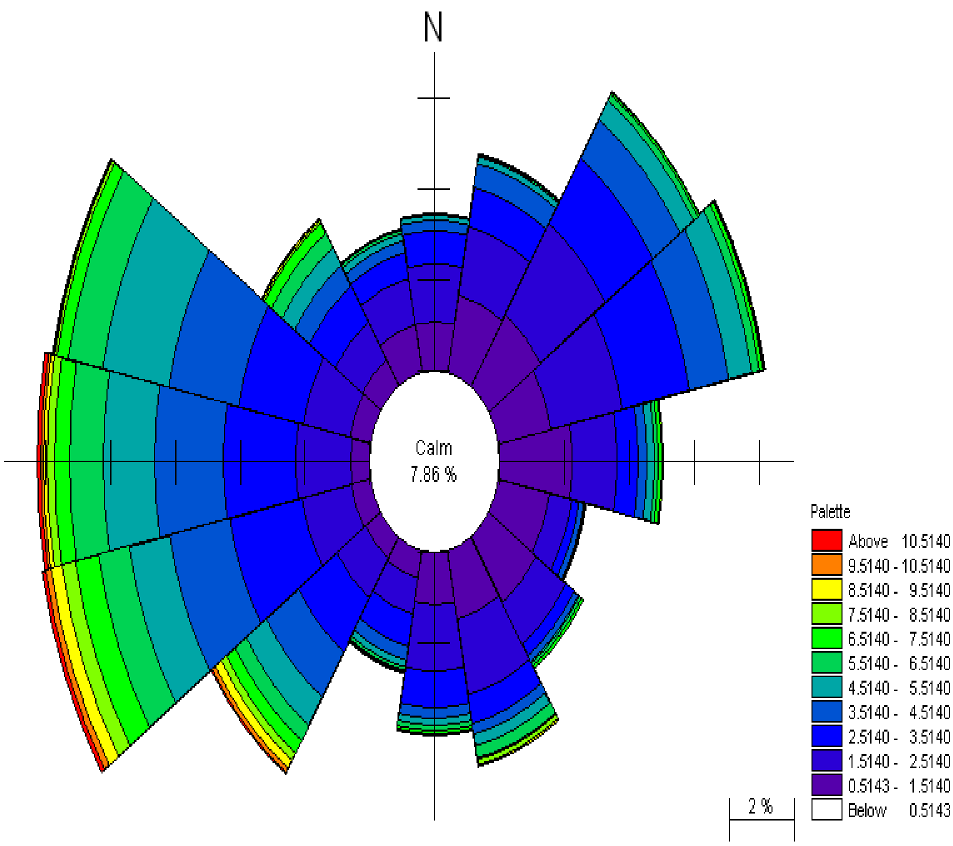

Fig. 4. Wind rose synoptic station in Bandar Turkmen in the period

Time changes in effective precipitation (precipitation minus evaporation) were collected to be 10 minutes of evaporation station and were collected by rain nearby lake. Step running time of 600 seconds was considered the model that fits courant number was 0.7. After creating input files and import them into a hydrodynamic model using Manning roughness coefficient, water flow velocity was extracted. For calibration and validation operations to a series of real values of the parameters of the water flow velocity the data parameter measured flow velocity has been achieved in the Gorgan Bay. This step must be performed the operation hydrodynamic model calibration and optimization of Gorgan Bay Manning roughness coefficient to be determined. During calibration operation, hydrodynamic modeling for different values of the coefficient of Manning in range (0.0-02.025) was repeated, the results of modeling indicated the difference with Manning roughness coefficient values. For the calibration of flow velocity field information was used in the Gulf. At this stage, after hydrodynamic model calibration, validation of the models was performed. Model verification results indicated that the model is the development and calibrated thus, if a hydrodynamic model developed for the Gorgan Bay by a factor of 0.021 Manning is approved it can be used for any period of time and for the entire Gorgan Bay.

Results and discussion

Gorgan Bay behavior under the influence of various factors on the hydrodynamic. The effect of entrance debi on open border of Gorgan Bay.

General circulation of water in Caspian Sea can enter flows through the northeast open border of the Gulf, even if in the absence of large fluctuations in the water level of the Caspian Sea in Gorgan Bay does not exist. Mean flow velocity at different levels was about 0.15(m/s). According to the strait and its average depth, the rate of debi was approximately 450-650 Cubic meters per second respectively. As shown in (Fig. 5) the entrance of flow occurs due to the narrow lanes of the Strait and has created a remarkable velocity in flow, the velocity resulting in areas of central and western was not remarkable. The flow was in the direction towards the south and southwest.

Caspian Sea level changes at the entrance to Gorgan Bay

One of the factors that could cause significant flows in the Gulf of Caspian Sea is the rise of water level and its impact on the Gulf through the Strait. Due to the rising water will cause a dip in the water level, the Gulf will create far greater speeds. Such a flow due to fluctuations in the Caspian Sea could be important. However, due to the fluctuations that occur during longer changes was more slowly and therefore create fluctuations in the flow pattern can be effective in the long run. Analyzes conducted by the model also confirms this issue. These analyzes indicated that by the rise of sea-level to 0.5 meters at a speed of about 0.11 meters per second at the beginning of Gulf Stream there is far more to have delivered the bay in the longitudinal direction of the effect that of entering debi. In this case, the direction of the prevailing flow was along with the length of the bay and was the only input at the beginning of the bay which dumped into a bit to the south near the border (Fig. 6). Such a model shaped after about 3 hours of rising water in the Gulf and after about 13 hours reduce after removing the water from the bottom of the bay to the primary areas, the velocity began to decline stems.

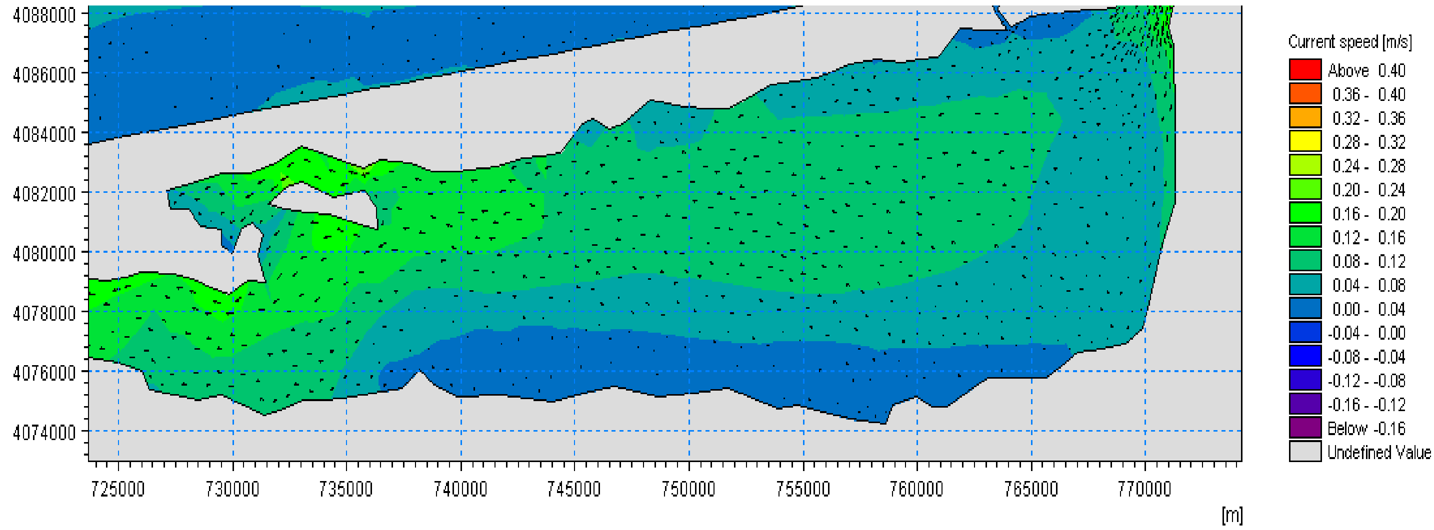

Fig. 5. The input of flow in the Gulf due to the open border

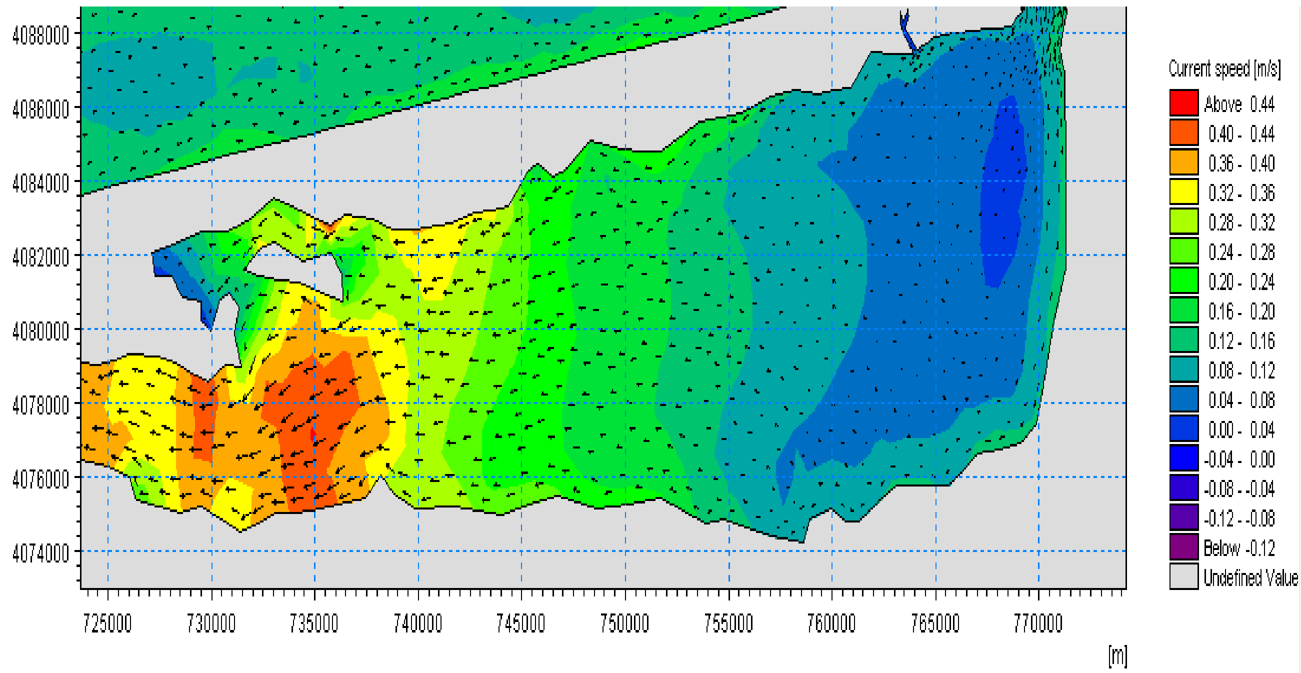

Fig. 6. The flow pattern in the Gulf created by the rising of water level in the inlet of Gorgan Bay Wind Effects.

In general, the effect of the wind on the water flow velocity level is visible and is effective on the flow pattern of lower depths especially in cases where the effect of other hydrodynamic factors is strong. Of course, this issue is largely due to changes in wind direction, velocity limits and most importantly depend on the wind continue and this latter factor can play a major role in creating a stable and effective pattern of wind-driven flow. Wind rose checking in area (Bandar Turkmen station) illustrated that winds over 5 meters per seconds are low in the area. Regarding to the annual winds blowing at a speed of 2.5 meters per second can be representative to examine the effect of the wind. The speed and direction of wind blowing across the bay from south to north creates after about 4 hours the same flow pattern (Fig. 7). It is seen that the created velocity is negligible. Due to low width of bay in wind direction, the created flow after the collision to these borders returned and gradually created vortex flow patterns in the border of Gulf. In the case of a large entrance to the Gulf does not exist to openings, the resulting vortex flow of the wind scattered around the entire bay will prevail. The vortex intensity depending on the wind speed and roughness of the substrate somewhat moved by changing the values dumped into them, but the general pattern is the same in all cases.

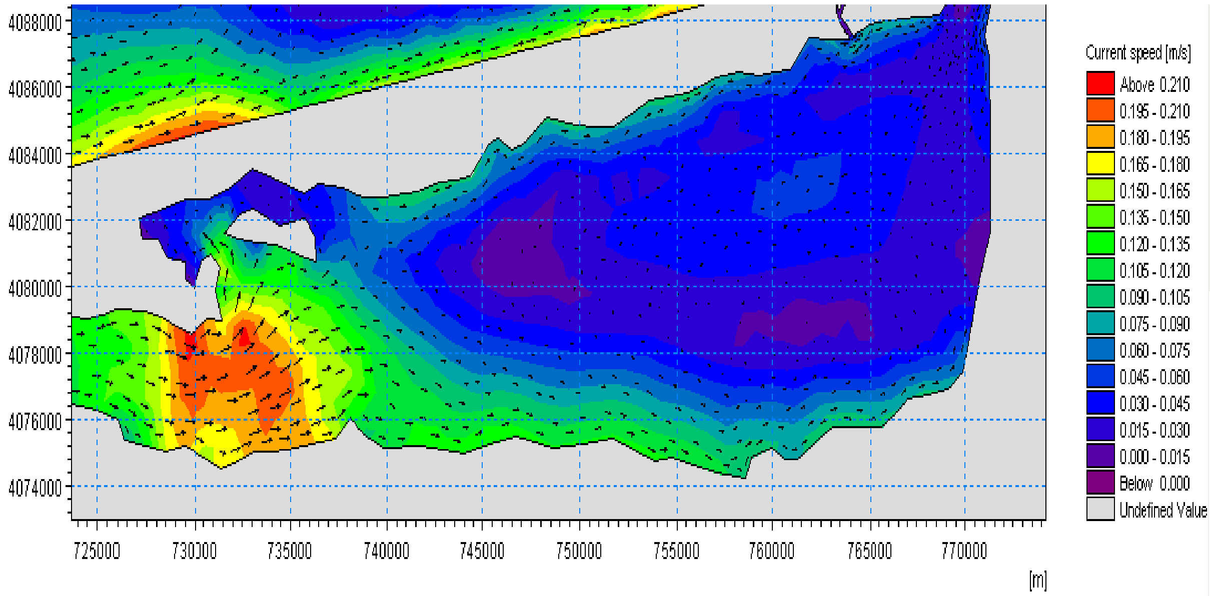

Fig. 7. The flow pattern created by the wind blowing at a speed of 2.5 meters per second in the Gulf

The effect of rainfall and evaporation

The usual amounts of rainfall and evaporation in the implementation model represent a very small impact of these factors of the bay on stream. In fact, these two factors are important particularly evaporation in creating long-term cycles.

For depth measurements, after entering the border points and Gulf level data into the Mike software, the interpolation of the aligned data is performed and the Gorgan Gulf Water Mapping Map is constructed in the Mike 21 environment in (Fig. 8) is provided. Modeling was performed with different amounts of Manning roughness coefficient and finally, the amounts of Manning in the calibration factor was equal to 0.021 respectively.

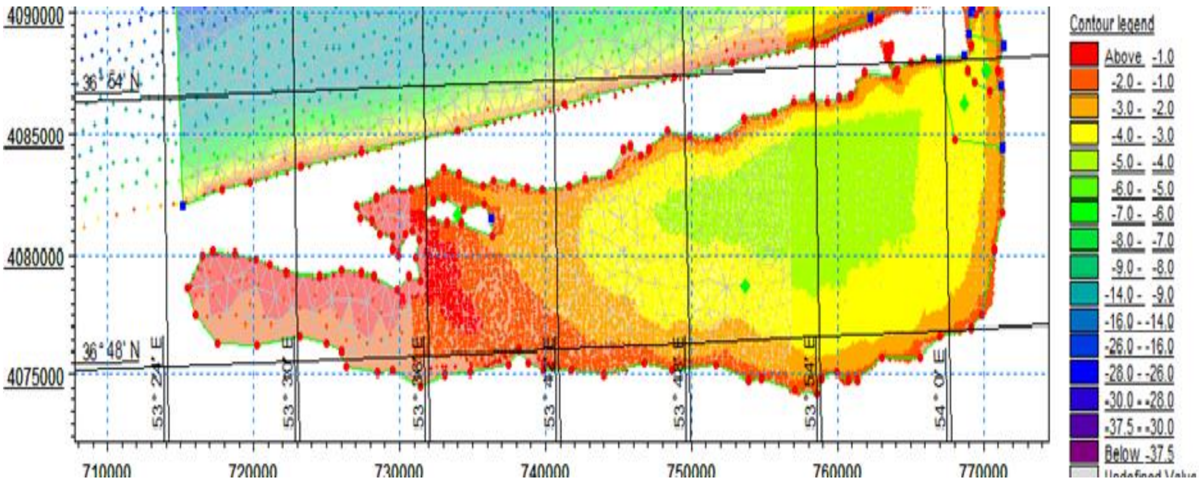

Fig. 8. Align map of Gorgan Bay in MIKE21

In this section, the results of the calibration and validation of hydrodynamic model is presented. In (Fig. 9) the flow velocity values obtained from the model with the actual flow velocity obtained in April 2011 in the Gorgan bay were compared for calibration.

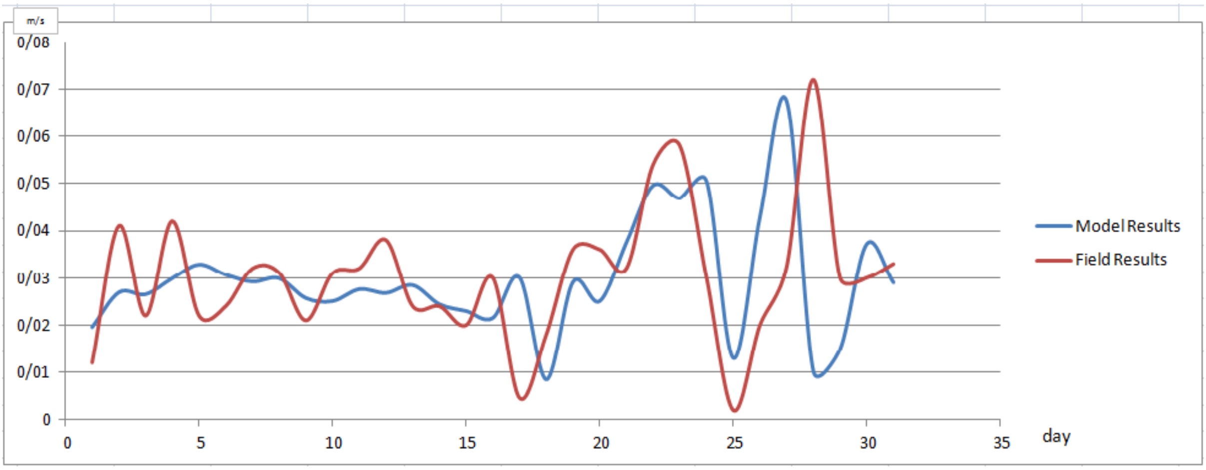

Fig. 9. Water flow velocity obtained from the analysis model and values of the field in April 2011

After calibration of hydrodynamic model, it is needed for validation of the model. Manning optimal accuracy by a factor of 0.021 was carried out in (Fig. 10) values water flow velocity of the model with actual results in the first eight days of May 2011 were compared together. Overall dozen results demonstrated appropriate modeling.

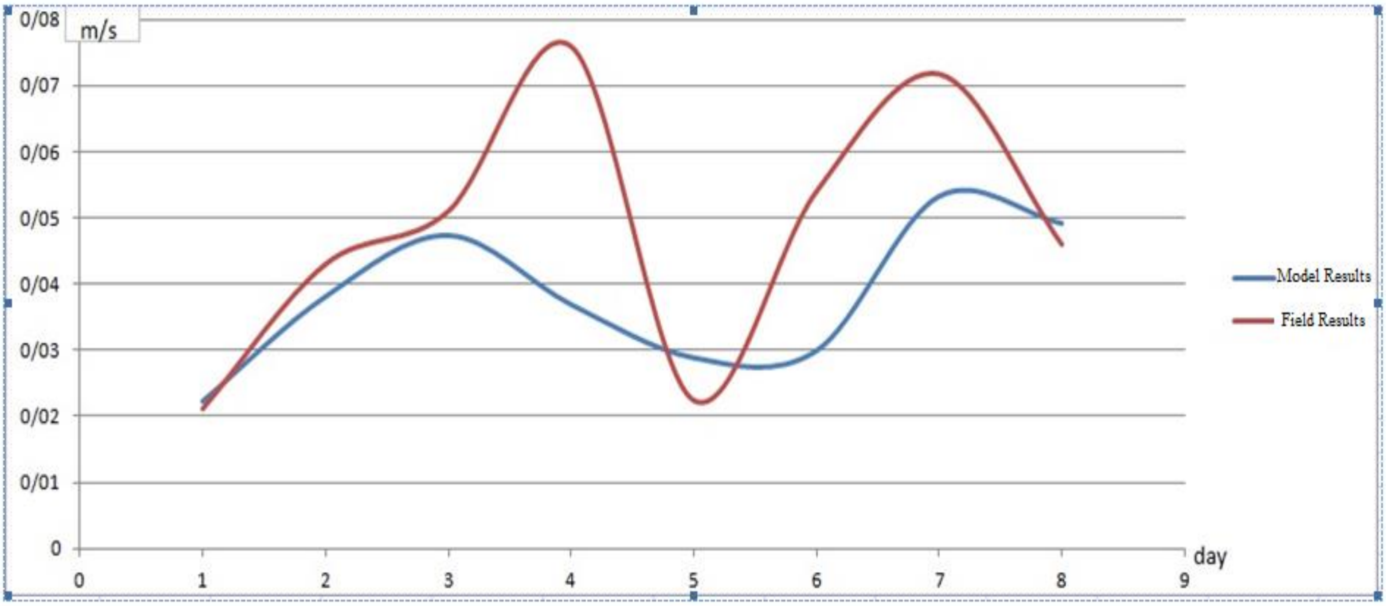

Fig. 10. Water flow velocity obtained from the analysis model and values of the field in the first eight days of May 2011.

However, Gorgan Bay hydrodynamic model has been developed that would be state of the water flow velocity of the hydrodynamic model output, for utilization in different areas of Penn Culture including the creation and development of a variety of fish species extracted. Therefore, the Average amount of water flow velocity was 0.029 meters per second.
The mean flow direction in the Gorgan Bay is from the west to the east and is clockwise (Fig. 11) The flow velocity and vector velocity for water flow in the Gorgan Bay are shown (Fig. 12).

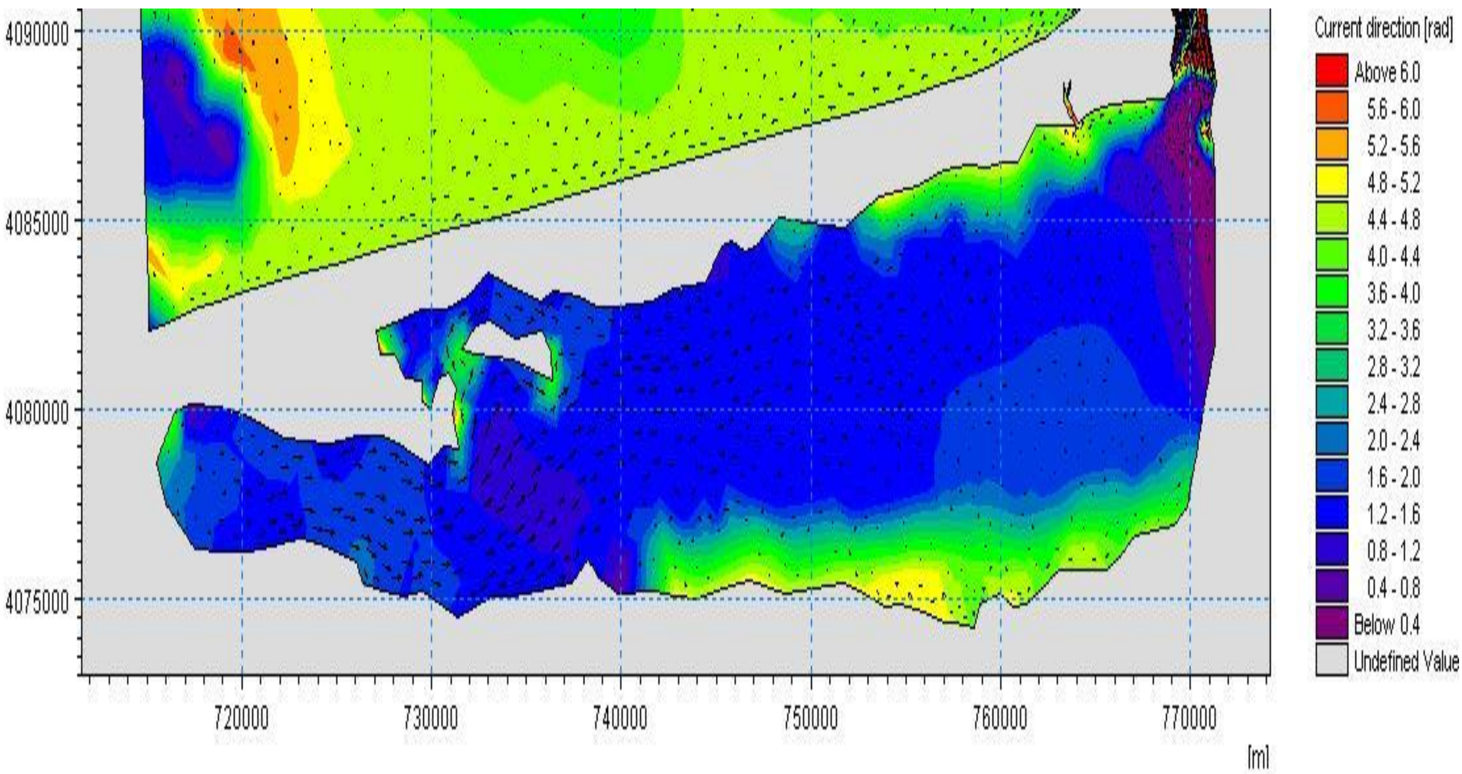

Fig. 11. For the flow of water in Gorgan Bay (2011)

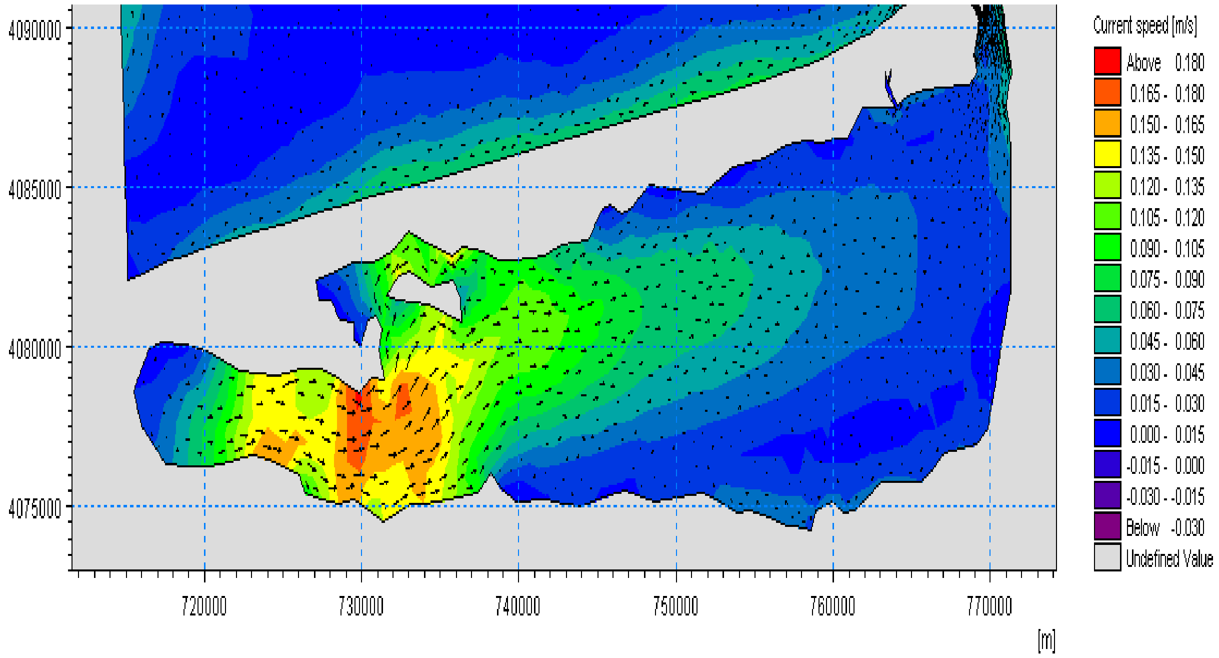

Fig. 12. Flow rate and water flow velocity in Gorgan Bay (2011)

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