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The Modelling of Bathymetry Changes in Creation of rip Currents

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Abstract: In this research the rip currents and effects of bathymetry, on creation of this phenomena, is modeled. One of these bathymetry changes is perpendicular rip channel to a shore. The rip channel was modeled by Mike21 software, BW model and the effects of rip channel on creation of rip currents were studied. At first a shore with constant slope was modeling and then, creating rip channel at the center of the model, modeling toke place. Crating rip channels, a powerful returning current toward offshore was created at the middle of shore which its velocity was twenty times faster than the velocity of returning current belonged to constant slope. These returning currents cause drastic fluctuation on the height of water in a 1.5m range. At the middle of rip channel, the height of water is always lower than the other areas beside it (at distance less than 200m from center). After formation of the circular cell pair of currents, which together form the rip current, three critical areas were created in the shore which can jeopardize the life of individuals and also can cause changes at the shore bottom of sea, gradually.

Key words: Rip current, Rip channel, Wave, Bathymetry

INTRODUCTION

Shore currents have important role in transferring of sediments both along shore (alongshore currents) and toward sea (rip currents). Rip currents are approximately perpendicular to shore, seaward-directed jets that originate within the surf zone, and broaden outside the breaking zone and can relatively have fast velocity (see fig. 1). These currents naturally fall down in the surf zone area and then oriented toward sea and flow toward it.

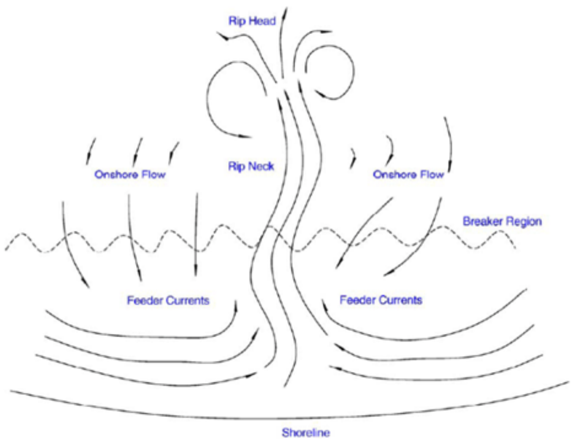

Fig. 1: the structure of rip current (MacMahan *et al.,* 2006).

Also, these currents have the velocity of 0.5 to 1 m/s and in Palm Beach in Australia, they reach to 2 m/s (MacMahan, J.H. and Thornton, 2005). Rip currents flows are partitioned into mean, infra gravity, very low frequency (vorticity), and tidal contributions, and it is found that each contributes significantly to the total. Data from the laboratory and the field suggest that the rip current strength increase with increasing wave energy and decreasing water depths. The maximum mean current occurs inside the surf zone, where the maximum forcing is present owing to the dissipation of waves.

Identifying ways of rip current consist of:

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-The existence of a stormy and turbulent water channels
-Color Differences of water (it's possible that suspended sediments come back to sea)
-The existence of spume line having sphagnum and mud toward the sea.
-Breaking in the pattern of incoming waves

The direction of the placement of shore and angle of incoming waves are the essential key of understanding the potential of the formation of the rip currents in special shore (Dronen *et al.,* 2002).

The boundary interactions of waves, the morphology of the bottom of surf zone areas, the mild slope of shore, rip channel, offshore structures, sand bars along the shore and tides are playing role in formation of returning rip currents. The numbers of rip currents in the shore with mild slope are seen more than the areas with steep slope but the width of the head of rip currents in the coasts with steep slope are wider (MacMahan *et al.,* 2008).

Structure of Rip Currents:

Rip currents are formed when the waves and water are accumulated near the coast and, then, they suddenly turn back toward the sea. So, the velocity of rip currents is variable and may, during some minutes, be increased by interring of bigger waves or instabilities of the circulation of water. Whatever the rip currents have more distance to each other they have more velocity, and whatever the rip currents have less distance it indicates a less velocity (Dronen *et al.,* 2002).

Essential structure of rip current is others side of breaking zone and is determined by fungous propagation or circulation. This part, in which the velocity and resistance of rip current is weakened significantly, is known as the head of rip current. Another part of rip current is known as the jet of rip current that it is located in the breaking zone and is defined by slender strip of water with high velocity fig. 1. A rip current is more dangerous when it has more velocity and more rotation. The current feeders, also, become convergence and appear parallel before forming the jet of rip current (Beji S. and Battjes J.A., 1993).

Theory of Rip Currants:

To study more about most of the cases which cause appearing of rip currents which are good motivator to expand these currents, it's better to know about different theories of rip currents; the first attempt was made to describe rip currents according to Kinematic argument. But if the distance between rip currents goes toward extreme, the flow which passes throughout the rip channel, inevitably, should goes toward extreme and, clearly, such a thing will not happen. Svendsen *et al.* (2000), numerically found that the total transport through the rip channel does not depend on the spacing of the rip channels (Svendsen *et al.,* 2000).

All dynamical models of rip currents are forced by alongshore variations of wave height that result in alongshore variation in wave-induced momentum flux, termed radiation stress by Longuet-Higgins and Stewart (1964). A convenient starting point is the depth-integrated, horizontal momentum balance equation that are averaged over many wave groups representing stationary wave condition (Phillips, O.M., 1977).

The Perception of rip current ordering is very important and determinant to foresee its occurrence. Rip currents can be determined by depth changes in the coastal line which can affect on breaking wave pattern changes and It is due to the movement of water current from a cross column toward water channels.

$$d/d_{xj}(\tilde{U}_i\tilde{M}_j + Si_j) = -\rho g(h+\tilde{\eta})\frac{d\tilde{\eta}}{dx_i} + R_i \tag{3.1}$$

Where i,j=1,2, and M_j is the total mean momentum flux per unit area, U_i is the depth averaged velocity (u_i= m_i /(p(h+η)), S_{ij} are the radiation stress, η is the mean water level and h the still water depth, and R_i are the stresses. Considering the cross-shore (x) momentum balance equation, and assuming the waves are normally incident and bottom contours straight and parallel, changes in cross-shore radiation stress, S_{xx} , are balanced by the hydrostatic pressure gradient,

$$\frac{ds_{xx}}{dx} = -\rho g(h+\tilde{\eta})\frac{d\tilde{\eta}}{dx} \tag{3.2}$$

Where ρ is the density of seawater and g is the gravitational acceleration. Applying linear wave theory in shallow water, S_{xx}=(3/2)E, where E is wave energy, results in wave set-down outside the surf zone as the wave energy increases due to shoaling, and set-up inside the surf zone as the waves break and the energy decreases (Bowen, A.J., 1969).

The vertical imbalance between the cross-shore pressure gradient and wave forcing produces an offshore return flow within the surfzone between the bed and the trough that often is referred to as undertow (Dyhr-Nielsen, M., Sorensen, T., 1970). In the tree-dimensional case of alongshore variations in wave height of normally incident waves on an alongshore uniform beach, the larger waves generate larger set-down/up, which creates alongshore pressure gradients both outside and inside the surf zone. Considering the alongshore (y) momentum equation, forcing is given by

$$Fy = \frac{dS_{yy}}{dy} - \rho g(h+\tilde{\eta})\frac{d\tilde{\eta}}{dy} \tag{3.3}$$

Where S_{yy}=E/2 in the shallow water. Out of the surf zone, alongshore pressure gradients are balanced by the alongshore gradients in radiation stress. However, inside the surf zone, the gradients in the alongshore radiation stress and pressure act together to produce a flow of water from the regions of high waves to the regions of low waves. Approximating wave breaking as proportional to the total depth of watern$H=\gamma(h+\eta)$, and $E=1/8\rho gH^2$, the alongshore momentum balance in the surfzone is given by:

$$Fy = \frac{1}{8}\rho g y^2 (h+\tilde{\eta})\frac{d(h+\tilde{\eta})}{dy} - \rho g(h+\tilde{\eta})\frac{d\tilde{\eta}}{dy} \tag{3.4}$$

Rip spacing is often observed to be quasi-periodic at O(100m), motivating modeling efforts to find and impose alongshore perturbations on this scale. Mechanisms used to explain alongshore variations in wave height can either be wave-wave interactions (Bowen, A.J., 1969), or imposed perturbations either on wave height directly, or on bathymetry, that results in variations in wave height owing to shoaling, refraction and breaking (Dalrymple, R.A., 1975).

Starting with models on alongshore homogeneous beaches, Dalrymple and Lozano (1978) imposed alongshore wave height variations to show that refraction by the outgoing rip current causes the waves to impinge on the beach obliquely, generating convergent longshore currents, which then flow offshore as a rip current. The result is a self-sustaining rip current, although the initial perturbation on the wave heights is not addressed. Alongshore variation of wave height can also be the result of wave-wave interactions.

Bowen (1969) was the first to show that alongshore perturbations in bathymetry result in alongshore variations in wave height, which generate rip currents. A number of models have followed with various refinements, which include improved nonlinear bottom shear stress and turbulent momentum mixing (Noda, E.K., 1974).

More recent models, although forced by monochromatic waves, allow for time dependence, include nonlinear Boussinesq waves in which wave-current interaction is incorporated (Sorensen *et al.,* 1998), and have a quasi-3d formulation (Haas *et al.,* 2003). Wave-current interaction is included by Yu and Slinn (2003), who find that the rip current produces a negative feedback on the wave forcing to reduce the strength and offshore extent of the flow. Complex flow patterns result with instabilities formed at the feeder currents with the unsteady rip flow characterized by vortex shedding.

Governing Conditions:

One of main reasons of creation of rip currents is normal rip channel on the shore. Consequently, here we study this characteristic and its effects on creation of rip current. To study this characteristic, initially, a shore without rip channel and with 3.3 % slope is considered and model making is done for it. In the next step, a shore with 3.3 %slop with a rip channel at the middle of it is considered and the modeling is performed for it (see fig. 2).

Within two presented model in this study, domain ranges are 1200m * 1200m, the height of regular waves is 2.8m, its period is 7.9 s (the total time of model making is 20 second). For all models a spongy layer is purposed to attract waves in the offshore and one is purposed in the shore.

A filter is used in order to remove high frequency of waves which is created during wave attacks and it is, also, devised in order to control and remove wave energy, where the surface roller waves doesn't disappeared. These filters are applied in the waters which have less than 0.5 m depth.

5. The Results and Analysis of Modeling:

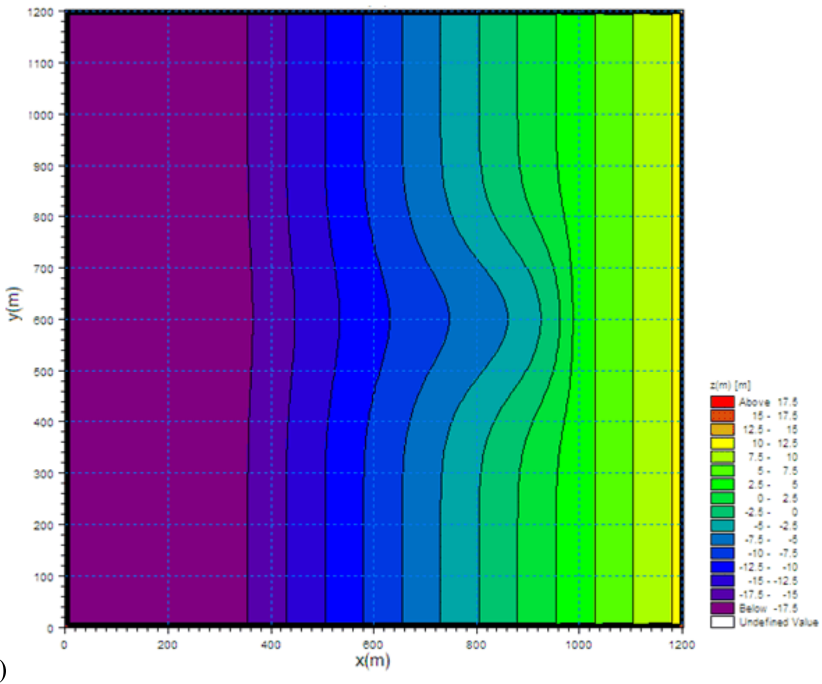
5.1. Shore with Constant Slope:

In the fig. 3 a view of wave run-up is shown. The velocity and height changes is the same and don't create any rip current along the shore.

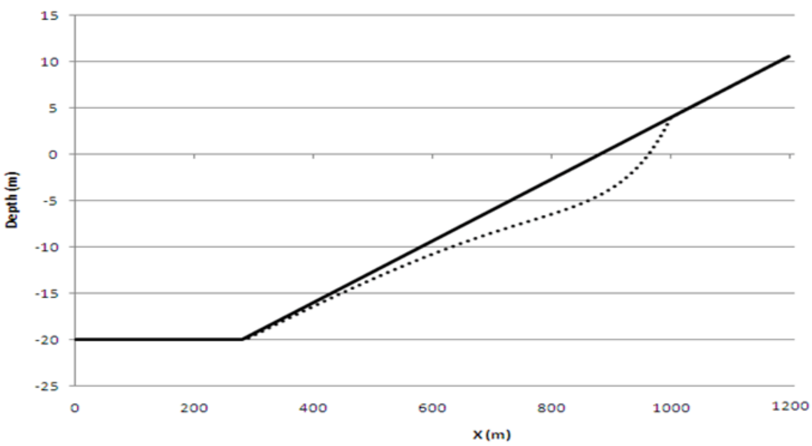
5.2. Shore with Rip Channel:

Field of wave of model is shown in the fig. 4. this picture was taken 15 minutes after starting of the simulation when the rip current is created by two circular cells. The surface rollers are shown in white.

Due to the increased depth and due to depth refraction by the rip channel, incipient breaking is seen to occur comparatively close to the shore along the centerline. Here, the setup is quite small and the larger setup appearing away from the rip channel gives an alongshore gradient in the mean water surface forcing a current towards the centerline. The flow from the two sides join to form a rip current and two symmetrical circulation cells appear. A contour plot of the shore- perpendicular velocity (shown by u) is shown in the fig.5. and Fig. 6. Fig. 6 is subdomain of fig. 5 through which can show the velocity changes in rip channels easily. It is seen that three nearly circular areas are located in (896 m, 570 m), (896 m, 630 m) and (850 m, 600 m) which have the velocity higher than 1.2 m per second in direction of the offshore. These velocities threatened the life of any swimmers. In fig. 7, velocity in the rip channel areas is demonstrated vectorially and velocity besides of rip channel is parallel to the shore and in the central part of rip channel, currents are perpendicular to the shore. so to perceive the velocity changes in direction perpendicular to shore (u) and parallel shore (v) ,the velocity changes is shown in the fig. 8 and fig. 9 in coordinates of (896m, 570m) and (850m, 600m) in a 15 minutes period of time.



(a)



(b)

Fig. 2: Model setup for the rip channel test. (a) Contour plot of the bathymetry and (b) beach profiles. (—), along a plane beach section; and (…), Along the rip channel.

According to fig. 8, it is cleared that the velocity of u in the center of channel to the outsides of channel is more than, and it is toward offshore. it causes the interaction between incoming waves and toward offshore currents and also cause a wave height decrease in the center of rip channel to its sides (in the distance less than 200 m from the center of rip channel), as shown in fig. 10. But the height of wave at the center of the channel is variable to the areas far from the center of rip channel (in the distance more than 200 m from the center of rip channels) in different times, as in the time of t = 16 min and t = 17 min, changes of the height of wave in the center are respectively less and more than areas which are far from the center of channel. Generally, return currents toward the offshore cause drastic fluctuations in the height of water at the center of rip channel. These changes have the tolerance of ± 1.5m.

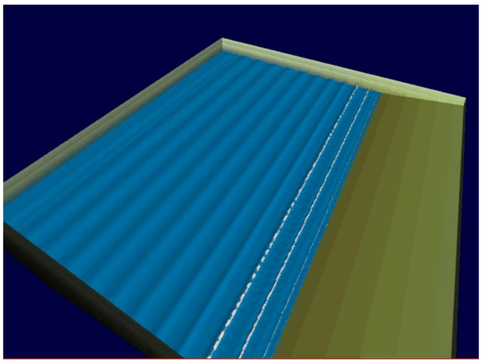


Fig. 3: Instantaneous surface elevation for the shore with constant slope (the surface rollers are shown in white).

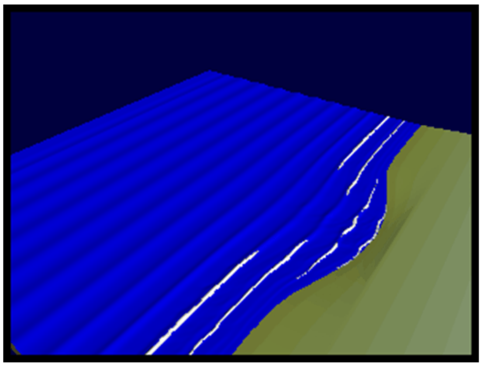


Fig. 4: Instantaneous surface elevation for the rip channel case (the surface rollers are shown in white).

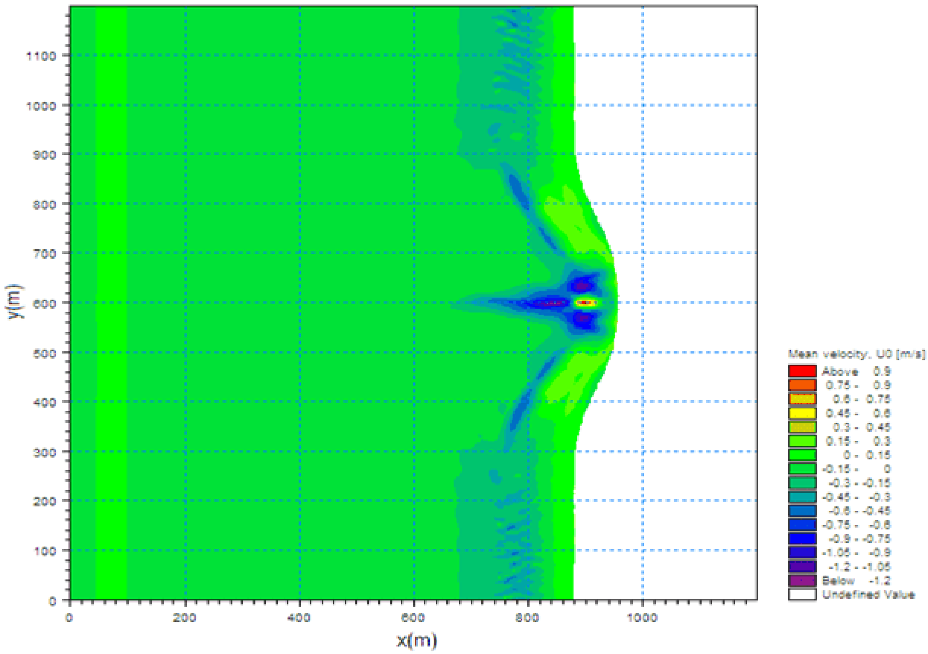


Fig. 5: Snapshot of Instantaneous velocity perpendicular to shore (u) in the time of t=16 min.

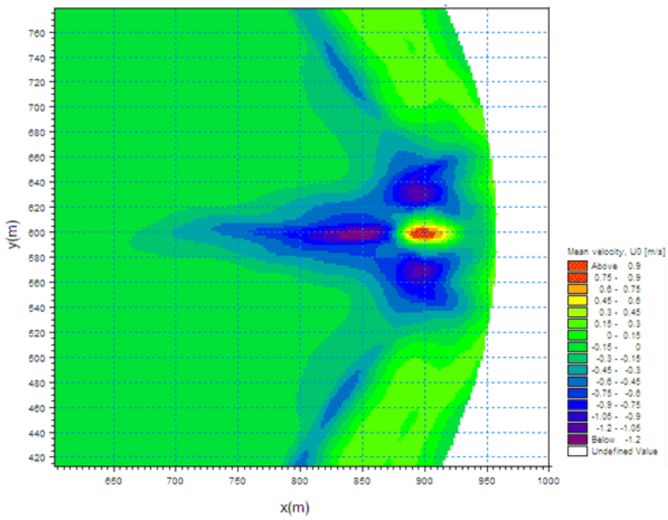


Fig. 6: Snapshot of Instantaneous velocity perpendicular to shore (u) in the time of t=16 min (fig. 7 is a subdomain of fig. 6).

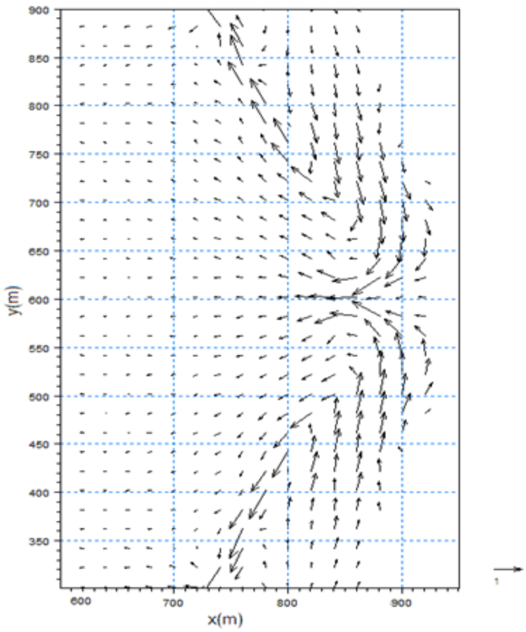


Fig. 7: Depth-averaged velocity focusing on a rip channel.

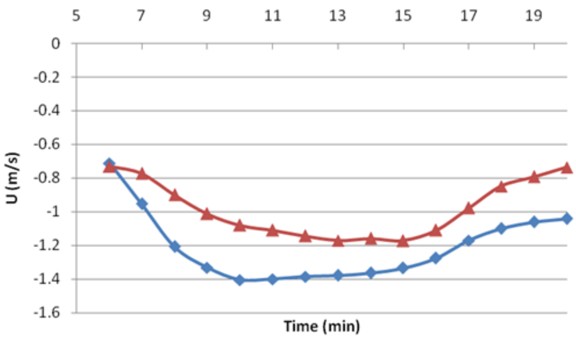


Fig. 8: Velocity changes perpendicular to shore, the line (–Δ–) represent the velocity in the coordination of (896 m, 570 m) and the line of (–○–) represent the velocity in coordination of (850 m, 600 m).

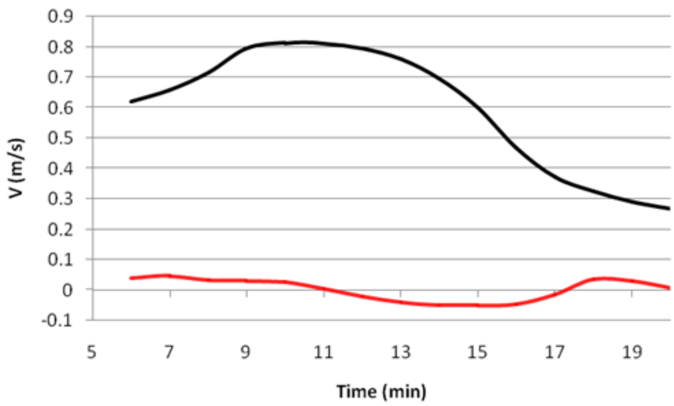


Fig. 9: Velocity changes parallel to the shore (v), the black line represents the velocity in coordination of (896 m, 570 m) and the red line represents the velocity in coordination of (850 m, 600 m).

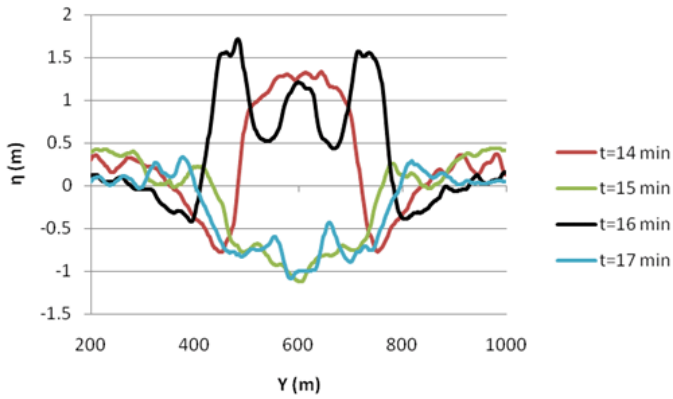


Fig. 10: Height changes of water along the shore where with the length of x = 850 m

Also it is clarified from the fig. 9 that the velocity v, has more velocity in the sides of rip channel to the center of channel which these velocity changes themselves indicates the circular structure of rip currents.

Finally in order to study the effects of rip channels on the shore, the velocity perpendicular to the shore (u) is compared for constant slope of shore and the shore with rip channel together. Fig. 11, clearly, shows the effects of these channels on creation of rip currents in the sides of the shore.

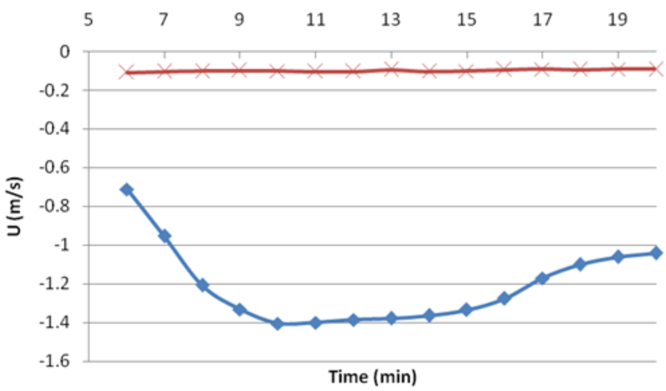


Fig. 11: Velocity changes in coordination of (850 m, 600 m), the line (–×–) represents the velocity in shore with constant slop and the line (–□–) represents the velocity in the shore with rip channel.

Conclusion:

In this research it is cleared that the existence of rip channels cause the creation of powerful rip currents which can create the velocity about 20 times more than shores which doesn't have rip channels. These currents can extend to areas near a shore.

Returning velocity of currents is more in part of jet of rip current to its outsides. But in general conditions, water height changes at the center of a channel are some times less and they, some times, are more from areas which are far from a channel. The water height changes are very much at the center of channel. These changes are about ±1.5 m.

In the other hand, the alongshore velocity is more than outsides of rip channels to its center. This causes the attraction of individuals who are outside of jet of rip current toward the channel or the center of the current, so their life is jeopardized.

In order to development of recognition of a rip current, the effects of the slop of shore, the alongshore bar on rip channels and the effects of a rip channel on sedimentations of areas should be studied.

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