ASSESSMENT of MORPHODYNAMICS and WATER QUALITY of AL MANSOURA NEW MEDITERRANEAN SEA ISLAND

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ABSTRACT: Al-Mansoura palm is locating about 40km west of Damietta promontory on Nile Delta coast. Surveyed bathymetry has been done by the Coastal Research surveying team with grid spacing 25m and depth 16m to cover the study area 10Km by 12Km. The sea bed slope ranged between 0.0031 to 0.0025 and sediment size (1.15, 3.11) mm. Al Mansoura coast is stable under wave and current attack till the manmade structures are constructed.

Numerical simulations using finite difference technique (Delft-3D coupled software) will be used to study wave, current, sediment transport and water quality. Calibration and validation processes have been done on Kitchener coast 25km western to the study area.

Nine scenarios have been studied to represent the most effective wave protection for the western side of the Island. Submerged breakwater has been tested to attenuate wave attack and successfully protect palm west fingers from severe waves. Graded groins have been used to reduce erosion at the east coast of the Island and successfully decreased the required annual sand nourishment for stabilization. Finally the water quality for sheltered area of the Island has been tested for all scenarios according to tidal waves. This research topic is contributing to the advancement of the pure science of mega structure implementations along coastal areas which can help many researchers on the long run to easily predict the interaction with the coast surf zone.

INTRODUCTION: -

Deltas are naturally dynamic coastal systems that are unique in their close links to both land-based fluvial and coastal ocean processes [1]. Egypt Delta North coast is dynamic due to significant coastal changes due to both human and natural influences [1]. Driving wave force is a fundamental reason for coastal process and shoreline dynamic response; the breaking of the waves within this zone is responsible for the transformation of organized wave motion into chaotic turbulence, which mobilizes and suspends the sediments composing the beach. Also, the breaking waves create near shore currents that flow along the shoreline and in the cross-shore direction. These currents can transport large quantities of sediment in both directions; the net of transported sediments for the Nile Delta coast is going from west to east [1] [2] [3]. El-Mansoura new city locates 25km Eastern to Kitchenar drain and 30km Western to Damietta port on the Nile delta Northern coast as shown in Figure 1. It is noted that study area has more oblique inclination shoreline compared with Kitchenar zone to the west as shown in Figure 1-(C). As a result, the proposed zone for reclamation is more exposed to littoral current due to Northern west, Western, Northern waves. This part of Egyptian coast is exposed to waves with almost 85% from Western north direction and only 15% from the East as being described in wave rose in Figure 1-(F), while wave heights and percentage are shown in Figure 1-(G). According to CoRI, the proposed palm location has a stable shoreline with average annual erosion of 10m and average accretion of 20m in various locations as shown in Figure 1-(E) which compares measured shorelines since 2013 to 2016 [4]. Since few decades and particularly since building of the High Aswan Dam in 1964, sediment discharge at the Nile promontories has reduced to near zero and the continued action of waves and currents acts to induce beach erosion while the study area showed various accretion and erosion rates 50m and 30m, respectively [5] [6] [7] [8] [9]. To protect Kitchenar drain a number of 15 groins were implemented in the western side of the drain to mitigate the high erosion rate happened after the construction phases which showed almost stable erosion rate of 20m per year [10]. Many recent research indicate that the study area is a sable under the ongoing natural forces while any anthropogenic human work will interrupt the stabilized system which will eventually cause a kind of accretion and dramatic erosion in the upstream and down drift, respectively.

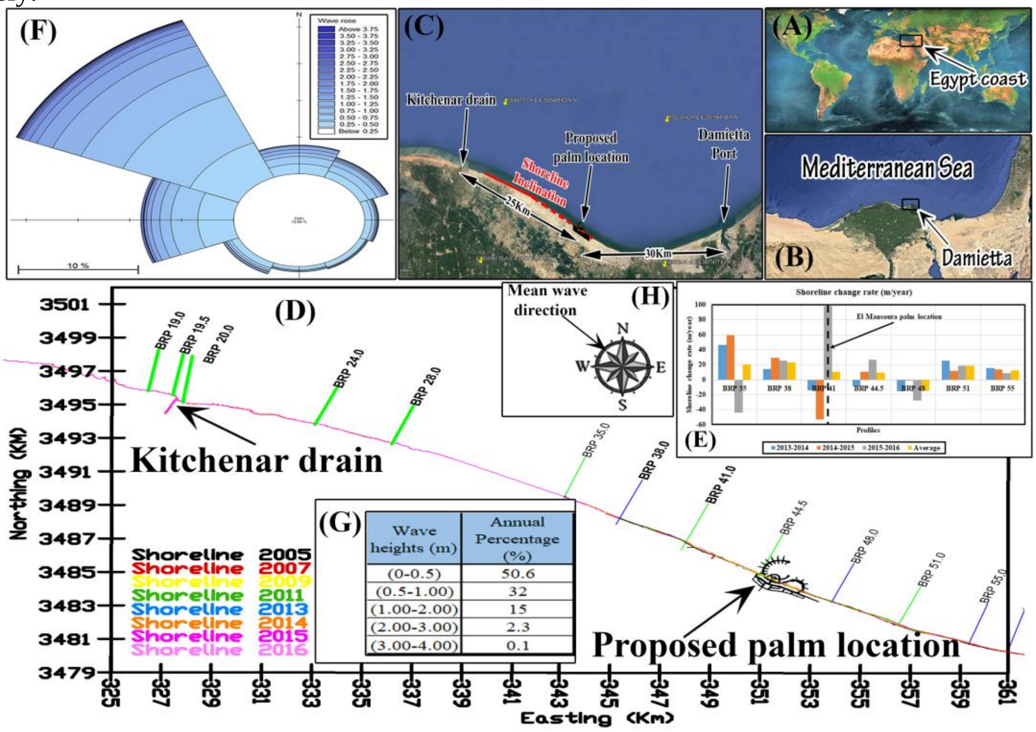

Figure 1 (A) Egypt coast location, (B) Project location, (C) Layout of proposed palm and location, (D) Surveyed Bed Profiles locations, (E) shoreline change rates, (F) measured wave rose, (G) Wave heights annual percentage and (H) mean wave direction

METHODOLOGY: -

In this study, finite difference numerical technique will be the main modelling tool. For this purpose, the open source Delft-3D software, extensively used and improved at Deltares and TU Delft, will be used. The study area was assessed by very dense bathymetric profiles surveyed by Coastal Research Institute (CoRI) reaching the 16m depth in 2016 to generate the initial contour map as shown in Figure 1 also in order to cover the study area 10Km and 12Km eastern and western of the proposed palm, respectively. Tidal water levels measured by CoRI tidal stations in 2016 are used to simulate the tidal waves along the study area. Sediment samples are also gradually taken by CoRI in various places along the study area.

NUMERICAL MODELLING SET-UP: -

The grid used by Delft-3D is curvilinear grid with high dense of 10m in the study area to highly accurate simulate the palm hydrodynamics and morpho-dynamics increasing to be 50m along the model boundaries to minimize the calculation time as shown in Figure 2. The tidal annual wave is fully simulated and spring wave cycle is found to be representative of both maximum and minimum tidal range about 0.4m and 0.09m, respectively. In addition, Hrms was calculated to be 0.195m using measured tidal data by CoRI in 2016. The model layout is presented in Figure 2-(M).

CALIBRATION AND VALIDATION: -

Model (1): -

Model (1) simulated the changing morphodynamics using Van rijn 1993 equation [11] [12] [13]. in Kitchenar zone 25km west to the study area with curvilinear grid of 10m. Initial bathemetric map is generated by using profiles measured by CoRI in 2012. Calibration process was done through the first model using measured current velocities, measured water levels and measured four bathymetric profiles done by CoRI in 2013 after one year from the initial state which can be shown in Figure 2-(C:F). Maximum standard deviation according to error is presented to be less than 20% comparing the model simulated bed change and the measured profiles.

Model (2): -

The first model is overlapped into the second one with grid 50m which extends from western of Kitchener drain to Baltim beaches where the palm is to be positioned. The validation process was done using four bathymetric profiles surrounding the palm region surveyed by CoRI in year 2013 by using Kitchener last mentioned calibration parameters. The validation process represented in Figure 2-(G:L) showed very good matching comparing the model output and the measured profiles by CoRI with error maximum standard deviation less than 20% which can guarantee the model reliability for simulating the study area.

Model (3): -

The third model was used finally to simulate the study area with 10m grid to get the most required accuracy while simulating the palm coastal region.

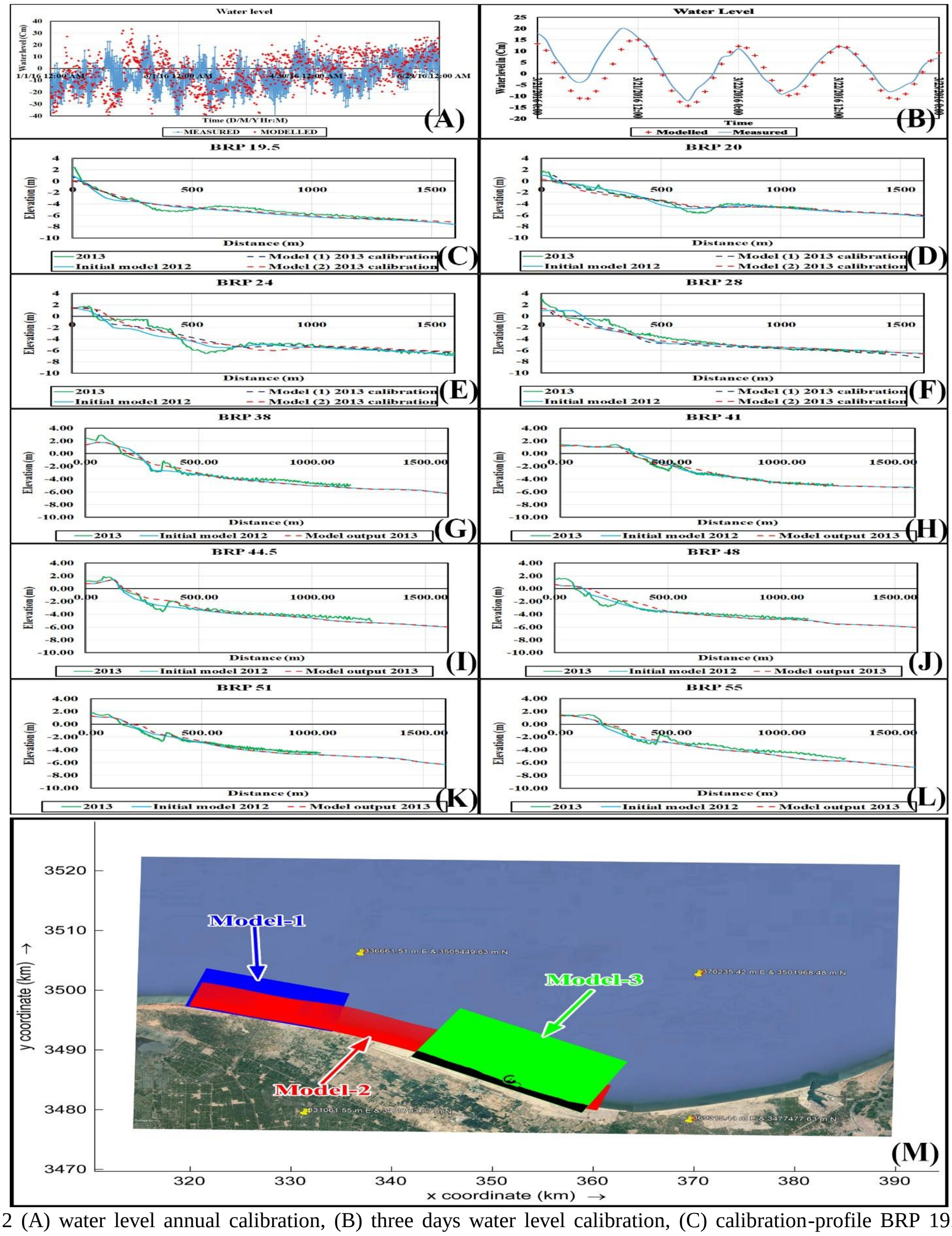

Figure 2 (A) water level annual calibration, (B) three days water level calibration, (C) calibration-profile BRP 19.5, (D) calibration-profile BRP 20, (E) calibration-profile BRP 24, (F) calibration-profile BRP 28, (G) Validation-profile BRP 38, (H) Validation-profile BRP 41, (I) Validation-profile BRP 44.5, (J) Validation-profile BRP 48, (K) Validation-profile BRP 51, (L) Validation-profile BRP 55, and (M) Model layouts

SIMULATED SCENARIOS: -

TEN DIFFERENT SCENARIOS ARE SIMULATED TO INVESTIGATE BOTH DOWN DRIFT MORPHO-DYNAMICS AND PURIFICATION. FIRST SEVEN ARE INVESTIGATING THE DOWN DRIFT MRPHO-DYNAMICS WHILE LAST THREE ARE MEANT FOR PURIFICATION INVESTIGATION. THE LAYOUTS FOR THE DIFFERENT SCHEME IS PRESENTED IN INITIAL SITUATION: -

The initial proposed layout is shown in Figure 3-(A) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. significant wave propagation is shown in Figure 4-(A). Depth averaged velocities are shown in Figure 5-(A). Figure 6-(A) illustrates the annual changing rates of the study area bathymetry. Figure 7-(A) shows the resident time.

SCENARIO (1): -

The first proposed layout is shown in Figure 3-(B) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. significant wave propagation is shown in Figure 4-(B). Depth averaged velocities are shown in Figure 5-(B). Figure 6-(B) illustrates the annual changing rates of the study area bathymetry.

SCENARIO (2): -

The second proposed layout is shown in Figure 3-(C) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. 300m sea bed 1m layer is replaced eastern to the proposed graded groins. significant wave propagation is shown in Figure 4-(C). Depth averaged velocities are shown in Figure 5-(C). Figure 6-(C) illustrates the annual changing rates of the study area bathymetry.

SCENARIO (3): -

The third proposed layout is shown in Figure 3-(D) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). significant wave propagation is shown in Figure 4-(D). Depth averaged velocities are shown in Figure 5-(D). Figure 6-(D) illustrates the annual changing rates of the study area bathymetry.

SCENARIO (4): -

The fourth proposed layout is shown in Figure 3-(E) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. 300m sea bed 1m layer is replaced eastern to the proposed graded groins. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). significant wave propagation is shown in Figure 4-(E). Depth averaged velocities are shown in Figure 5-(E). Figure 6-(E) illustrates the annual changing rates of the study area bathymetry.

SCENARIO (5): -

The fifth proposed layout is shown in Figure 3-(F) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). Eastern submerged breakwater is added 350m away from the eastern part with 25m crest width and (0.00 elevation level). significant wave propagation is shown in Figure 4-(F). Depth averaged velocities are shown in Figure 5-(F). Figure 6-(F) illustrates the annual changing rates of the study area bathymetry.

SCENARIO (6): -

The sixth proposed layout is shown in Figure 3-(G) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. 300m sea bed 1m layer is replaced eastern to the proposed graded groins. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). Eastern submerged breakwater is added 350m away from the eastern part with 25m crest width and (0.00 elevation level). significant wave propagation is shown in Figure 4-(G). Depth averaged velocities are shown in Figure 5-(G). Figure 6-(G) illustrates the annual changing rates of the study area bathymetry.

SCENARIO (7): -

The seventh proposed layout is shown in Figure 3-(H) that insists of six western outer groins, nine internal groins, four eastern groins and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. 300m sea bed 1m layer is replaced eastern to the proposed graded groins. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). Western opening is closed and new opening is proposed between the second and third eastern groin. significant wave propagation is shown in Figure 4-(H). Depth averaged velocities are shown in Figure 5-(H). Figure 6-(H) illustrates the annual changing rates of the study area bathymetry. Figure 7-(B) shows the resident time.

SCENARIO (8): -

The eighth proposed layout is shown in Figure 3-(I) that insists of six western outer groins, nine internal groins, four eastern groins and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. 300m sea bed 1m layer is replaced eastern to the proposed graded groins. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). Western opening is closed and new opening is proposed to be opened on the internal part of the palm. significant wave propagation is shown in Figure 4-(I). Depth averaged velocities are shown in Figure 5-(I). Figure 6-(I) illustrates the annual changing rates of the study area bathymetry. Figure 7-(C) shows the resident time.

SCENARIO (9): -

The ninth proposed layout is shown in Figure 3-(J) that insists of six western outer groins, nine internal groins, four eastern groins and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. 300m sea bed 1m layer is replaced eastern to the proposed graded groins. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). Eastern submerged breakwater is added 350m away from the eastern part with 25m crest width and (0.00 elevation level). Third eastern groin is to be extended with submerged breakwater to prevent eastern opening sedimentation. Western opening is closed and new opening is proposed to be opened behind the first eastern groin. significant wave propagation is shown in Figure 4-(J). Depth averaged velocities are shown in Figure 5-(J). Figure 6-(J) illustrates the annual changing rates of the study area bathymetry. Figure 7-(D) shows the resident time.

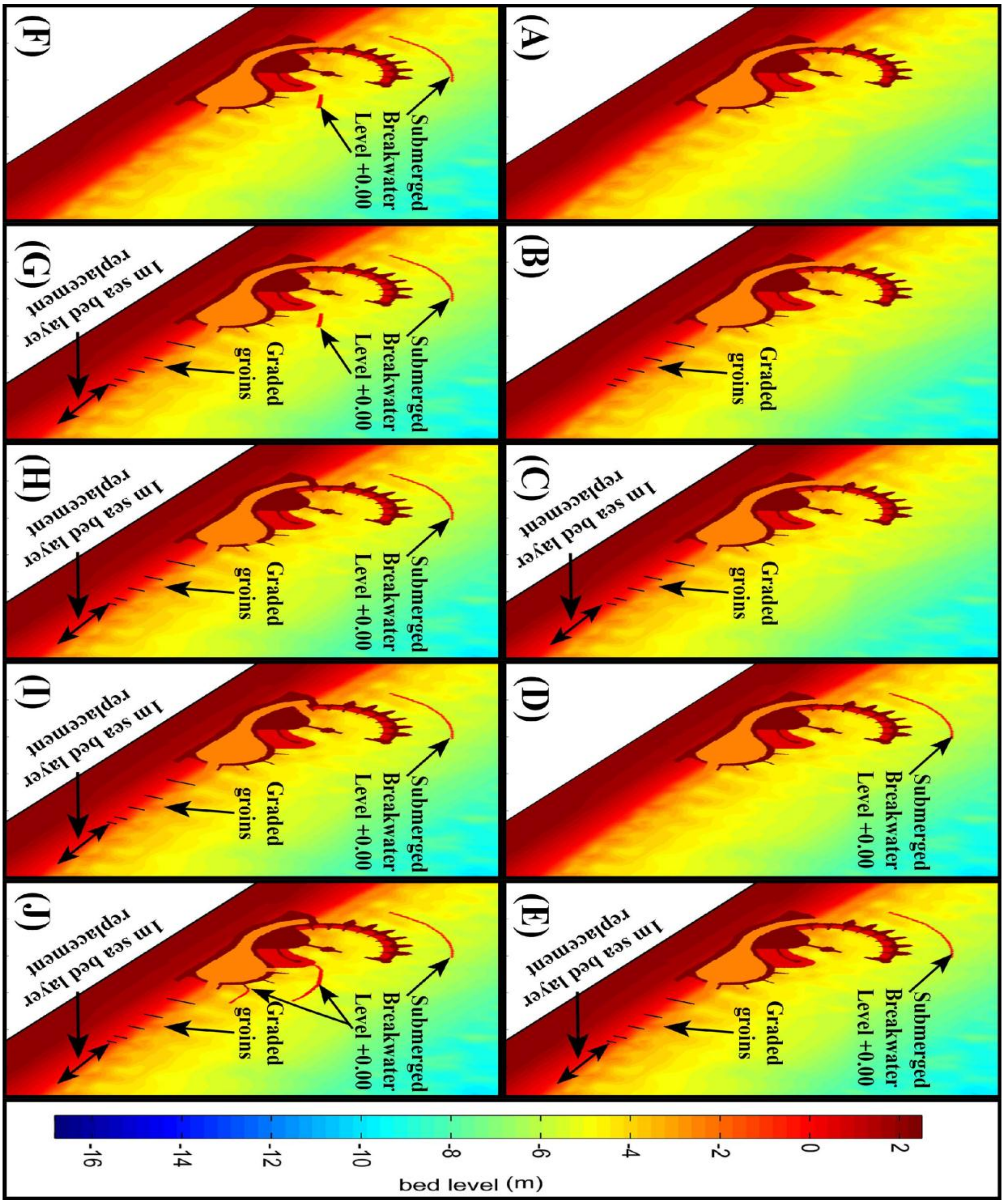
(A)
(B)
Graded groins
(C)
1m sea bed layer replacement
Graded groins
(D)
Submerged Breakwater Level +0.00
(E)
1m sea bed layer replacement
Graded groins
Submerged Breakwater Level +0.00
(F)
Submerged Breakwater Level +0.00
(G)
1m sea bed layer replacement
Graded groins
Submerged Breakwater Level +0.00
(H)
1m sea bed layer replacement
Graded groins
Submerged Breakwater Level +0.00
(I)
1m sea bed layer replacement
Graded groins
Submerged Breakwater Level +0.00
(J)
1m sea bed layer replacement
Graded groins
Submerged Breakwater Level +0.00
-16
-14
-12
-10
-8
-6
-4
-2
0
2
bed level (m)

Figure 3.

INITIAL SITUATION: -

The initial proposed layout is shown in Figure 3-(A) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. significant wave propagation is shown in Figure 4-(A). Depth averaged velocities are shown in Figure 5-(A). Figure 6-(A) illustrates the annual changing rates of the study area bathymetry. Figure 7-(A) shows the resident time.

SCENARIO (1): -

The first proposed layout is shown in Figure 3-(B) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. significant wave propagation is shown in Figure 4-(B). Depth averaged velocities are shown in Figure 5-(B). Figure 6-(B) illustrates the annual changing rates of the study area bathymetry.

SCENARIO (2): -

The second proposed layout is shown in Figure 3-(C) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. 300m sea bed 1m layer is replaced eastern to the proposed graded groins. significant wave propagation is shown in Figure 4-(C). Depth averaged velocities are shown in Figure 5-(C). Figure 6-(C) illustrates the annual changing rates of the study area bathymetry.

SCENARIO (3): -

The third proposed layout is shown in Figure 3-(D) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). significant wave propagation is shown in Figure 4-(D). Depth averaged velocities are shown in Figure 5-(D). Figure 6-(D) illustrates the annual changing rates of the study area bathymetry.

SCENARIO (4): -

The fourth proposed layout is shown in Figure 3-(E) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. 300m sea bed 1m layer is replaced eastern to the proposed graded groins. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). significant wave propagation is shown in Figure 4-(E). Depth averaged velocities are shown in Figure 5-(E). Figure 6-(E) illustrates the annual changing rates of the study area bathymetry.

SCENARIO (5): -

The fifth proposed layout is shown in Figure 3-(F) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). Eastern submerged breakwater is added 350m away from the eastern part with 25m crest width and (0.00 elevation level). significant wave propagation is shown in Figure 4-(F). Depth averaged velocities are shown in Figure 5-(F). Figure 6-(F) illustrates the annual changing rates of the study area bathymetry.

SCENARIO (6): -

The sixth proposed layout is shown in Figure 3-(G) that insists of six western outer groins, nine internal groins, and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. 300m sea bed 1m layer is replaced eastern to the proposed graded groins. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). Eastern submerged breakwater is added 350m away from the eastern part with 25m crest width and (0.00 elevation level). significant wave propagation is shown in Figure 4-(G). Depth averaged velocities are shown in Figure 5-(G). Figure 6-(G) illustrates the annual changing rates of the study area bathymetry.

SCENARIO (7): -

The seventh proposed layout is shown in Figure 3-(H) that insists of six western outer groins, nine internal groins, four eastern groins and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. 300m sea bed 1m layer is replaced eastern to the proposed graded groins. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). Western opening is closed and new opening is proposed between the second and third eastern groin. significant wave propagation is shown in Figure 4-(H). Depth averaged velocities are shown in Figure 5-(H). Figure 6-(H) illustrates the annual changing rates of the study area bathymetry. Figure 7-(B) shows the resident time.

SCENARIO (8): -

The eighth proposed layout is shown in Figure 3-(I) that insists of six western outer groins, nine internal groins, four eastern groins and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. 300m sea bed 1m layer is replaced eastern to the proposed graded groins. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). Western opening is closed and new opening is proposed to be opened on the internal part of the palm. significant wave propagation is shown in Figure 4-(I). Depth averaged velocities are shown in Figure 5-(I). Figure 6-(I) illustrates the annual changing rates of the study area bathymetry. Figure 7-(C) shows the resident time.

SCENARIO (9): -

The ninth proposed layout is shown in Figure 3-(J) that insists of six western outer groins, nine internal groins, four eastern groins and C-shaped palm with internal lagoon along the palm length. Five graded groins are added to the down drift with lengths and spacing of 240m-550m, 146m-490m, 116m-350m, 116m-300m, 50m-150m, respectively. 300m sea bed 1m layer is replaced eastern to the proposed graded groins. Submerged breakwater is simulated western to the palm away from the palm with 350m, 25m crest width and (0.00 elevation level). Eastern submerged breakwater is added 350m away from the eastern part with 25m crest width and (0.00 elevation level). Third eastern groin is to be extended with submerged breakwater to prevent eastern opening sedimentation. Western opening is closed and new opening is proposed to be opened behind the first eastern groin. significant wave propagation is shown in Figure 4-(J). Depth averaged velocities are shown in Figure 5-(J). Figure 6-(J) illustrates the annual changing rates of the study area bathymetry. Figure 7-(D) shows the resident time.

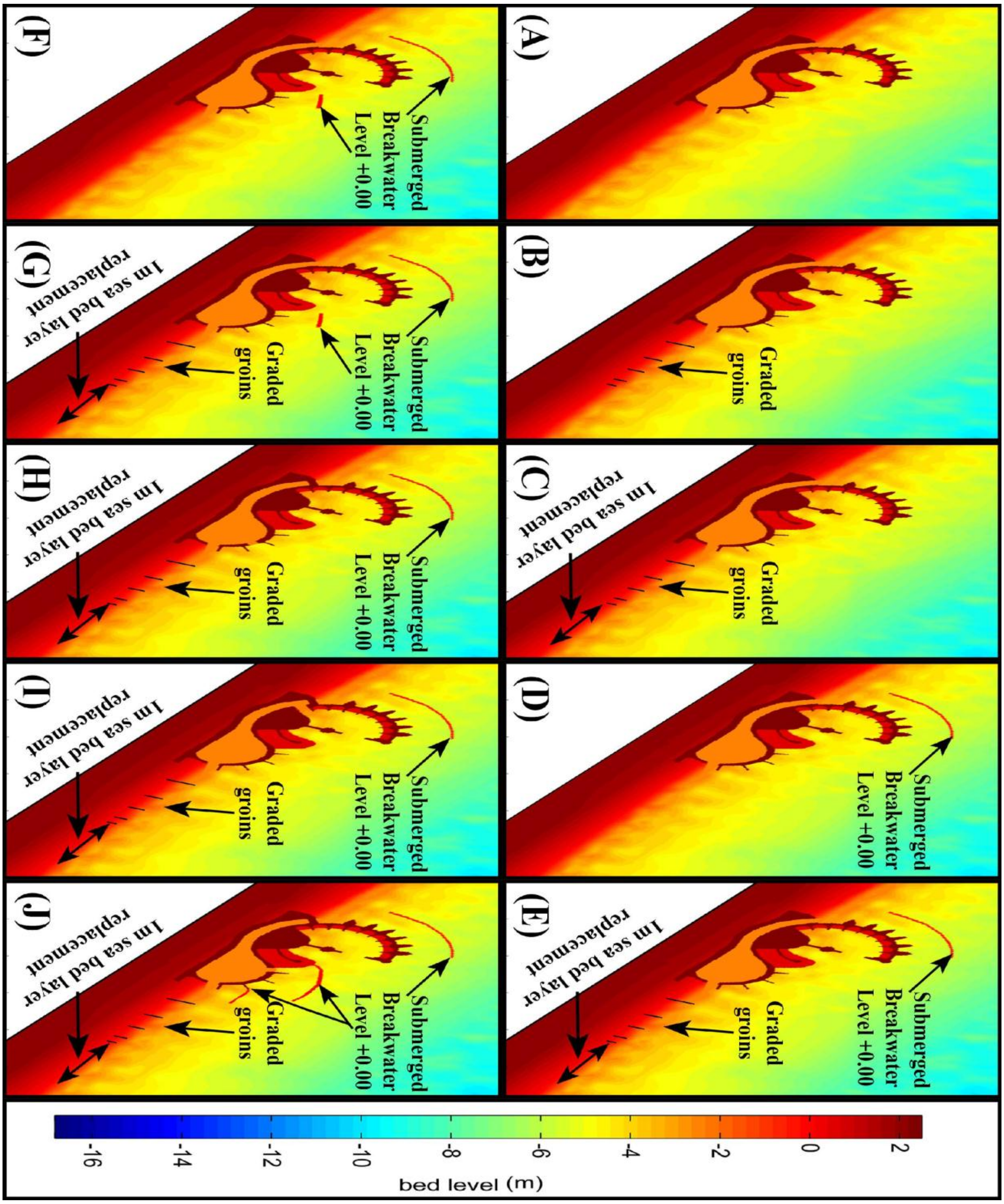

Figure 3 Simulated scenarios' layouts (A)Initial state, (B)scenario-1, (C)scenario-2, (J)scenario-3, (E)scenario-4, (F)scenario-5, (G)scenario-6, (H)scenario-7, (I)scenario-8, (J)scenario-9.

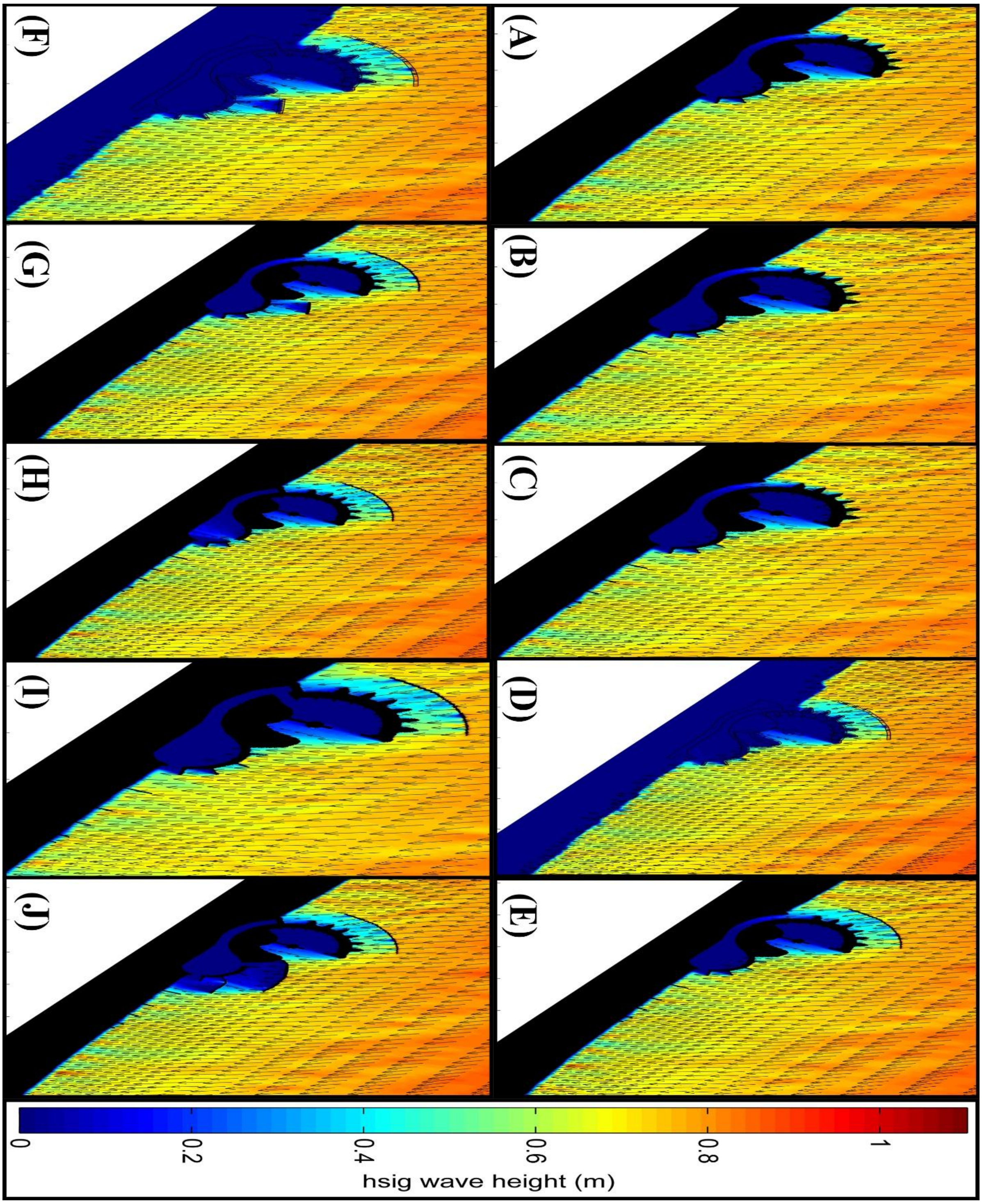

Figure 4 Simulated scenarios' significant wave propagation (A)Initial state, (B)scenario-1, (C)scenario-2, (D)scenario-3, (E)scenario-4, (F)scenario-5, (G)scenario-6, (H)scenario-7, (I)scenario-8, (J)scenario-9.

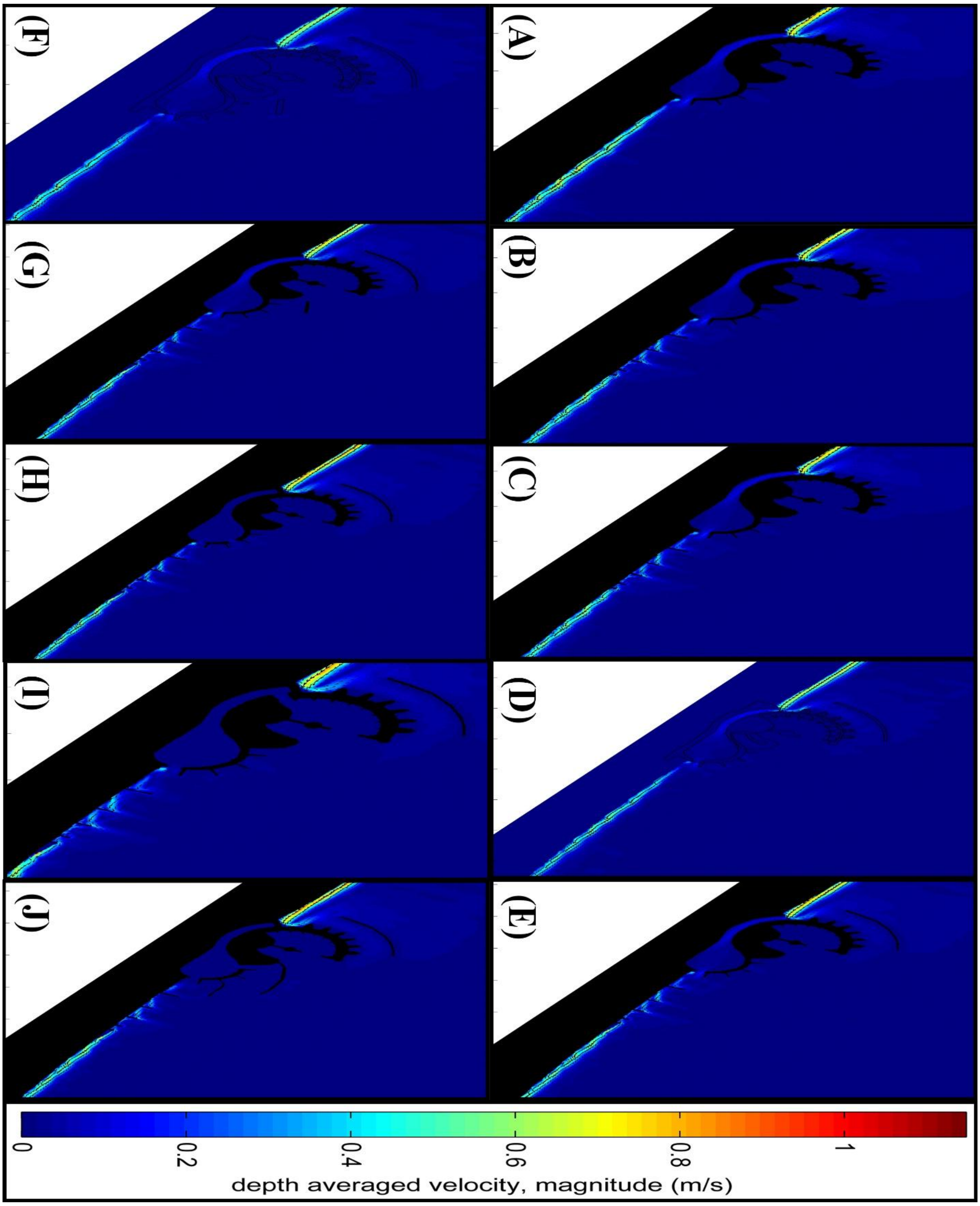

Figure 5 Simulated scenarios' depth averaged velocity (A)Initial state, (B)scenario-1, (C)scenario-2, (D)scenario-3, (E)scenario-4, (F)scenario-5, (G)scenario-6, (H)scenario-7, (I)scenario-8, (J)scenario-9.

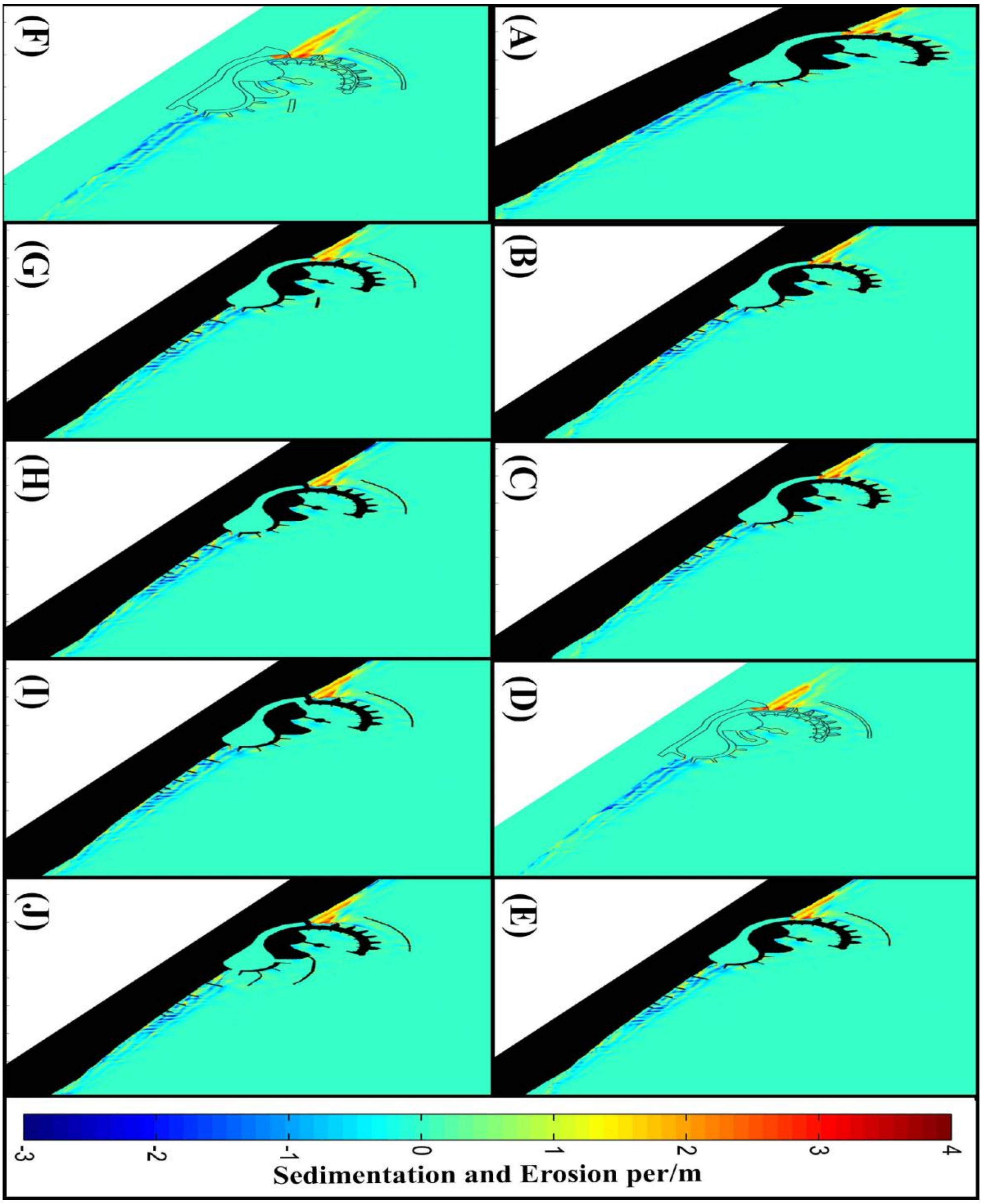

Figure 6 Simulated scenarios' morpho-dynamics (A)Initial state, (B)scenario-1, (C)scenario-2, (D)scenario-3, (E)scenario-4, (F)scenario-5, (G)scenario-6, (H)scenario-7, (I)scenario-8, (J)scenario-9.

Table 1 Sediment eroded length and volume

Scenario	Total Eroded length (m)	Erosion volume (m3)
initial	2211	127242.8
Sec.1	1108	94724.9
Sec.2	373	4928
Sec.3	3641	147085.85
Sec.4	163	2321.5
Sec.5	2776	179090
Sec.6	566	16389
Sec.7	525	15618
Sec.8	417	5604.3
Sec.9	313	14637

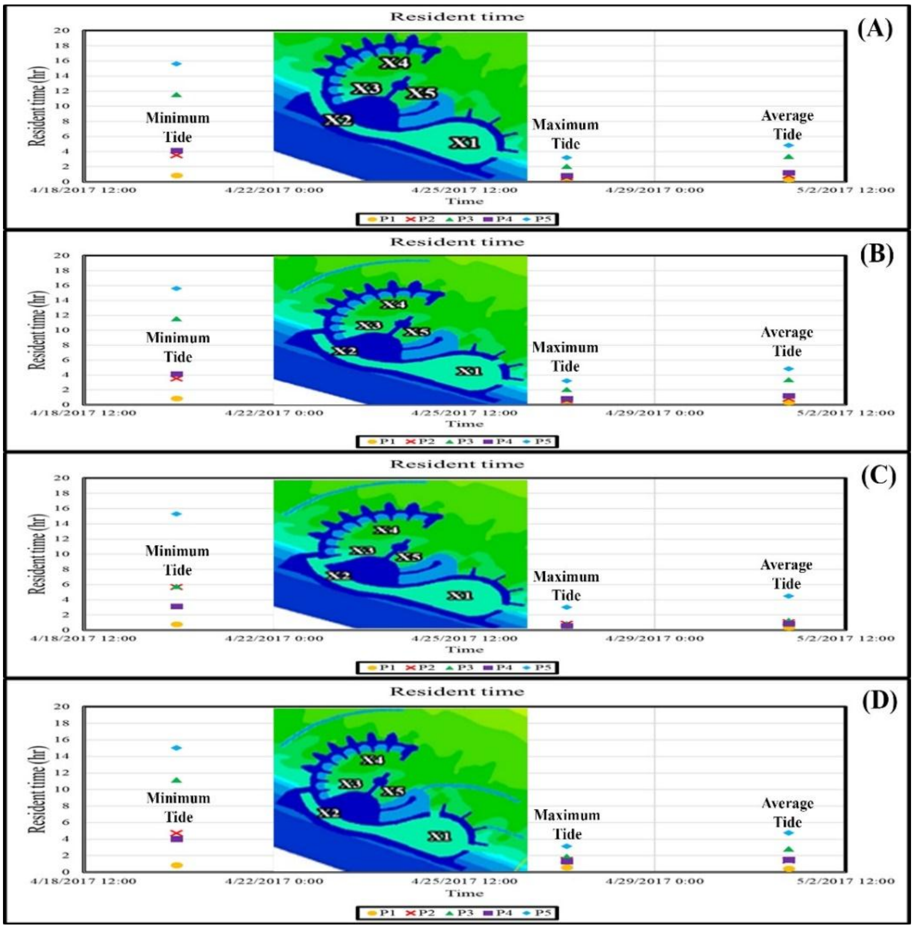

Figure 7 Simulated Resident time (A)Initial state, (B)scenario-7, (C)scenario-8, (D)scenario-9.

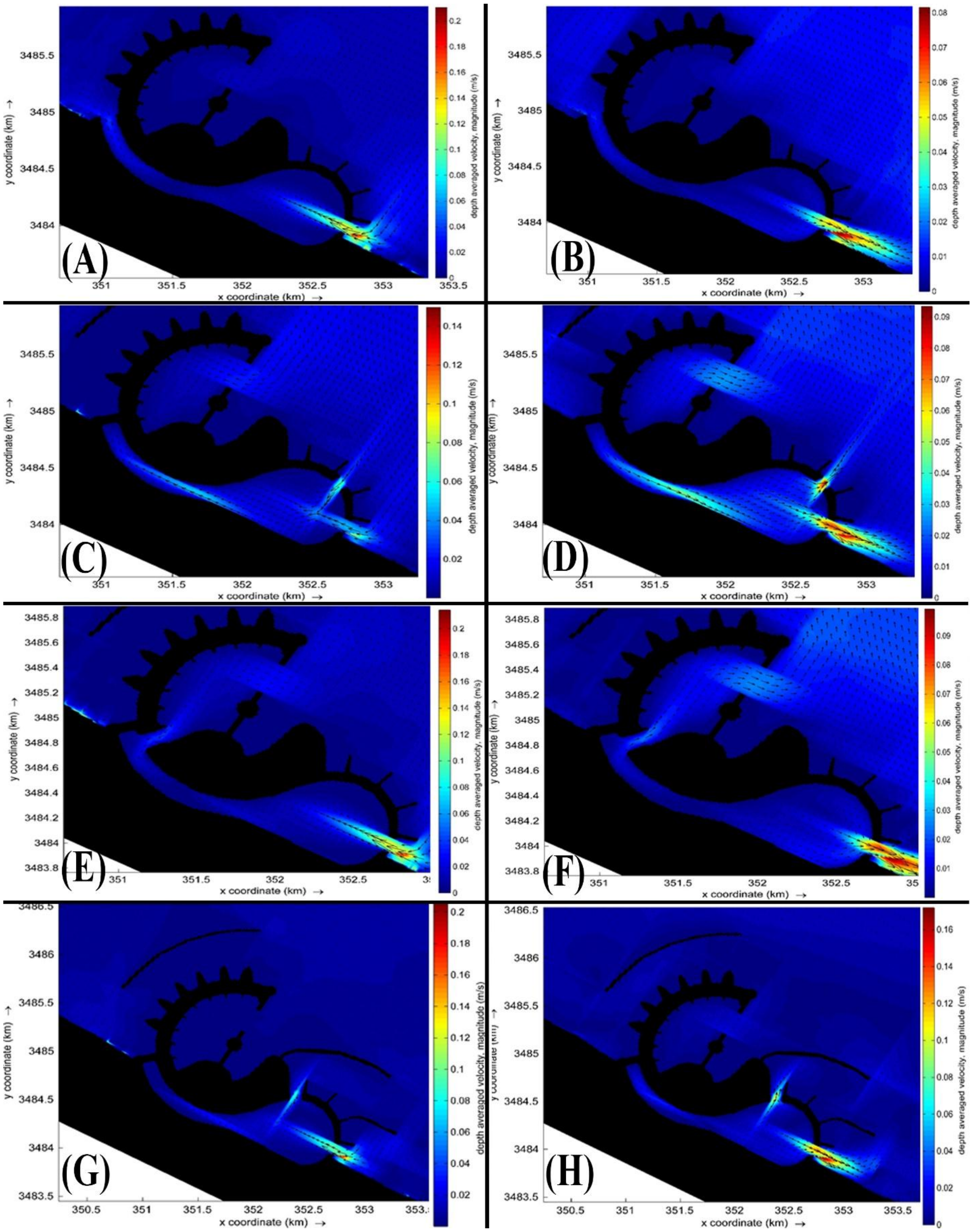

Figure 8 Simulated Resident time (A,B)Initial state, (C,D)scenario-7, (E,F)scenario-8, (G,H)scenario-9.

Results and discussion: -

It is highlighted that palm inclination towards the Eastern side is preferred to create sheltered area that can be presented as low wave heights zone which is suitable for both swimming and yachts marina implementations. It is clear from the hydrodynamic and water quality simulations that all the tidal current and resident time values are acceptable in all calculation points except for the inner points inside the proposed lagoons due to lack of any interaction with the sea water and low purification rate. Western proposed groins will be structurally uneconomically designed due to high storm incident waves and unbenefited marketing sales for the proposed residential units. Also the morpho-dynamics study showed high accretion rate on the western side and eastern erosion along 1.5km to the East. Consequently, the palm can be treated in the future research as a great jetty influencing the natural sediment transport rate along the littoral drift zone. The proposed scenario and its main alteration in the basic layout showed high improvement specially, regarding the resident time which can be reported to be 22 hours in the lowest purified zone.

Summery and conclusion: -

As a solid conclusion, it is obvious that the primary layout of the project is well wave resisted however, the western proposed groins will be structurally uneconomically designed due to high storm incident waves and unbenefited marketing sales for the proposed residential units. Western submerged breakwater is found to be a good solution for such issue. Graded groins along with eastern 1m sea bed layer replacement is found the most reliable and effective scenario that will reduce the eroded length to be 300m. Eastern submerged breakwater is preferable to protect eastern groins and reduce the implementation costs, in addition to protect eastern opening from sedimentation and create sheltered area for berths and navigation process. A volume of 20,000 m^3 nourishment is proposed to be sufficient along with the last mentioned scenario for study area stabilization According to water quality investigation, the resident time for most inner crystal lagoon region is huge due to lack of any regenerating and interaction with the sea, especially after western opening sedimentation which is also clear from the low current velocity speeds. Western opening is to be closed where opening new opening to be connected with the inner lagoon or between second and third eastern groins will efficiently reduce the resident time with no opening clogging. This research topic is contributing to the advancement of the pure science of mega structure implementations along coastal areas which can help many researchers on the long run to easily predict the interaction with the coastal aquifer.

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