Lowland Technology International 2018; 20 (3):351-356
International Association of Lowland Technology (IALT): ISSN 1344-9656

Research Paper

Effects of hydrodynamic regimes from a proposed marine park in monsoon seasons

N.T. Mai [1] and N.T.M. Hang [2]

ARTICLE INFORMATION

Article history:

Received: 06 January, 2018
Received in revised form: 21 May, 2018
Accepted: 23 May, 2018
Publish on: 07 December, 2018

Keywords:

Hydrodynamics
Sediment transport
Monsoons

ABSTRACT

The process of building the Son Tra Ocean Park in Danang city, Vietnam will contribute certain impacts to hydrodynamic regimes leading to erosion or accretion on the coast. In this paper, we used numerical models to simulate hydrodynamic flows, waves, and sediment transport for two scenarios of “without” and “with” project. The results showed that the Park would alter the dynamic flow and lithospheric process in the area and surrounding. Most affected range is of about 200m-800m from the location adjacent of Park. Nearshore current velocity is increased and accretion and erosion in monsoon seasons are usually mild.

1. Introduction

Son Tra Ocean Park has been planned to be built at Son Tra peninsula, Da Nang city, Vietnam with the area of nearly 100 ha, of which reclamation area is accounted for 75% (**Fig.1**).

Danang city is located in the Central coast regions have very sophisticated topography: narrow flat areas with some small and low hills on the East and a part of Truong Son high mountain ridge on the West with many mountains pass crossing to the East (Yokoi and Matsumoto, 2008). The topography is quite a steep stretching from West to East, causing the very short and steep rivers.

The construction of the Park will have certain impacts on waves, hydrodynamic flows and so on (VNN, 2017a, 2017b, Sun Group, 2016). This paper therefore presents the application of models for simulating erosion, and sedimentation so as to providing sound technical solutions for construction.

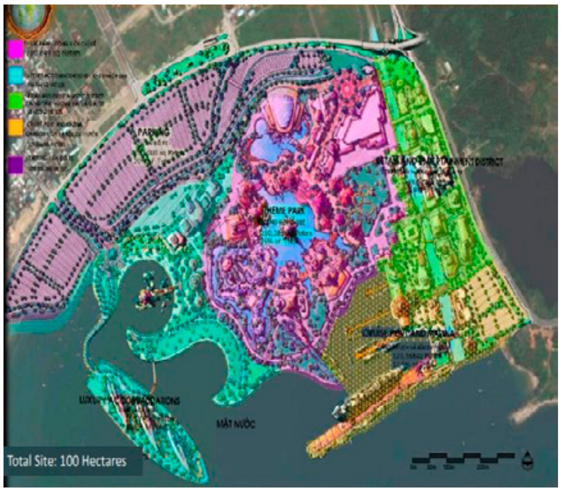

Fig. 1. Project of Son Tra Ocean Park.

[1] Institute of Physics, Vietnam Academy of Science and Technology, Ba Dinh, Hanoi, VIETNAM
[2] Corresponding author: Assoc.Professor, Thuyloi University, 175 Tay Son, Dong Da, Hanoi, VIETNAM, hangntm@tlu.edu.vn
Note: Discussion on this paper is open until June 2019

2. Methods

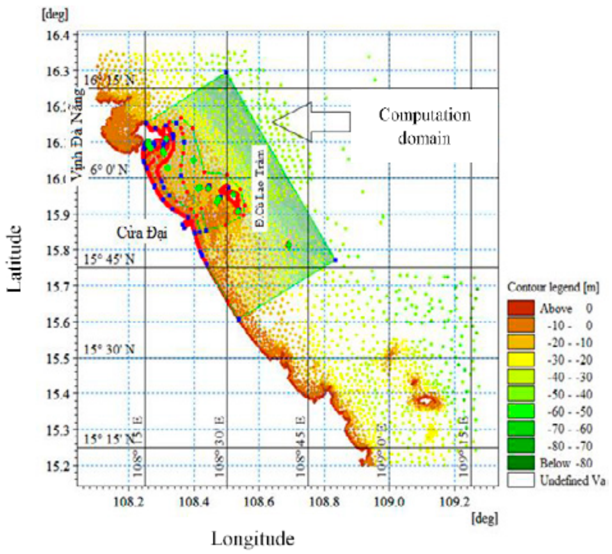

Fig. 2. Model domain and its bathymetry.

2.1 Model description

MIKE 21FM model (DHI, 2007), a general 2D hydrodynamic modeling system for simulation of flows in estuaries, bays and coastal areas, and in oceans, from DHI Water and Environment was used for numerical modeling. The discretization in solution domain is performed using a finite volume method. The spatial domain is discretized by subdivision of the continuum into non-overlapping cells.

The model solves in two dimensions (in the horizontal plane) stationary/non-stationary flow of incompressible Reynolds averaged Navier-Stokes equations, subject to the assumption of Boussinesq and of a hydrostatic distribution of pressure.

The continuity equation is written as

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial \omega}{\partial z}=S \qquad [1]$$

And the two horizontal momentum equations for the x and y component, respectively

$$\frac{\partial u}{\partial t}+\frac{\partial u^2}{\partial x}+\frac{\partial vu}{\partial y}+\frac{\partial wu}{\partial z}=fv-g\frac{\partial \eta}{\partial x}-\frac{1}{\rho_0}\frac{\partial p_a}{\partial x}-\frac{g}{\rho_0}\int_z^\eta \frac{\partial \rho}{\partial x}dz +F_u+\frac{\partial}{\partial z}\left(v_t\frac{\partial u}{\partial z}\right)+u_sS \qquad [2]$$

$$\frac{\partial v}{\partial t}+\frac{\partial v^2}{\partial y}+\frac{\partial uv}{\partial x}+\frac{\partial wv}{\partial z}=fu-g\frac{\partial \eta}{\partial y}-\frac{1}{\rho_0}\frac{\partial p_a}{\partial y}-\frac{g}{\rho_0}\int_z^\eta \frac{\partial \rho}{\partial y}dz +F_v+\frac{\partial}{\partial z}\left(v_t\frac{\partial v}{\partial z}\right)+v_sS \qquad [3]$$

Where: t: time, u, v, ω: velocities in x,y,z directions, η: elevation above mean sea level, σ: vertical transformed co-ordinate, d: water depth, ρ: density, g: acceleration due to gravity, f: Coriolis parameter, v_t: turbulent eddy viscosity, p_A: atmospheric pressure, u_s, v_s: speed.

For spatial discretization the model uses continuous and non-overlapped triangular elements (final volumes), and the model spatial domain is therefore covered by an unstructured mesh network Alcrudo (1993); Zhao et al. (1994); Sleigh et al. (1998). Horizontal convective members are calculated by using the Riemann's solver with Roe's approximation Roe (1981), Toro (1997).

The following modules were applied to simulate hydrodynamic flow (HD), waves (SW), and sediment transport (ST) in the study area.

2.2 Model settings

The model domain of interest is the coastal area around the Park area and extends north-south as shown in **Fig. 2**.

Bathymetry data was extracted from the offshore terrain and the coastal areas of Quang Nam - Da Nang combined with field measurements.

Water level data at the boundaries were extracted from computed results of a wide domain of the East Sea model.

3. Results and discussion

3.1 Model calibration and validation

The numerical model was calibrated for actual water levels at the Son Tra station, using Nash index coefficients (Krause et al., 2005; Nash and Sutcliffe, 1970):

$$R^2=\frac{\sum_1^N (H_i-\overline{H})^2-\sum_1^N (H_i-H_{ci})^2}{\sum_1^N (H_i-\overline{H})^2} \qquad [4]$$

of which, Hi: observed data at time i; $\overline{H}$: average values of measured water levels (or velocities); Hci: Computed data at time i; N: total number of calculations

The results of Nash-Sutcliffe coefficient from calibration process show that R^2=0.88, which means the model was well calibrated. The results of computed water levels were well following the observed data, however, the amplitude was higher due to the water levels at Son Tra station being affected by the flows from the Han River.

Model calibration and validation were done using observed data from 0h of 12th to 23h of 14th, Jan. 2015 and from 0h of 10th to 23h of 12th, Oct. 2015.

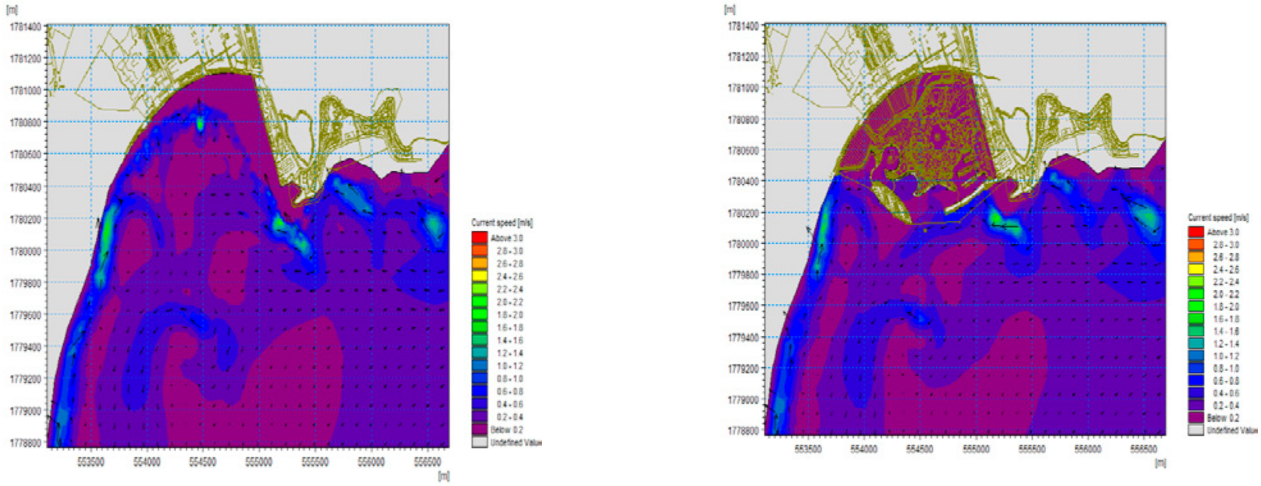

Fig. 3. Current velocities in Southwest monsoon in PA1 (left) and PA2 (right).

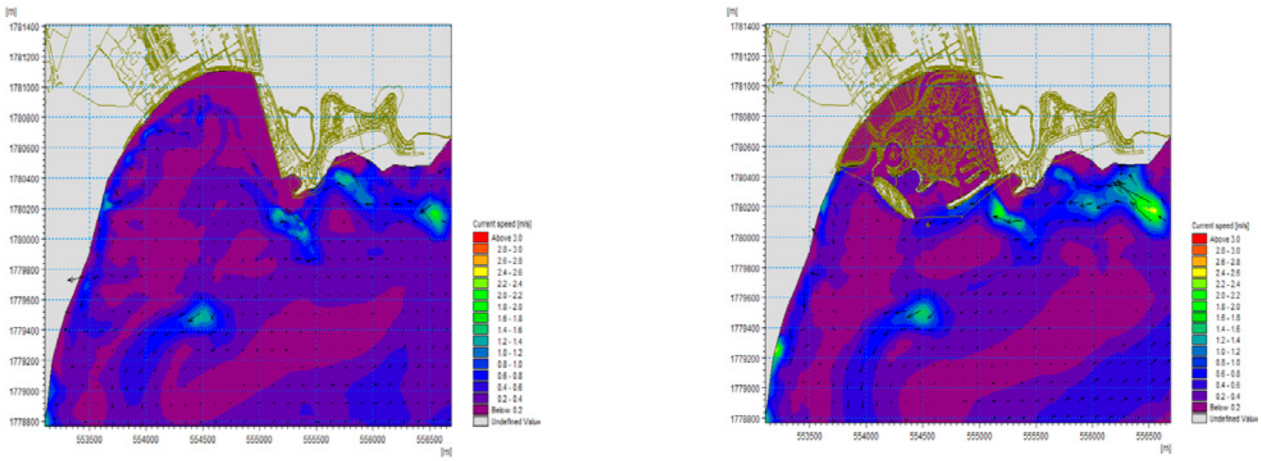

Fig. 4. Current velocities in Northeast monsoon in PA1 (left) and PA2 (right).

Results of model validations for waves and water levels with Nash index of 0.84 and 0.81, respectively, meaning that a good model has been obtained, which can be used for simulating subsequent scenarios.

3.2 Development scenarios

In the following parts, we evaluated the impact of the scenario ”with Park” on wave, flow, and sediment transport. Each factor is evaluated for cases of northeast monsoon and southwest monsoon seasons, of which, two scenarios of ”without Park” (PA1) was compared to that of ”with Park” (PA2).

3.2.1 Results of HD model

Figures 3 and 4 show the comparison between current velocities in southwest monsoon and northeast monsoon for both scenarios of PA1/ without Park and PA2/ with Park, respectively.

It can be seen that due to the Park area covered by Son Tra peninsula, in the northeast monsoon season, the current velocity field in this area is rather stable. However, nearshore areas often have high flow velocities (averaged from 0.5 m/s to 0.6 m/s). These dominant trends tend to flow from the North to the South and the whole area is still interspersed with rather complex vortex. In the northeast monsoon, the flow velocity in this area is quite small (in average, less than 0.2 m/s).

3.2.2 Results of wave module (SW)

Figures 5 and 6 show the comparison between waves in the southwest monsoon and northeast monsoon for both scenarios of ”without Park” and ”with Park”, accordingly.

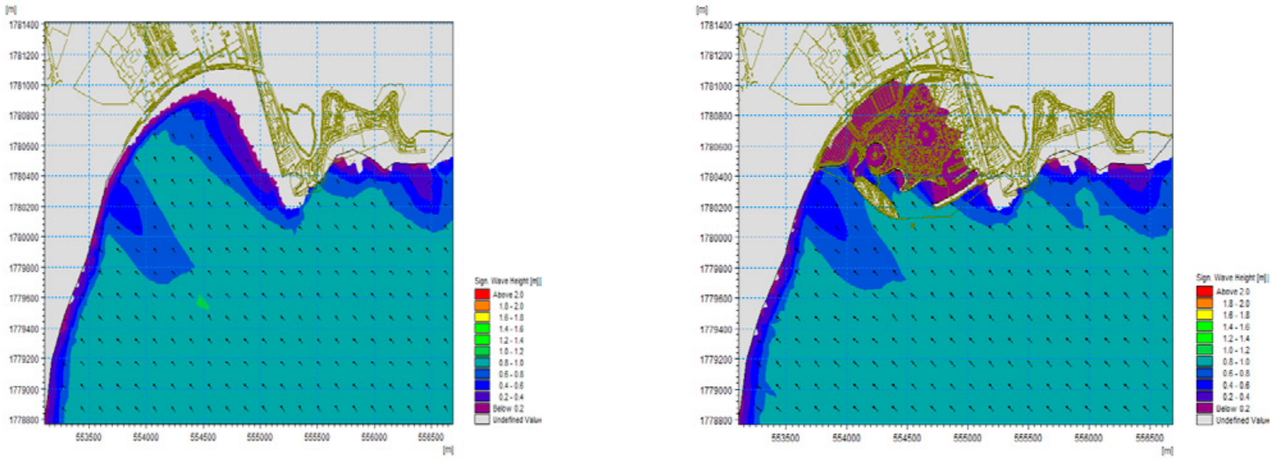

Fig. 5. Wave field in Southwest monsoon in both PA1 (left) and PA2 (right) scenarios.

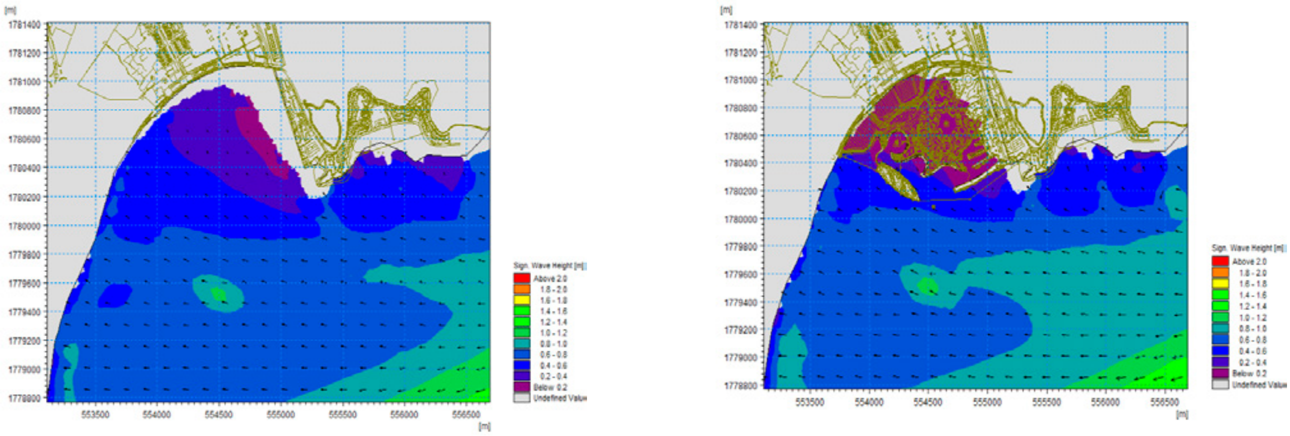

Fig. 6. Wave field in Northeast monsoon in both PA1 (left) and PA2 (right) scenarios.

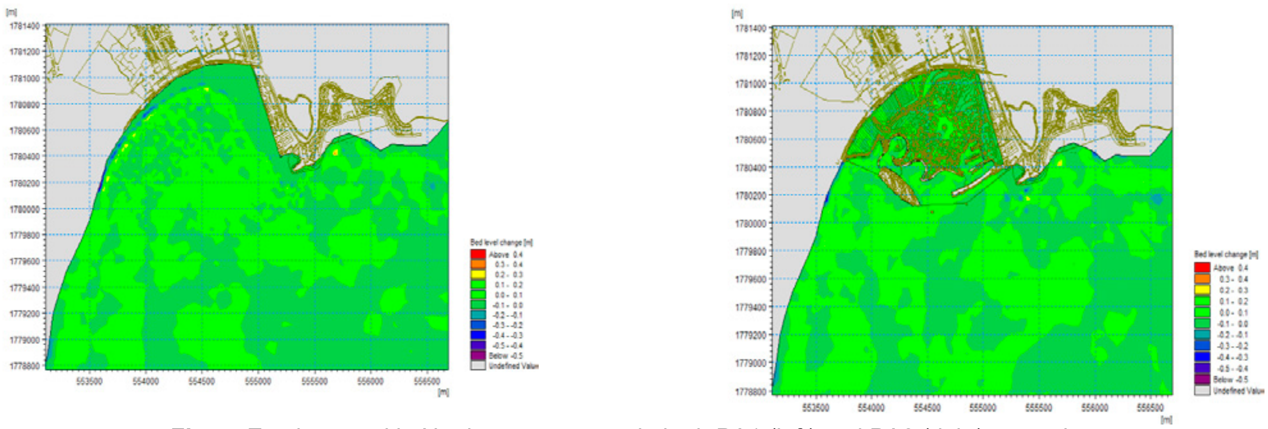

Fig. 7. Erosion trend in Northeast monsoon in both PA1 (left) and PA2 (right) scenarios.

Figure 5 shows that there is not much difference between PA2 and PA1. It means that the influence of the park to wave mode in the neighboring southwest wind season is not great. In **Fig. 6**, the differences of PA1 and PA2 show that there is no difference in both wave height and wave direction. This also shows that the Park will not affect much to the wave condition in the northeast monsoon in the vicinity areas.

3.2.3 Results of sedimentation transport module (ST)

Figures 7 and 8 show the comparision betweeen erosion trends in the northeast moonsoon and southwest moonsoon for both scenarios of PA1/ without Park and PA2/ with Park, accordingly.

The results in **Fig. 7** show that after the northeast monsoon season, the current status of the project area (PA1) and the surrounding area form a parallel erosion strip, in which the erosion strips along the inner banks, the longitudinal strip extends parallel to the erosion strip.

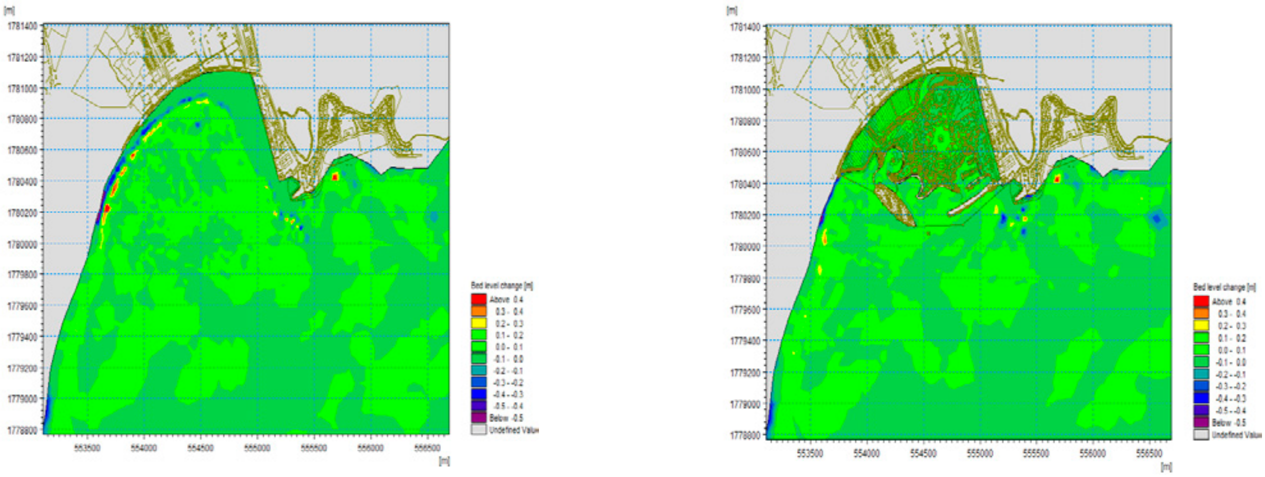

Fig. 8. Erosion trend in Southwest monsoon in both PA1 (left) and PA2 (right) scenarios.

The maximum value on the scour strip can be up to -40 cm and on the strip also up to + 40 cm. This strip is about 850m long along the coast, of which about 400m in the Park area. However, when the park was built (PA2), the formation of this band after the northeast monsoon season is no longer clear.

The results of PA2 following the southwest monsoon (**Figure 8**) show an alternating erosion trend, with an average erosion rate of about 10cm. Occurrence occurs in some locations where local erosion occurs in coastal areas. It can be said that this area is quite stable in terms of erosion in southwest monsoon conditions.

3.2.4 Discussion

In the northeast monsoon, the wave height is more complicated than the southwest monsoon, but when transmitted to the main wave area, it is mostly perpendicular to the shore, or south and southwest. The Park area has a deep bottom elevation (close to the outer edge of the depth of about -7 m), so in the storm or large northeast wave, wave height near the Park can reach over 1.5 m.

Current velocities in the Park area according to the monsoon seasons show that the current flow is quite complicated due to the bathymetric terrain conditions. Flow velocities are often of great values in close proximity to the shore, except for the area of Hon Push and areas of rocky or coral rocky bottom.

High velocity values in storms and high northeast monsoons can reach over 3.0 m/s. Direction of current flow in the northeast monsoon is from north to south, where as direction of flow in the southwest monsoon is reversed, alternating in both directions with some coastal vortices.

The morphological changes in the area are quite stable over time, the trend of accretion and erosion in windy seasons as well as storms are usually mild. The maximum amplitude ranges from -0.45 m to +0.45m and exists in some coastal locations. Often this area has the accretion strip in the direction of the shore (the area of breaking waves inward), accretion offshore. Through hydrodynamic flow computations, there is an occurrence of the rip flow/circulation. In addition, here the formation of local small vortices and quite complex. This is also one of the reasons why dominant sedimentation in the direction of perpendicular to the shore.

Based on the comparison results of the two scenarios “without” and “with Park”, it is clear that the Park has influenced the morphological changes as well as the dynamic flow in the surrounding areas (200m-800m from the edge of the Park).

The impact of the project to the surrounding area is about 200m - 800m. In this area, there will be quite strong fluctuations. However, when comparing the difference in variation between the two scenarios, the highest difference in erosion values calculated in a typhoon was ± 30 cm; the highest wave height of 40 cm; In monsoon seasons, the difference is reduced by 50%. From these values, it can be concluded that PA2 “with Park” has little influence on natural erosion.

In general, “with park” scenario is more or less influenced by the changing dynamics of flow and lithospheric process in the area and surrounding. The most affected area is only about from 200m to 800m from the site, but the lithospheric processes is more intense in monsoons (Nhan and Hung, 2013).

4. Conclusion

This paper analyzed and evaluated the impacts of a Park of nearly 100ha to be build in Son Tra peninsula, Danang city, Vietnam, using existing data and the use of hydrodynamic models to simulate flow, wave and sedimentation in monsoons.

The results show that the Park does not cause major fluctuations in dynamic lithospheric processes in nearby the project area and its surroundings. The distance from the Park to 200m - 800m offshore is slightly affected and concentrated about 200m-400m on the south area (from the project to the south). Due to the influence of the project, the nearshore current velocity is increased, especially in the case of large monsoons.

This result can be used in the next steps after the construction of the project to assess the impact of the park construction to the dynamics of hydrodynamic regime in Son Tra Peninsula.

References

Alcrudo, F., Garcia-Navarro, P.A., 1993. High resolution Godunov type scheme in finite volumes for the 2D shallow-water equation. Int. J. Numer. Methods Fluids, **16** (6): 489-505.

DHI., 2007. MIKE 21 Flow Model User Guide and Scientific Documentation, Danish Hydraulic Institute: 3-27.

Krause P., Boyle D.P., and Base F., 2005. Comparison of different efficiency criteria for hydrological model assessment, Advances in Geosciences, **5**: 89-97.

Nash, J.E., Sutcliffe, J.V., 1970. River flow forecasting through conceptual models parts I-A discussion of principles. J. Hydro. **10** (3): 282-290. http://sci-hub.bz/10.1016/0022-1694(70)90255-6.

Nguyen Huu Nhan, Phan Manh Hung (2013). Impact of coastal hydrodynamic regime on coastal erosion in Tra Vinh, Journal of Hydraulic Science & Technology, **17**, 9/2013.

Roe, P.L., 1981. Approximate Riemann solvers, parameters vectors and difference schemes. Journal of Computational Physics, **43**: 357-372.

Sun Group Joint Stock Company, Son Tra Ocean Park Environment Impact Accessement Report, 2016.

Sleigh, D.H., Gaskel, P.H., 1998. An unstructured finite volume algorithm for predicting flow in rivers and estuaries. Computer and Fluids, **27** (4): 479-508.

Toro, E.F., 1997. Riemann Solvers and Numerical Methods for Fluid Dynamics, Springer, Germany.

VNN, 2017. Son Tra langurs threatened by resort plan, at website http://english.vietnamnet.vn/fms/environment/179042/son-tra-langurs-threatened-by-resort-plan.html; accessed July 2017.

VNN, 2017, Unique Son Tra Reserve under threat, at website http://english.vietnamnet.vn/fms/environment/175210/unique-son-tra-reserve-under-threat.html; accessed July 2017.

Yokoi, S., Matsumoto, J., 2008. Collaborative effects of cold surge and tropical depression-type disturbance on heavy rainfall in central Vietnam. Mon. Wea. Rev. 136, 3275-3287. http://dx.doi.org/10.1175/2008MWR2456.1.

Zhao, D.H., Shen, H.W., Tabios, G.Q., Tan, W.Y., 1994. Finite-volume two dimensional unsteady flow models for river basins. Journal of Hydraulic Engineering, ASCE, **120** (7): 833-863.