

A STUDY ON THE SAND-MUD MIXTURE AT NORTH-WESTERN PART OF THE PERSIAN GULF

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A numerical model is used for simulating the transportation process of sand-mud mixture at Shah-Abdollah Port located on the north-western shoreline of the Persian Gulf. Available hindcast wave data were adopted in combination with tidal water level variations as the boundary conditions of the numerical model. The existing extracted shoreline changes around Shah-Abdollah Port through GIS analysis of satellite images were used to assess the general morphological changes in the study area. The modeling results of sediment transport shows that the net longshore sediment transport at both sides of the port reduces to very small values near the port location implying that this location is acting as a null net drift point dividing the eastern sandy and western muddy coastlines.

Keywords: sediment mixture transport; Persian Gulf; delft3D; Shah-Abdollah Port; hindcast wave; tide

INTRODUCTION

Sediment transport is one of the most important issues affecting coastal regions. Sediment transport could play an important role in different areas of coastal engineering fields, constructing ports and breakwaters or assessment of environmental hazards. Sediment mixtures might be found at coastal areas near river mouths where fine and cohesive sediments get into the sea water which already has a combination of cohesive and non-cohesive sediments.

There are three main zones with significant amount of fine sediments in the Persian Gulf, i.e. the delta of Arvand River, the delta of Mond River and the coast of Gheshm Mangroves. While the oil and gas fields and/or the valuable fish resources in these areas encourage development plans and constructions of the ports, the existence of soft muddy beds and sand-mud mixtures has limited the developments of these coasts. Therefore, the study of the complex behavior of the sediments at these areas is essential for the future designs and development plans.

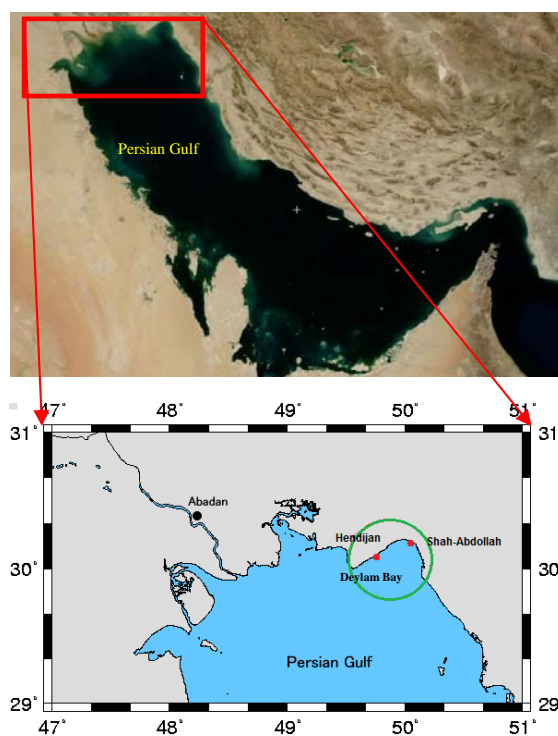


Figure 1. Study area at north-west of the Persian Gulf

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The north-western part of the Persian Gulf is covered with mud, originated mainly from the catchment area of Arvand River (Haghshenas and Soltanpour, 2010). Mud deposits up to 20 meters thickness is observed at the very shallow coast of Hendijan Fishery Port, located at the north-western shoreline of the Deylam Bay; while very fine sand with oolitic origin is dominant at Deylam Port in the south-eastern corner of the bay.

At the most northern part of the bay, there is a small village with a newly constructed port, called Shah-Abdollah, where repeating sequences of soft mud and fine sand could be observed on the beach. Significant subsidence of breakwater armors, up to 8 m, was reported at the site revealing the existence of considerable amount of soft fine sediments at port location. The existence of sand-mud mixture at the site indicates that this location might be at the marginal point between the eastern sandy and western muddy coastlines (Fig. 1).

Fig. 2 shows a view of the sediments near the port breakwater. Mud deposits and very fine sand can be seen at the northern part of breakwater. It should also be mentioned that only mud deposits exists at the southern part of the breakwater.



Figure 2. Repeating sequences of fine sand and mud deposition at the vicinity of Shah-Abdollah Breakwater

FIELD MEASUREMENTS

A set of field measurements was performed at the field site from 20th of February to 28th of March, 2007 (Haghshenas and Soltanpour, 2010). Directional wave spectra and vertical current profiles were simultaneously recorded at two nearshore (2.5 m deep) and offshore (10 m deep) stations. The locations for measuring wave spectra and current profiles can be seen in Fig. 3. This data is employed for the verification of the hydrodynamic model.

Disturbed sediment samples from the site shows that the grain size gets smaller as the water depth increases. Table 1 shows the location of the obtained samples and their corresponding mean diameters (D_{50}). The sediments can be categorized as fine sands and mud deposits. It is also observed that the diameters of particles are significantly lower at higher water depths.

	X	Y	Depth	D50
1	412126	3339463	Dune	0.07311
2	412122	3339460	Water line	0.19358
3	410900	3338383	-2 m	0.0302
4	410039	3337654	-5 m	0.00398

MORPHODYNAMIC CHANGES ALONG THE STUDY SHORELINE

Long-term morphodynamic changes of the shoreline are studied by the analysis of aerial photos and satellite images. Comparison of historical shorelines extracted from GIS analysis of Corona 1965 aerial photos and IRS 2003 satellite images reveals that the coastline is stable from 1965 to 2003; as shown in Fig. 4.

Two recent hydrography surveys with a short three years interval, i.e. before and after Shah-Abdollah Port construction, also do not show a remarkable change at both northern and southern sides of the newly built breakwater. Fig. 5 shows the hydrography surveys at the north part of the breakwater (Sahel Consulting Eng. Company, 2013). However, longer monitoring data, in the order of 10 years, is necessary to further validate the stability of the shoreline.

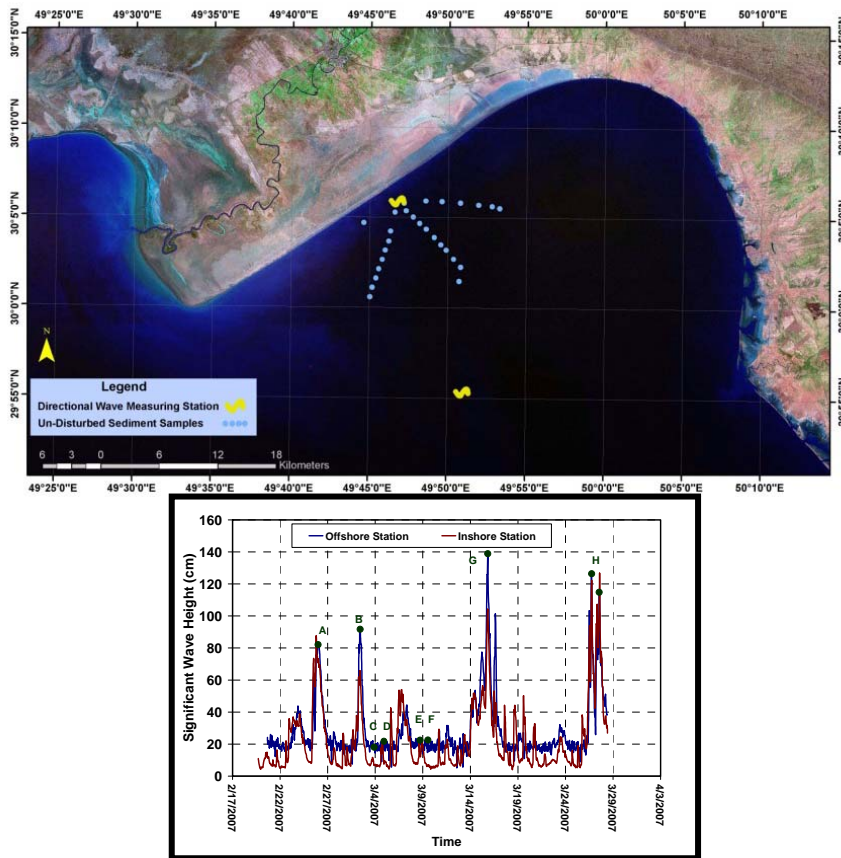


Figure 3. The location of measured hydrodynamic data (top) and time series of significant wave heights at offshore and nearshore stations (bottom), (Haghshenas and Soltanpour, 2010)

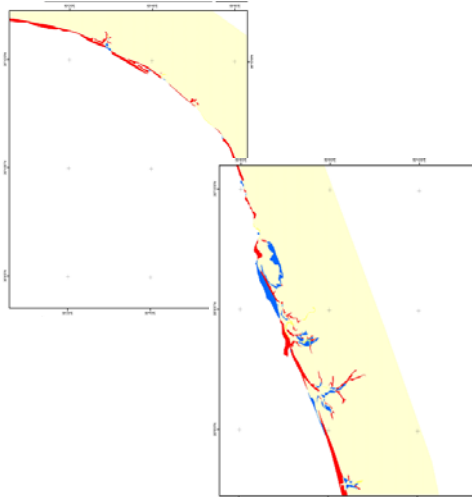


Figure 4. Comparison of historical air photos using Corona (1965) and IRS (2003), (JWERC, 2011)

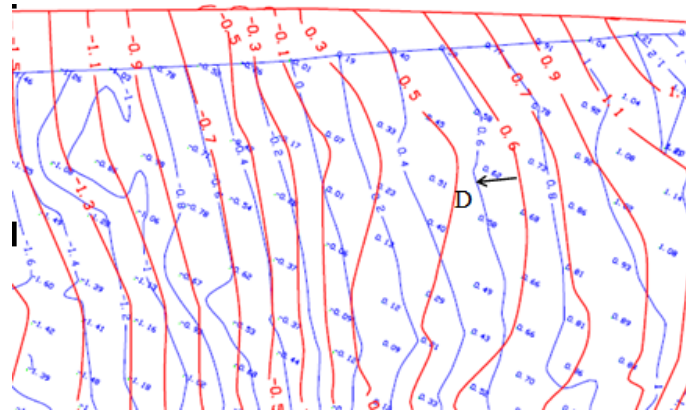


Figure 5. Parts of hydrography surveys at the site before (red line, 2010) and after (blue line, 2013) construction of the port, (Sahel Consulting Eng. Company, 2013)

NUMERICAL MODEL

Delft 3D package, capable to simulate the complex transport processes of sand-mud mixtures, is employed here to model the sediment transport and morphodynamic changes at the site. Using the online hydrodynamic model of wave and currents of Delft 3D software, 2DH wave-induced currents and tidal currents are calculated and introduced to the sediment transport model.

Fig. 6 presents the employed grid for simulations. A total number of 3478 elements with the grid sizes of 60 to 4700 meters were considered. Along the shoreline of Deylam Bay, cross sections were defined perpendicular to land boundary to obtain the longshore sediment transport rate at different areas.

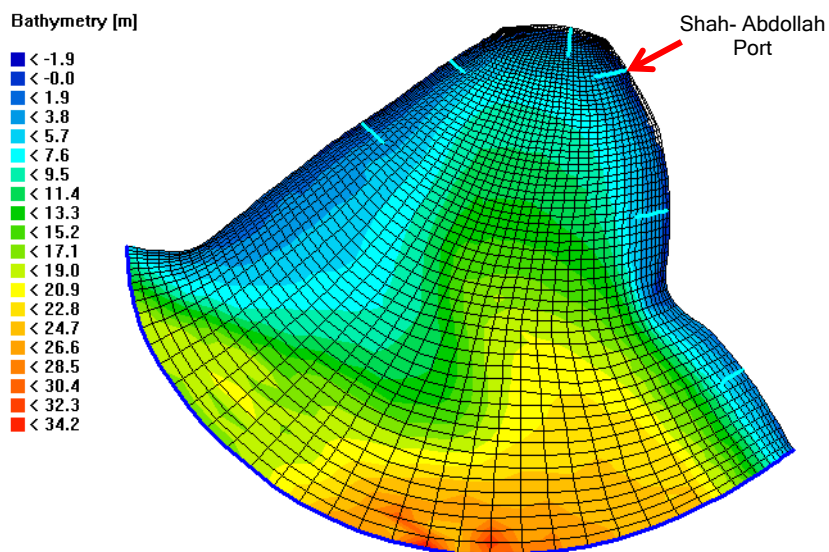


Figure 6. Grid size, water depth and defined cross sections at the computational domain

The hydrodynamic input data at the offshore boundary of the model are tidal water level (Fig. 7) and wave characteristics (Fig. 8). The tidal water levels show a dominant semi-diurnal mixed tide (Fig. 7). The offshore waves are adopted from 25-years hindcast data of the Persian Gulf (Baird and Associates, 2010).

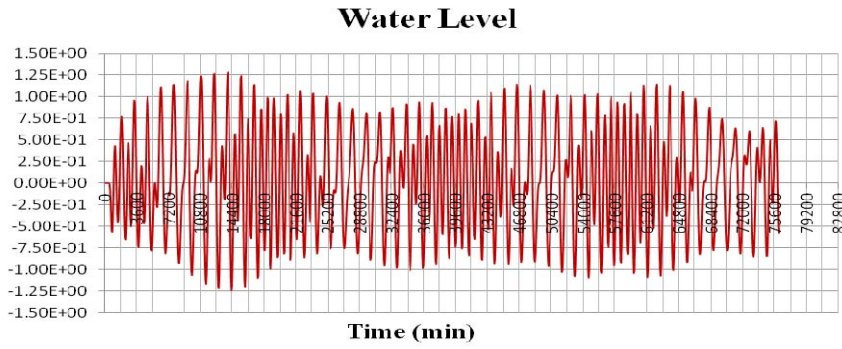


Figure 7. Water level fluctuations at offshore boundary of domain

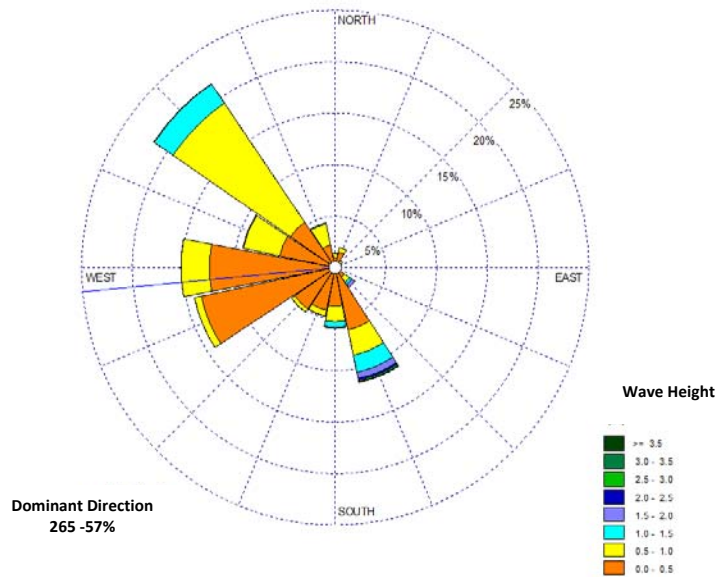


Figure 8. Hindcast wave rose at offshore boundary for the period from January 1984 to December 2008

RESULTS AND DISCUSSION

Comparisons of the model outputs and field measurement data at the nearshore station are carried out for the verification of the model. Figs. 9 and 10 show the comparisons of calculated and measured depth-averaged velocities and wave heights, respectively. It is observed that the model is capable to predict the hydrodynamic of the study area and it can be used for calculating the sediment transport rate at the selected cross sections.

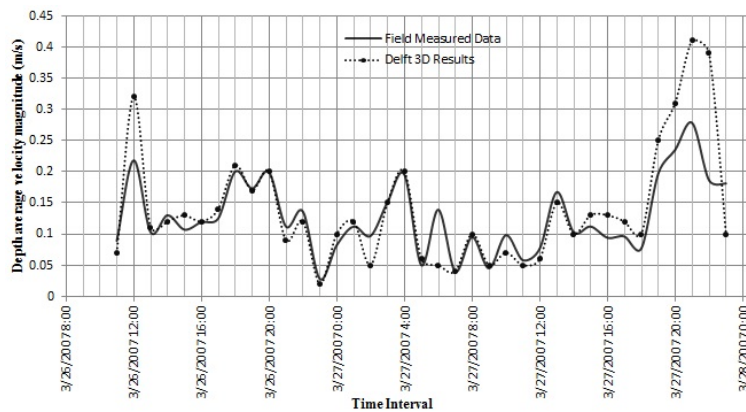


Figure 9. Comparisons of calculated and measured depth-averaged velocities at nearshore station

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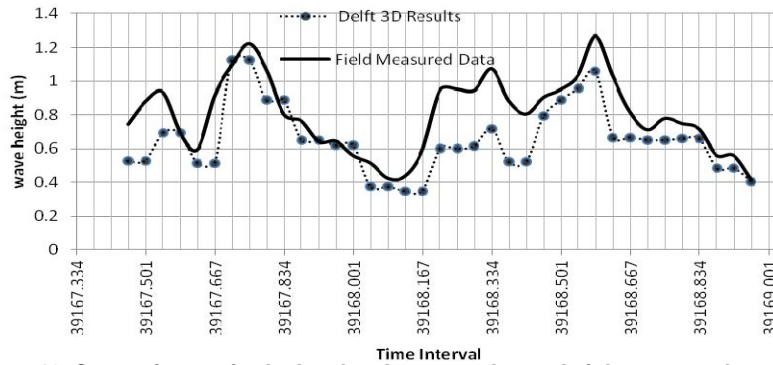


Figure 10. Comparisons of calculated and measured wave heights at nearshore station

The applied hindcast wave data are divided into 10 directional bins to consider the combined effects of waves and currents on sediment transport. Introducing the offshore waves at each bin and water level variations to the model, the potential sediment transport is separately calculated for the directional bins. The total potential sediment transport rate at each grid point is then defined by adding the corresponding values of individual directional bins. Figs. 11, 12 and 13 show the rates of bed load, suspended load and total sediment transport (summation of bed load and suspended load) at defined cross sections, respectively. The longshore sediment transport of Fig. 13 shows different directions at eastern and western part of Shah-Abdollah, transporting sediments towards the site (Fig. 13). However, the rate of sediment transport reduces to small values near the port, i.e. null point-zero net drift. As no sediment passes this location, it can also be defined as a boundary of sediment cell. Fig. 14 shows the major littoral cells along the Iranian coastlines (Dibajnia et al., 2012). It is observed that north of Deylam Bay is the boundary between cell 1 and cell 2.

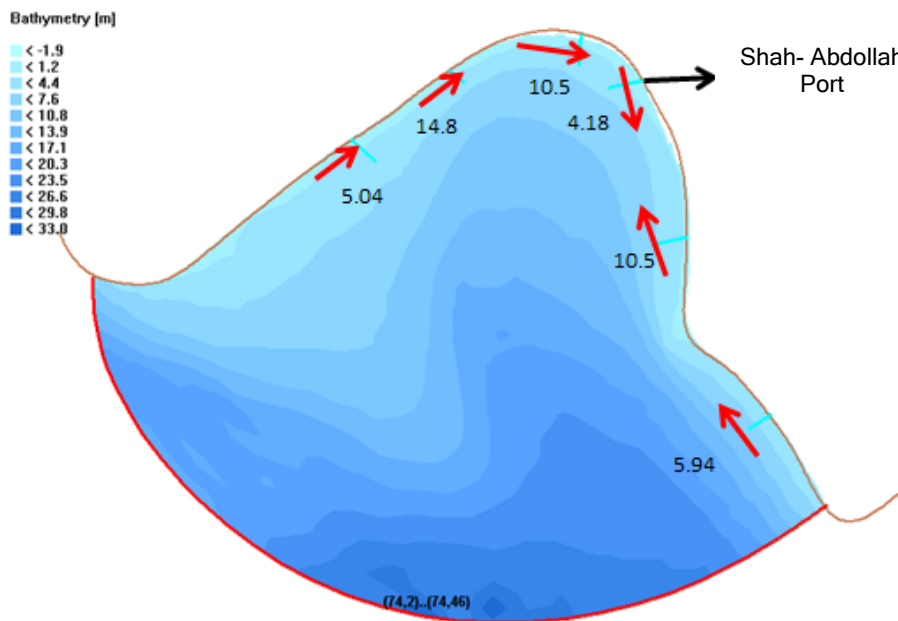


Figure 11. Bed load transport (1000 m³ /year)

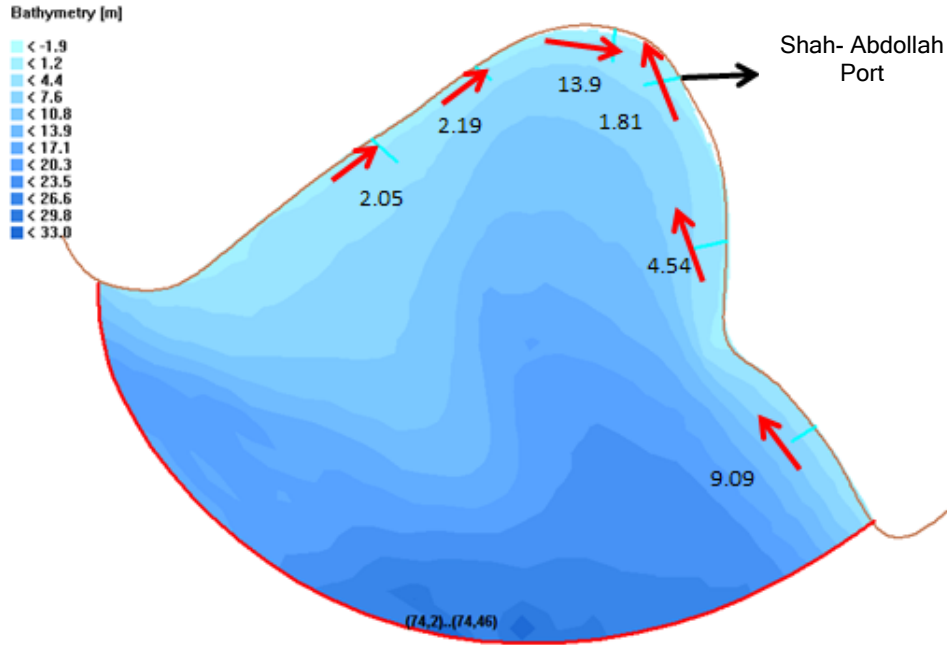


Figure 12. Suspended sediment load transport (1000 m3 /year)

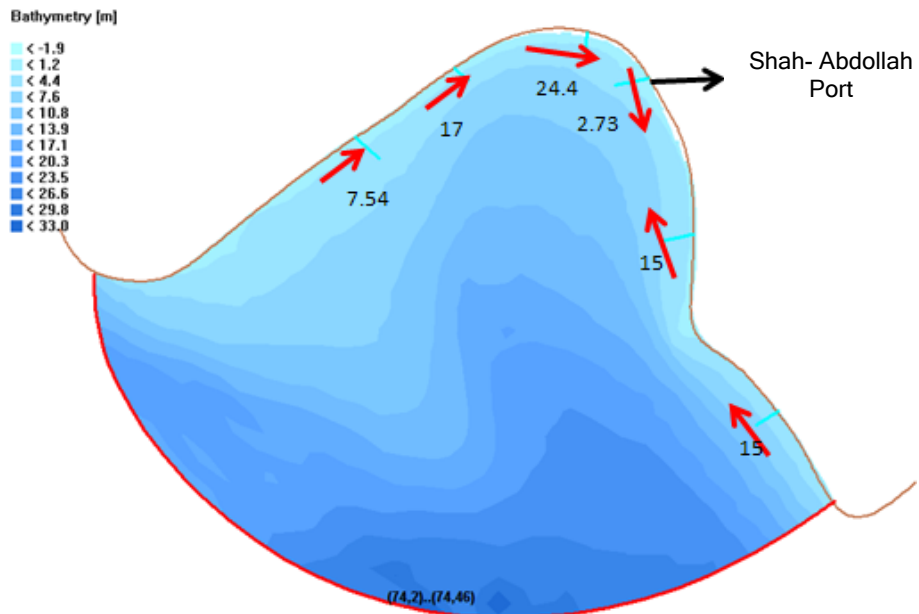


Figure 13. Longshore sediment transport rate (1000 m3 /year)

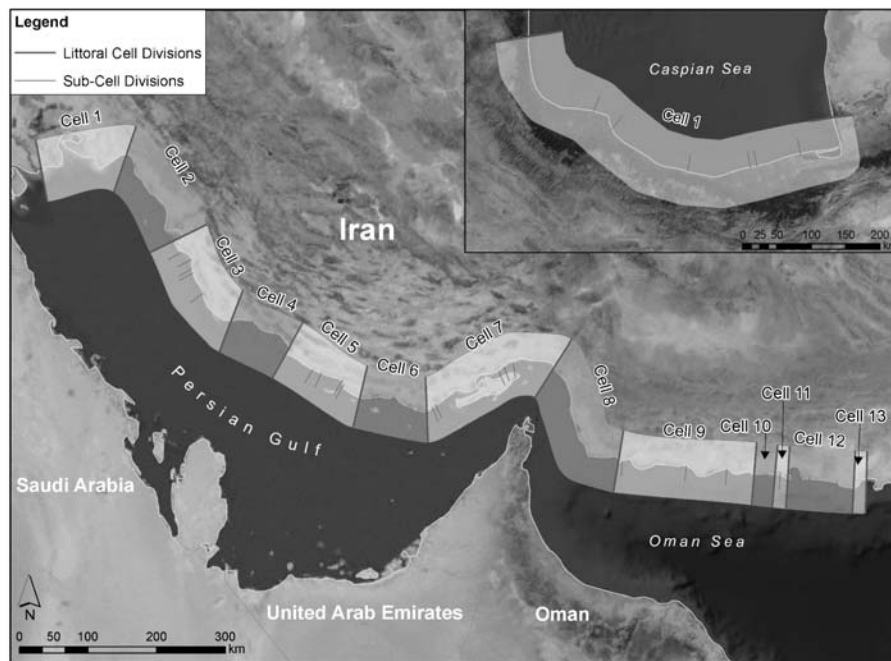


Figure 14. Littoral cells and their approximate boundaries along the Iranian coastline (Dibajnia et al., 2012)

SUMMARY AND CONCLUSIONS

Delft-3D, one of few available numerical models to simulate the transport of mixed cohesive and non-cohesive sediments, was applied to model suspended and bed load sediment transport at Shah-Abdollah Port, in the north-western part of the Persian Gulf.

The hydrodynamic model was verified comparing the outputs of the flow model and wave's with field measurements, showing reasonable results. The comparisons of satellite photos do not reveal any remarkable shoreline erosion/deposition at the site. Using the hindcast waves and tidal level data, the long-term potential sediment transport rate was calculated at the study area.

A clear border between muddy and sandy coasts can be observed near the port. The site can also be distinguished as the boundary of neighboring littoral cells with small sediment bypass. As the large rivers with the huge sources of cohesive materials are all located at the west part of the port, this negligible transport rate at Shah-Abdollah implies that the sand coming from the east side and mud originated from the west part will mostly stop at the port location. In other words, the sands located at the eastern sandy beaches and mud from the western muddy coasts does not bypass the port location. Thus, the existence of sand-mud mixture at the coast of Shah-Abdollah can be explained as the site is at the marginal point between the sandy and muddy environments.

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