1. Introduction
In Iran, installation of offshore platforms in the Persian Gulf began in 1960s in Bahreganser field. Till 1979, tens of platforms were installed in four operational fields namely Bahregansar, Khark, Lavan and Sirri.

After the revolution, South Pars field was also developed. Nowadays about two hundred platforms are in operation in Iranian waters of the Persian Gulf.

This key note lecture reviews the practice for design of these structures in the past. Challenges, which have been overcome and the experiences gained will be discussed. On the other hand, given the number and the age of the existing platforms, the challenges, which the technical community may face in the future with regard to assessment of these structures either to decommission them or to extend their service life will be presented.

2. Design of New Platforms
Often offshore platform in Iran are designed based on API-RP 2A code of practice. Similar to other design guide and standards, this document has undergone revisions during past decades. As the results of these revisions, more sophisticated methods of analysis and design must now be used. These structures are normally designed for several load combinations, which generally fall into two categories:

- In-service conditions
- Pre-service conditions

The most important types of analysis, which need to be carried for in-service conditions, are as follows:
- In-place analysis
- Fatigue analysis
- Seismic analysis
- Ship impact analysis

Design life of these platforms is usually between 25 to 30 years. The design life directly affects the fatigue design of structure and indirectly affects the design environmental conditions. The design environmental criteria should be developed from the environmental information and/or a risk analysis.

The difficulties that the designers have been facing in the past for gathering the information, selecting the design parameters and modelling the structures, for the purpose of analysis and design will be discussed in this lecture.

The most important types of analysis, which need to be carried for pre-service conditions, are as follows:
- Load out analysis
- Transportation analysis
- Lift/Launch analysis
- Un-piled stability analysis
- Pile driving analysis

In this phase of operations some incidents and/or accidents have happened in the past. Some of them have had major financial consequences. Some have been attributed to wrong operations and some to shortcomings in design procedures and assumptions. The problems that the designers have been facing in this regard will also be discussed in this lecture.

3. Assessment of Existing Platforms
Currently there are many platforms in operation in the Persian Gulf. Design life of quite a number of these platforms has already expired. Taking into account the assets installed on topsides of these platforms, they worth hundreds of millions of Dollars.

Mechanisms that may reduce the structural capacity of a platform during its operational life, are as follows:
- Dropped objects
- Vessel collision
- Corrosion
- Fatigue
- Installation damage
- Fabrication flaws
- Seabed scour or seabed build-up
- Overload
- Accidents such as fire and explosion.

Therefore, apart from a good practice in design, construction and installation, in order to ensure that a platform can serve its design life, a proper maintenance program is necessary. Even if a proper maintenance program is implemented, when the design life of a platform is expired, the whole structure needs to undergo an assessment process.

Previously a chapter of API-RP 2A code of practice was devoted to the subject of assessment of existing platforms. However due to its growing importance recently a separate document called API-RP 2SIM has been developed for this purpose.
Structural Integrity Management, SIM, is a continuous process, which can be used for demonstrating the fitness-for-purpose of an offshore structure from installation through to decommissioning. SIM provides the process for understanding the effects of deterioration, damage, changes in loading, and accidental overloading. In addition, SIM provides a framework for inspection planning, maintenance, and repair of a platform or group of platforms. Application of SIM requires different types of analytical procedures and more realistic information and data regarding site environmental, seismic hazard and soil conditions.

So far only a few platforms have undergone this process, mostly using the provisions of previous editions of API-RP 2A. Challenges facing the engineers in futures, with regard to assessment of old existing platforms will form the second part of this lecture.
1. Introduction

The evolution of sandy, often human-impacted coasts over decades is of great interest to coastal scientists, engineers and managers. Existing modeling approaches focus on the plan-view development of the coastline, on the evolution and variability of the beach and dune profile, or try to simulate the evolution of the complex bathymetry and topography of the beach-dune system; however, the state of the art of existing models is not up to what is expected of them.

2. Shoreline: A New Coastline Modelling Concept

In coastline plan view modeling, existing model approaches only allow for incremental coastal evolution relative to a fixed reference line. This does not allow the evolution of important features such as spits and sandy hooks, tombolo’s and migrating islands. We have recently developed a new coastline model, ShorelineS [1], that has abandoned the fixed shoreline grid approach in favor of a completely free description where the coast is schematized to strings of grid points that can move about freely and interact with each other.

The freedom of this approach allows an easy definition of the model domain and input wave climate or time series. We recently added approaches to represent diffraction behind breakwaters the full evolution to a (series of) salient and tombolos can be simulated.

3. Applying XBeach for Longer Timescales

Figure 2. Effect of ‘bermslope’ effect on nearshore profile evolution; bottom panel: with, top panel: without.

A limitation of XBeach for longer-term applications is the fact that, especially for reflective and semi-reflective beaches, XBeach tends to grossly overpredict erosion at the water line, since it does not resolve the small-scale and highly dynamic swash processes there. While efforts to improve this situation are ongoing using the non-hydrostatic mode, here we apply a pragmatic approach outlined in [2], where the profile in a very limited area near the water line is ‘nudged’ towards a given ‘bermslope’, using an upslope transport process. This simple modification has a dramatic effect on the behaviour of steep beaches (see example in Figure 2) and allows the full range of scarping to berm building, maintaining the general shape of the intertidal beach through erosive and accretive sequences.
4. Including Wind-Blown Processes

A new model, Duna [3], coupled with XBeach, simulates the evolution of dunes as a result of input conditions (e.g. wind, vegetation cover, moisture) that can change over time and interact with the dune topography. The model computes and updates the horizontal distribution of the cross-shore and longshore wind velocity, the velocity thresholds of sand movement, the growth and the coverage of the vegetation, and the sediment transport. The results from each time step allow the update of the dune topography and vegetation cover. The coupled XBeach-Duna system was calibrated to represent the evolution of two beach-dune profiles in Praia de Faro, Portugal, over a 2-year period.

5. Effects of Longshore Transport Gradients

In profile models usually the total cross-sectional area of the profile is conserved, limiting the application to situations where the profile moves around a quasi-equilibrium. This can be overcome by assuming that the longshore transport gradient, responsible for structural erosion or accretion, is proportional to the longshore transport itself, divided by a typical length scale. In such a way long simulations can be carried out where, amid intra-annual variations, the coastal profile, including the dune, retreats or advances while the location of the accretion or erosion in the profile is simulated realistically. Figure 3 shows an example 10-year simulation for seriously eroding, relatively stable and strongly accretive profile evolution.

The model captures a balance between longshore gradients and cross-shore processes in the surf zone, competing effects of moderate conditions and storms in the intertidal area and between build-up by storm waves and aeolian transport on the berm. Vegetation behaviour is shown to play a key role in the development of the shape of the foredunes. The relation between progradation or recession rate and foredune height as often reported in literature is reproduced.

6. The Dream: Hybrid Modelling of Complex Areas

While efforts will continue to simulate long-term evolution of complex areas with detailed morphodynamic area models, we see a large scope for considerably faster concepts that combine simplified but effective models of coastline behaviour and profile response, or coastline models with area models that do not need to resolve the wave-driven processes. This will bring much-needed simulations over decades to centuries, needed to assess impacts of increasingly alarming climate change scenarios, to within acceptable computation times.

7. References


1. Introduction

At the 2016 ICOPMAS, we presented the results of a hydrodynamic model of water movement in the Persian Gulf, added the projected nutrient discharges from proposed mariculture installations, and warned that the increased nutrients could threaten coral reefs and artisanal fisheries in the Gulf. There are now several fish farms established in the Gulf, and some monitoring data are available to allow some highly tentative conclusions to be drawn.

These results are important for Iran, because of issues of food security and environmental maintenance. Excessive nutrient inputs will lead to Red Tides, possible sulfide toxicity, and damage to surrounding ecosystems. If aquaculture activities are found to overload the natural absorptive capacity of the sea bed, then either operations will need to be curtailed, or land-based systems considered.

2. The Slippery Concept of Carrying Capacity

There are many definitions of carrying capacity in use: 1) Physical carrying capacity—the number of fish farms that can fit in a given space. 2) Production carrying capacity is the stocking density at which production is maximised. 3) Ecological carrying capacity is that density above which unacceptable damage results to the ecosystem, and finally 4) Social carrying capacity is the level at which the aquaculture operations do not cause societal disruption.

The most important of these is ecological carrying capacity, which we define as that level of aquaculture activity that does not result in permanent or long-standing change to the environment. Most of the damage from open-net fish farms results from the organic discharges, and we will focus on that herein. This means that any organic matter deposited by a fish farm needs to be oxidised as rapidly as it accumulates [1].

3. Previous Research and Present Situation

Our paper at the previous ICOPMAS noted that the value of the coral reefs of Kish Is. Was about US$100 million, or $200,000/ha, and that the artisanal fishery (much of which depends on reef areas) had a market value of $200 million and employed about 20,000 people. Our model suggested that, with the projected number of fish farms operating, after one year all the reefs around Qeshm and Kish Is. would be killed, and in addition—there would be serious trans-boundary issues.

At time of writing, there are a few fish farms operating in Iranian waters, most around Kish Is. There is a limited amount of data available from monitoring programs.

<table>
<thead>
<tr>
<th>Time (Mos.)</th>
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<th>Control</th>
<th>Near Cage</th>
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<tr>
<td></td>
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<td>Sulfide</td>
<td>Eh</td>
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<td>40</td>
<td>50</td>
<td>-130</td>
<td>180</td>
</tr>
</tbody>
</table>
4. Sustainability
We suggest that, for operations to be sustainable, the sediment conditions under the fish pens show always show: pH>8; Eh 0 to -50, DO >2ml/l, and (perhaps the most important) sedimentary sulfide levels <1,000µM. Much of the labile N in the organic deposits is capable of being transported over large areas [2], so the OM under the cages should not increase, nor should there be accumulation of material [3].

5. Preliminary Results
Examination of the limited monitoring data shows that Eh is often at unacceptable levels, and sedimentary sulfide levels are starting to creep up to the boundary between Acceptable and Unacceptable. Refining the hydrodynamic model shows the potential for spreading organic pollution to other areas, as we suggested earlier.

6. Conclusions and Suggestions
Some of the farms are operating beyond the absorptive capacity of the environment. Stock reductions or fallowing are possible ways to remedy this. Continuation of the monitoring to a variety of fish farm operations should allow a rough estimate of carrying capacity of the Iranian side of the Gulf. In any event, the organic pollution from fish farms may become such a problem that land-based operations will have to be considered.

7. References
It is now well established that a number of important commercial muddy estuaries, Loire, Scheldt, Ems, Weser and reaches of the Elbe have become severely degraded due to a combination of marginal reclamation coupled with gross-scale over-deepening to facilitate passage of modern deep-draughted trading vessels. If the Gironde, Seine and Rhine have been similarly managed and investigated such studies are not, as yet, publicly available. Degradation manifests itself as a shift to much greater flood tide dominance, together with import of mud from a down-estuary direction and resulting in hyper-turbid, fluid mud, conditions. Estuary reaches affected have severely impaired ecosystems, whilst ground water effects in marginal land areas have manifested themselves in differential ground movements and subsidence of buildings etc.

Appreciation of these detrimental changes has led to intense studies of how to reverse this degradation?

It is already clear that this will require many years of effort along with a high cost. Early attempts to reduce the enhanced fine sediment load in the Inner Ems by creating backshore ponds accessed via deep, narrow cuttings aimed at siphoning off and capturing the fluid mud have proved impractical for the moment. Similarly suggestions to restrict up-estuary advection of fluid mud in the Loire by installing upstanding cross-channel cills or by use of cross-channel air bubble curtains have been dismissed as overly expensive and impractical.

Alternative and more readily reached-for options involve much wider application of the KSIS principal (Keep Sediment In the System) and the Ems Estuary could be a candidate for the worlds first sustainably managed cohesive sediment estuary. There are three objectives, port sediment, muddy fairway sediment and polluted sediment. The three significant muddy ports, Emden, Delfzijl and Leer along with Husum just outside already apply one or more generic SMS’s (Sediment Management Systems). These are total as opposed to partial solutions; implying fine cohesive sediment is no longer dredged, removed and dumped outside this estuary. Secondly, repeat experiments applying Active Nautical Depth in the Inner Ems fairway have proved successful; the engineered aerobic fluid mud cloud created allows ships to pass through it. At the same time the induced fluid mud advects short distances up and down the channel due to flood and ebb shear stress, so providing a significant degree of flood tide retardation. This assists in reducing excessive induced flood phase advective transport into the inner reaches of the Ems. Thirdly, it is well-established that aerobic suspensions created by Active Nautical Depth have the added side-benefit of destroying the contaminant TBT in situ. Since 1990 no TBT-contaminated mud has needed to be dredged and stored outside the Ems Estuary. Research is currently in progress to investigate whether this natural phenomenon can be enhanced into a viable industrial process – ‘in-situ bio-remediation’. Studies involve both laboratory and field tests seeking the dominant communities of natural aerobes most adept at this destruction. Lab tests on cold-stored mud samples are now being complemented by mesocosm experiments in impounded docks in Port of Liverpool, UK, most contaminated with TBT.
Attached graphs show conceptually how contrasted degrees of oxygenation and water temperature accelerate the process. This topic area remains, for now, in its infancy.

These novel strategies, altering port mud attributes to facilitate ship passage, permitting ‘Conditioned’ aerobic mud to lie in fairways and ‘in-situ bio-remediation’ each contribute to sustainability, whilst permitting maritime economic activity to continue.

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References
A SEMI-ANALYTIC MODEL OF COASTAL INLET EVOLUTION

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1. Introduction
The water exchange between the sea and a lagoon or bay through an inlet due to tides is a classical topic that has been investigated in a large number of studies [1, 3, 4, 6]. Initial efforts to calculate the inlet flow involved simplified governing equations that were solved in terms of non-dimensional variables, implying that key parameters could be displayed efficiently in diagram form [2]. Subsequently, numerical approaches have been taken that may include more general forcing, initial, and boundary conditions employing governing equations that involve less restrictions. However, the simplified approaches still have their use for making approximate estimates in the initial stage of a project or for smaller studies where available resources prevent large-scale numerical modelling. Also, in coupling inlet flow models to sediment transport and morphological change simulations, it may be advantageous to employ simpler models to achieve robust and reliable results at reasonable computational efforts.

The main objective of this paper is to derive a simple semi-analytic model of the flow induced by tides through an inlet connecting the sea to a lagoon or bay that can be used to develop explicit expression for key parameters associated with this type of flow, such as bay water level amplitude, tidal prism, maximum inlet velocity, and retention (mixing) time. The word semi-analytic is used to denote an approach that does not exactly solve the governing equation, but only satisfies it in an overall sense according to a specific criterion. Also, the inlet flow model is employed to explore inlet equilibrium and stability as well as inlet cross-sectional area evolution by using a sediment transport relationship together with a sediment balance equation for the inlet.

2. Model of Inlet Flow
The flow through an inlet connecting a lagoon (or bay) to the sea was described by [4] using the continuity equation for the lagoon together with the momentum equation for the inlet channel, resulting in,

\[
\frac{d\eta_B}{dt} = \frac{A_I}{A_B} \sqrt{\frac{2g}{K_f}} \sqrt{\eta_B - \eta_o} \text{sgn}(\eta_B - \eta_o) \tag{1}
\]

where \(A_B\) is the bay surface area, \(\eta_B\) the bay water level, \(A_I\) the inlet cross-sectional area, \(\eta_o\) the sea level, \(g\) the acceleration due to gravity, \(K_f\) a friction coefficient, and \(t\) time. Assuming a sinusoidal sea level variation with amplitude \(a_o\) and period \(T\), and introducing non-dimensional quantities, the repletion coefficient emerges as the main parameter controlling the inlet flow, defined as \(K = (A_I / A_B) \sqrt{2g a_o / K_f (T / 2\pi a_o)}\). Figure 1 shows the non-dimensional water level variation in a lagoon for different values on \(K\) at quasi-steady conditions obtained by numerically solving Eq. 1.

A semi-analytical approach can be taken to solve Eq. 1 using different matching conditions; for several such conditions the following solution is obtained,

\[
a_B = a_o \left(1 - \frac{(C_M K)^4}{4} \left(1 + \frac{4}{(C_M K)^4} - 1 \right)^{1/2}\right) \tag{2}
\]

where \(a_B\) is the bay amplitude and \(C_M\) is a matching coefficient equal to 1.23.

3. Inlet Flow Properties
Based on the semi-analytic solution, different inlet flow properties can be calculated and expressed in non-dimensional form. A common parameter employed to quantify the water exchange is the tidal prism, which expresses the volume of water that is transported into and from the bay during a tidal cycle. The tidal prism is given by \(P = 2a_o A_B\); if \(P_{\text{peak}} = 2a_o A_B\), then the non-dimensional tidal prism is \(\tilde{P} = P / P_{\text{peak}} = a_B / a_o\), which is given by Eq. 2. Other quantities that can be determined in a similar manner is the maximum and mean inlet velocity, and the bay retention time. In many studies on inlets a
strong connection between the inlet cross-sectional area and the tidal prism has been established. The present solution yields \( A_t / A_o = \hat{R} (1 - \hat{R}^2)^{1/4} \), where \( A_t = \pi P_{\text{max}} / T U_{\text{max}} \) with \( u_{\text{max}} \) being the maximum possible velocity through the inlet.

4. Model of Morphological Evolution

The semi-analytical solution can be employed to investigate tidal inlet area evolution. A sediment balance for the inlet involving the longshore sediment and inlet channel transport defines this evolution. The governing equation is given by [5, 7],

\[
B \frac{dA_I}{dt} = K_w (u_I^2 - u_c^2) W - m, \tag{3}
\]

where \( B \) is the barrier island width, \( K_w \) a transport coefficient, \( u_I \) the inlet velocity, \( u_c \) the critical inlet velocity for sediment movement, \( W \) the inlet width (related to \( A_I \) through assumptions about the cross-sectional shape), and \( m \) the longshore sediment transport. For steady forcing conditions, Eq. 3 approaches equilibrium, which may imply a stable, open inlet or one that experiences closure. Figure 2 displays the solution to Eq. 3 in non-dimensional form for \( dA_I/dt = 0 \), using different critical velocities and longshore transport rates (self-similar shape for \( A_I \)). The semi-analytic solution was employed to calculate \( u_I \) and Eq. 3 was solved in terms of the equilibrium repletion coefficient \( (K_w) \). The curves shown are analogous to the ones proposed by [3], indicating whether an inlet is stable or not.

5. Simulation of Inlet Area Evolution

In order to describe the time evolution of the inlet cross-sectional area, Eq. 3 must be solved with the proper initial conditions; this is done numerically, even for schematic cases, since the equation exhibits a complex nonlinear relationship involving \( K \) and other variables. Several simulation cases were investigated to demonstrate the behavior of an inlet under different initial and forcing conditions. As an example, Figure 3 shows the response to an increase or decrease in the LST transport rate with regard to the initial transport conditions in equilibrium, where both equilibrium situations (above and below maximum \( K_w \)) are considered. Small perturbations of the initial transport conditions lead to quite different responses, whether the initial repletion coefficient \( (K_w) \) is in the stable or unstable region. In the latter case closure may occur.

Figure 2. Equilibrium repletion coefficient for different critical velocities and longshore transport rates.

Figure 3. Inlet area evolution for different sediment transport rates and initial repletion coefficient values.

6. Concluding Remarks

In this study the basic properties of the coupled inlet hydraulics and morphological evolution models were investigated, and by a using semi-analytic approach these properties could be expressed in a compact manner through non-dimensional quantities. Asymptotic and equilibrium behavior could be established. The next step is to investigate the ability of the model to simulate the inlet evolution under more realistic conditions. A numerical approach will then be taken and comparison with field data will be performed.

7. References

1. Introduction
Catastrophic coastal flooding generated by the 2004 Indian Ocean Tsunami or the 2011 Tohoku Tsunami as well as by the 2005 Katrina and 2012 Sandy hurricanes have shown that, hydrodynamic loading aside, debris loading is a major contributor to the extreme damage experienced by coastal infrastructure. While extreme hydrodynamic loading due to coastal flooding events has been the object of intense research during the past decade, few studies dealing with debris impact and loading due to coastal flooding have been conducted. Post-tsunami forensic engineering field investigations conducted by the author of this paper (Nistor et al. 2005, Nistor et al. 2010, Nistor et al. 2011) and other researchers (Sato et al. 2014, Chock et al. 2012) revealed that debris loading and debris damming have a significant effect on the structural integrity of buildings and infrastructure in general, especially in high density urban areas. The new ASCE-7 Tsunami Loads and Effects Committee (of which the author is a Voting Member) has recognized the significant importance of debris loading and proposed several prescriptions pertaining to debris loading as well as debris spatial distribution during a tsunami-induced flood event. These prescriptions are based on limited data collected from field investigations (Chock et al. 2012, Naito et al. 2014,) and have yet to be validated as previous prescriptions often resulted in conservative estimations of debris spatial spreading and an inaccurate estimation of associated loading. The few experimental tests (Shafiei et al. 2014, Rueben et al. 2014) showed that accurate tracking of debris is complicated: hence, this study is geared towards investigating and tracking the spatial and temporal displacement of floating debris due to rapid coastal flooding in a built-in port environment.

2. Field Investigations
The author was part of several major international posts-tsunami forensic engineering surveys: (1) Thailand (Phuket) and Indonesia (Banda Aceh) following the December 2004 Indian Ocean Tsunami; (2) 2010 Chile Earthquake and Tsunami and (3) 2011 Tohoku Japan Tsunami. As part of these field surveys the effect of debris impact was analyzed in detail to assess in detail their impact on built infrastructure and to estimate the loading induced by them. Fig. 1 and 2 show examples of debris loading during the 2011 Tohoku Tsunami.

3. Experimental Investigations
This experimental program was conducted in two facilities: the Tsunami Wave Basin at the Coastal Engineering Laboratory at Waseda University in Tokyo, Japan (Shibayama, 2014) which is shown in Fig. 2 as well as in the Hydraulic Laboratory in the Department of Civil Engineering at the University of Ottawa, Canada.

Figure 2: Waseda Tsunami Wave Basin and experimental setup
The experimental program comprised of 12 preliminary (calibration and trial) runs and 48 further runs employing various combinations of “smart debris”. During tests, debris were placed parallel to the edge of the apron on either one or three rows, in single layer or two-layer stacked configuration. Additionally, to investigate the spatial motion of debris within a built-in environment of a port with warehouses and various constructions, one and
two rows of structures were installed on the horizontal apron, right behind the smart debris’ initial location.

For this particular experimental program, the authors designed and constructed a horizontal apron which simulated a horizontal quay (apron) with an adjacent port area. The vacuum-controlled wave maker has the capability to generate a solitary wave which broke at the edge of the apron further generating a hydraulic bore which propagated over its entire length.

Wave gages were located in the deep water section of the basin while some others were located at the inner edge of the apron and at the middle of the apron, respectively. An ECM (electromagnetic current meter) was placed close to the edge of the apron recorded the time-history of flow velocities. The experiments used a novel method to track the spatial motion of “smart” debris using (1) a wireless tracking device employing Bluetooth low energy technology (BLE) and (2) a motion sensor. A third (3), stereo video-analysis system combined with a newly developed algorithm helped further validate the accuracy of the “smart debris” tracking system.

The debris were scaled-down 20’ shipping containers and were manufactured from polyethylene (PE-HMW, 0.92 g/cm³) to simulate an average prototype container weight, W = 14,400 kg. Each debris was equipped with a BLE tag and a motion sensor which recorded the three-dimensional position and orientation, hence the term “smart” debris. The coordinate system and the debris rotation angles are shown in Figure 3.

Tracking data were recorded with a combination of different carefully synchronized data acquisition systems. A software-based video frame grabber was used to record images at 24 Hz. A Linux-based system drove the positioning engine to determine the (x,y,z)-positions in space with a sampling rate which was dependent on the number of debris used in each test. Sampling rates of 25 Hz were attained during the tests with 18 debris units. In addition to the positioning engine, a network time protocol server (NTP) was operated on the Linux-PC which broadcasted the current computer clock time into the network that connected the DAQ computer. According to the NTP-server output, synchronization accuracy in the order of 30 ms was achieved during the tests. Finally, a third computer, also connected to the NTP-synchronization network, was used to setup and read-out the motion sensors.

4. Results
The main goal of this experimental study was to assess the validity and accuracy of the prescriptions of the upcoming ASCE-7 Tsunami Effects and Loads chapter (Chock et al. 2015). The spreading angle and the longitudinal displacement of multiple “smart” debris were measured and processed for each test run. Stereo-images were processed using a color thresholding method in order to isolate the shapes/contours of the debris within each image frame. This allowed results from the BLE tags and the motion sensors to be compared with results from the stereo-imaging. This allowed to assess the performance of the “smart” debris tracking systems.

Figure 4 shows some of the results in terms of the trajectories of debris from their initial position on the horizontal bottom apron with the presence of structures, respectively. For all tests, debris trajectories remained bounded within the ±22.5° envelope suggested by the new ASCE-7 Tsunami Loads and Effects chapter (Chock et al. 2015). However, an increase in the number of “smart debris” was found to result in a decrease in their longitudinal trajectory length, which was confirmed also by Reuben et al. (2015).

5. Conclusions
This field and experimental comprehensive study presents novel results and analysis of the time history of the spatial motion of multiple “smart debris” displaced by overland tsunami bores. This work was conducted with the ultimate goal of assessing the validity of debris motion prescriptions made by the ASCE-7 Tsunami Loads and Effects Committee. An important component of this work was the development of laboratory measurement system capable of simultaneously recording the 6 degree-of-freedom of multiple debris as an alternative to previously used video-camera-based systems.

6. References
Due to space limitations, references mentioned are not listed herein.
TWO-EQUATION TURBULENCE MODELLING OF WAVE BOUNDARY LAYERS

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1. Introduction

Different turbulence models of variable complexity based on the user’s requirements are used to analyze turbulence boundary layers. The governing (Navier-Stokes) equation is a nonlinear, time-dependent, three-dimensional partial differential equation. The actual solutions of this equation are few and only applicable to laminar flow. At high Reynolds numbers, which is the case for most of the practical applications, the laminar flow undergoes instabilities, generally referred as turbulence. Since these instabilities generate three-dimensional features, no satisfactory 2D approximations for turbulent phenomena are available. In addition, turbulence being random process in time, the deterministic approach is not fully applicable. The turbulent flows contain small fluctuations, which can be resolved by choosing very fine grids and time steps, such that a direct simulation is not feasible for high Reynolds numbers.

Using Reynolds Averaged Navier-Stokes (RANS) models, the computational costs are significantly reduced, however, it requires closure assumptions for the higher moments. Large Eddy Simulation (LES) aims to reduce the dependence on the turbulence model by simulating the major portion of the flow without any models, resolving by the grid. Only the scales smaller than the resolution of the grid are simulated by a model. Such a computational strategy makes LES approach computationally more demanding than RANS. It is estimated that RANS models have a computing time of about 5% of the LES whereas, LES has a computing time of about 10% of DNS [1].

Owing to the computational economy and reasonable accuracy of RANS models, various practical flow phenomena have been simulated using different types of models. In this paper, a brief review of some of the applications of two-equation turbulence models in different types of wave boundary layers is presented. Such a review may be helpful in selecting an appropriate turbulence model for relevant field applications.

2. Types of RANS Models

Generally, RANS models are classified based on the number of transport equations of turbulent quantities employed in the model. Therefore, the names one-equation (using the transport equation of turbulent kinetic energy only) and two-equation (utilizing the transport equations of turbulent kinetic energy and another turbulent quantity such as the dissipation rate) are used in the literature. General availability of sufficient computational power has made the utilization of two-equation turbulence models more convenient than three decades earlier.

The most popular two-equation models are $k$-$\varepsilon$ and $k$-$\omega$ models, which have been used a large number of field applications [2].

3. Two-Equation Models and Wave BL

Originally, the two-equation models were developed for steady boundary layers. Later, these models were applied to various complex flows including the boundary layers under unsteady flow. However, using two-equation models for simulating wave boundary layers started in late 70s and became more popular in 90s. Since then, various types of wave boundary layers have been analyzed using two-equation models [3-8].

3.1. Sinusoidal Wave Boundary Layers

A total of five $k$-$\varepsilon$ model versions were applied to sinusoidal wave boundary layers and the model predictions were compared with the available DNS data [3]. It was found that the original model by Jones and Launder [9] performed better in predicting the transition, whereas the version by Myong and Kasagi [10] proved to be superior in predicting turbulent kinetic energy.

Another study employed three versions of $k$-$\varepsilon$ and three versions of $k$-$\omega$ models to analyze sinusoidal wave boundary layers. The comparison with the DNS data showed that the newer versions of $k$-$\varepsilon$ model showed overall better performance, whereas the $k$-$\omega$ model by Wilcox [11] showed better results for bottom shear stress.

3.2. Cnoidal Wave Boundary Layers

Cnoidal wave theory describes an asymmetric wave profile with a sharp crest and flat trough. In coastal environments, such type of waves exist in the vicinity of the breaking point. Figure 1 shows the $k$-$\varepsilon$ model results of temporal variation of the bottom shear stress in a wave cycle for various Reynolds Numbers ranging from laminar to turbulent condition [6]. For laminar flow, the computed and the analytical solution show almost perfect agreement. The time variation of the shear stress under asymmetric wave shows significantly different behavior than that in sinusoidal wave BL.
3.3. Saw-tooth Wave Boundary Layers

The saw-tooth waves occur at the breaking point in the coastal environments. The $k$-$\omega$ model results of acceleration parameter (Fig. 2) with the experimental data as a function of the wave skewness parameter, $\alpha$, show quite good agreement [7].

3.4. Irregular Wave Boundary Layers

Figure 3 shows the wall shear stress with the $k$-$\omega$ model predictions. The three versions show a good comparison of wall shear stress with the experimental data. However, the peak values of the shear stress, except the highest one, are underestimated [5].

4. Future Research

The ongoing research deals with the solitary wave boundary layers, wave-current combined motion, shear stress and sediment transport modeling under tsunami and other long waves. Although, LES and DNS simulations of wave boundary layers are becoming more popular owing to the availability of powerful computing facilities, the two-equation models are more popular among the practicing engineers by virtue of their simplicity and computational economy with reasonable accuracy.

5. References

1. Introduction
There have been significant storm surge and high wind wave attacks over the world in the past fifteen years. Hurricane Katrina (USA) in 2005, Cyclone Sidr (Bangladesh) in 2007, Cyclone Nargis (Myanmar) in 2008 and Typhoon Haiyan (Philippines) in 2013 are some of the most recent important examples. To predict the behaviours of storms and resultant surges or waves, numerical simulation models are proposed and examined in recent times. The model still has shortcomings, but it is now possible to conduct accurate predictions. The model is composed of three sub-models: climate, storm surge and wind wave. They are applied for cases in the Philippines and Japan. The model limitations are also discussed.

2. Framework of Prediction Models
2.1. Storm Surge
The storm surge prediction model is composed of the Weather Research and Forecasting model, WRF [1], and the Unstructured Grid Finite Volume Coastal Ocean Model, FVCOM [2]. Figure 1 shows the general flow of the model elements. In order to predict the storm surge heights with good accuracy, it is necessary to capture the wind and pressure fields of strong typhoons with high precision.

2.2. Wave
The wave prediction model is a combination of WRF and the third generation wave forecast model, SWAN [3]. Figure 2 shows the general flow of the model elements. Here as well, the accurate wind field predictions under low pressure conditions are the most important factors for high precision results.

3. Real-world Applications
Figure 3 shows the comparison of measured and predicted values by the present model system for the storm surge heights in Leyte bay during the attack of Typhoon Haiyan in 2013. In the figure, we also draw the predicted values corresponding to the conditions after global warming (2100 RCP8.5). In general, the agreements between the predicted and the measured values are not very good. In order to get better estimations, it is necessary to try the calculations in parallel by changing physics models or given conditions and calculate ensemble means of the results.

Storm Surge Prediction Model:
 coupled weather-storm surge-wave-tide model
WRF-FVCOM-Xtide-MIROC5

3.2. Wave Model - Japan Coast
Hindcast simulations are conducted to evaluate the wave climate in Japanese islands for the whole year of 2014. In the area, typhoons pass the Pacific coast side frequently during the summer season. The calculation results of wave heights are highly dependent on typhoon route. This results in the difficulty to continuously calculate the wave conditions for a whole month period during summer. Instead, we calculate by changing the
duration of one prediction appropriately, typically less than one month, and combine the results for the whole year in order to improve the accuracy of calculated waves. From the comparison of the hindcast and measured values, we can judge that the calculation results give good agreements after the justification of calculation duration by using trials and errors.

4. Conclusions
The present forecasting models composed of climate, storm surge and wind waves sub-models give good estimation by considering the precise physical processes. However, if they are applied to real phenomena under typhoon attack, there are discrepancies for typhoon route and intensity. In order to improve the accuracy of the models, it is necessary to use ensemble prediction by calculating several cases. For wind-wave prediction, it is necessary to modify calculation durations for long-term predictions.

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6. References
AN ALTERNATIVE TO SAVING OUR BEACHES FROM SEA LEVEL RISE: THE SAND ENGINE

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1. Introduction

The Netherlands has recently adopted a boldly innovative intervention approach named “The Sand Engine”. The Sand Engine is a very large, locally concentrated sand nourishment of 21.5 Mm3, aiming to provide safety against flooding in combination with new spatial values. Such an approach could provide useful elements for other low-lying areas around the globe. The Sand Engine nourishment initially spans the coastal system over a 2.4 km stretch, and extends up to 1 km offshore following a specific shape (Figure 1). The main expectation is that the Sand Engine will stabilize the coastline at its present position and feed the adjacent coastal sections over an extended length of time (20 years) and space (order of 10 km). Here, for the first time, we describe the thinking behind this world-first climate change adaptation strategy and present numerical model predictions of its long-term evolution along with the observed natural evolution of the Sand Engine during its first year of existence. However, implementing far-reaching interventions like the Sand Engine in the modern reflective society requires a paradigm shift that is necessary to implement such interventions in the light of possibly accelerated climate change.

Figure 1. Aerial photograph of the Sand Engine after completion (September 2011) looking southward. Picture courtesy of Rijkswaterstaat/Joop van Houdt.

2. Paradigm shift

The paradigm shift in the approach of water and coastal management that is observable during the last decades represents a major challenge for the coming century. Where in the past the challenge was formulated as to “fight” the forces of nature, today’s approach recognizes the many issues other than protection against flooding and especially the multiple ecological forces that have to be accommodated and can help the processes of protection. While this issue has received attention in the western world since about two decades, it is increasingly also being recognized by the non-western world, notably the growth countries. This implies that water and coastal management have become interdisciplinary as well as transdisciplinary [1]. Some of the issues and dilemmas involved in this challenge are illustrated by the following examples.

In a critical evaluation of the morphological, ecological and socio-economic effects of large number human interventions in the Dutch Delta project (following the 1953 flood disaster), Saeijs et al. [2] advocate working with nature in any future flood protection project in estuarine and coastal environments. A number of their recommendations exemplify this: “…(1) If there is still is a choice, leave untouched estuaries and deltas alone. … (2) If there is already a history of human intervention, try to adopt the most flexible approaches to safety and development. … (3) Reversible and local measures within the limits of the natural processes are preferable….”.

The recommendations of [2] regarding working with nature are in line with today’s policy (cf. the coastal policy to maintain the coastline with “soft” solutions rather than hard (concrete) barriers). Nevertheless implementing the recommendations appears to be complex. For instance, sea revetments may hamper natural processes, but from an economic viewpoint it is generally not justifiable to remove revetments, let alone from a socio-emotional perspective. The complexity may be further illustrated by the conclusions of Jonkman et al. [3] drawing lessons for the Dutch from the New Orleans flood disaster of 2005. These authors observe a tendency in Dutch policy to head towards the US model of mitigating the consequences instead of strengthening the flood defences, while prevention of floods is receiving gradually and relatively
less attention. Then, arguing that (1) the protection standards are over 40 years old and have not evolved with the increase of economic value of the protected area over time, and that (2) the societal risks associated with flood defences on a national scale are larger than in other domains of the Dutch society (Ten Brinke and Bannink, 2004), these authors concluded that a fundamental debate on the required safety levels of Dutch flood defences is necessary. This will undoubtedly lead to the need for stronger flood defences challenging the proponents of soft solutions to fulfil safety requirements as well as incorporating ecological and societal aspects in an evaluation of a design.

Coping with these dilemmas, is an example of the major challenge for the near future. It illustrates that “building with nature” (De Vriend and Van Koningsveld, [4]) not simply implies the use of methods from natural sciences, but involves a range of different disciplines and asks for a transdisciplinary approach. This paradigm shift is very prominent in Dutch coastal zone management and it is within this context that the Sand Engine concept was developed.

3. The Sand Engine

The above discussion and context calls for adaptation strategies that are unprecedented; both in form and magnitude. Recognizing this need, policymakers in the Netherlands, in close collaboration with the scientific community, have recently adopted an innovative intervention approach named “The Sand Engine” (Zand Motor, www.zandmotor.nl) to address the potentially massive threat of flooding in the low lying coastal zone of the Netherlands from projected Sea Level Rise (SLR). The Sand Engine is a very large sand nourishment of 21.5 Mm$^3$; a nourishment magnitude for defence against flooding that is unprecedented anywhere on the globe.

The initial nourishment spans the coastal system over a 2.4 km stretch, and extends up to 1 km offshore following a specific shape (Figure 1). The shape of the nourishment was largely inspired by the potential to provide areas for nature and recreation. It consists of a large hook-shaped peninsula attached to the shoreline by a base of ~ 1 km and including a small (7.5 ha) lake (Figure 1). The curved tip of the peninsula provides shelter from waves and the shallow artificial lagoon formed behind the tip is expected to offer habitats for flatfish and other organisms.

The responsible decision makers found this solution attractive and approved the mega-nourishment of 21.5 Mm$^3$ at Ter Heijde coast in the province of South Holland. The Sand Engine was, to a large extent, constructed between March and July 2011 using sand mined from approximately 10 km offshore, with some additional work in early 2012. It presents a world-first research site as well as a practical demonstration of total coastal management system linking a coastal engineering construction with environmental, ecological and social considerations. To date, the project has received a very positive response by the general public and especially by recreational beach users, notably wave, wind and kite surfers.

The main expectation is that the Sand Engine will perturb the coastal system such that the coastline will, as a minimum, be stabilized at its present position over an extended length of time (20 years) and space (10 km). An anticipated secondary benefit is the creation of environmentally and recreationally attractive space in this strongly urbanized coastal stretch.

4. Conclusions

A boldly innovative soft engineering intervention, comprising an unprecedented 21.5 Mm$^3$ sand nourishment known as the Sand Engine, has been recently implemented in the Netherlands. The Sand Engine is a pilot project to test the efficacy of local mega-nourishments as a counter measure for the anticipated enhanced coastal recession due to accelerated sea level rise in the 21st century. This single mega-nourishment is expected to be more efficient and economical in the long term than traditional shoreface nourishments that are presently being used to negate coastal recession. Preliminary numerical model results indicate that this nourishment will result in the widening of the beach along an 8 km stretch of the coastline, and a beach area gain of 200 ha over a 20 yr period. First observations show indeed a redistribution of the sand, feeding the adjacent coasts, roughly 40% towards the south and 60% towards the north. While the jury is still out on this globally unique intervention, if proven successful, it may well become a global generic solution for combating sea level rise driven coastal recession on open coasts.

5. References


The scale at which humankind interferes in coastal systems is growing exponentially, owing to demographic developments, urbanization and the size of constructions. Adverse effects, such as coastal erosion, poor water quality and degraded ecosystems are visible across the world. Losses of sediment in upstream reservoirs or across the continental shelf (New Orleans), large scale sand mining, subsidence and climate change further threaten coastal communities and ecosystems. Reasons for these adverse effects are well-known and range from uneducated/uninformed interventions to mono-disciplinary management.

In particular, violating the physical laws of nature can be extremely harmful, whereas nature can be a strong ally of mankind, when treated with respect. This is the basic idea behind Building with Nature (BwN), which promotes to use the power of nature to achieve societal goals, rather than working against nature. The philosophy behind BwN contains the following elements:

1. Integration of all interests – refrain from mono-disciplinary solutions,
2. Involve all stakeholders from the very beginning,
3. Use natural processes to achieve one’s goals,
4. Obey the inherent time scales of natural processes in the management of coastal systems,
5. Follow a flexible and adaptive design and construction strategy, which allows learning-by-doing and learning-from-mistakes,
6. Respect, and where possible, enforce local ecosystems in order to maintain ecosystem services.

As many problems in coastal systems are the result of uninformed and uneducated interventions, education and communication form an important aspect of all BwN projects.

Letting nature do the work for you of course requires a thorough understanding of the natural system and its forces and possibilities. Development of knowledge and know-how is too often categorized as costs, whereas they generally provide a very high return-on-investment. As such, BwN is often an economic alternative for practices developed in the course of the 20th century – economic on both short term and in particular in the long term.

The management of the Dutch coastal zone is a typical example on how knowledge and know-how steered the evolution of an ever more reliable and at the same time cheaper and less offensive strategy. The current zenith of this approach is the installation of the Sand Motor, details of which are presented in another presentation by Prof. Stive.

BwN is a design and construction philosophy and does not provide a “one size fits all” – solutions are always site-specific. What works at one location, not necessarily works elsewhere. But our experience with BwN can give guidelines. As an example, Figure 1 presents an array of solutions, depending on available space and hydrodynamic forcings.

Figure 1: Array of BwN solutions
In this presentation we elaborate on our BwN experience in muddy-mangrove coasts. These coasts contain important ecosystems, which may be provide many USD 10,000/ha worth of ecosystem services. The basic scientific background for the BwN works in these coastal systems is fairly simple (equation (1)):

\[ \text{coastal development} = \text{deposition} - \text{erosion} \]  

(1)

Of course, if there is more erosion than deposition, the coastline will retreat, and vice versa. However, the important observation is that the two gross terms on the right hand side of equation (1) are many orders of magnitude larger than the net coastal development. This implies that small changes in deposition and/or erosion rates may have very large effects on the net coastal development. In our presentation, we show how net erosion rates of many 10s to 100 m/yr are induced by small changes in deposition rates, and how BwN works can stop and reverse this erosion.

Our example refers to Demak, Indonesia, which suffers from coastal erosion rates of over 100 m/yr. The trigger to this erosion is large scale cutting of mangroves in favor of aquaculture ponds. This case is exemplary for 10,000s km of mangrove coastline across the world in Asia, Africa and South and Latin America. Our philosophy is to stop/reverse coastal erosion by restoring the protecting mangrove green belt, which is achieved by restoring the mangrove habitat, which is accomplished by restoring the local sediment balance.

In Indonesia, conversion of mangrove forest to aquaculture ponds is done because of mono-interest management of the coastal zone, i.e. earn much money in a brief period. However, the ponds are productive for a few years only, upon which local communities lose their land and fall back into poverty. The Indonesian government estimates the annual loss in economic growth due to land erosion in Indonesia at three billion USD. Our BwN project therefore also includes a strong socio-economic component, teaching local communities techniques for sustainable aquaculture and other means of income from the mangrove forest.