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Modelling of Brine Waste Discharges Spreading Under Tidal Currents

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Abstract: Desalination of seawater produces brine, wastewater containing a high salt concentration to be disposed of into the environment. It is common practice for coastal seawater desalination plants to discharge the brine waste into the sea via an outfall at some distance from the beach. In Kish Island is the one of the most important seawater desalination plant which located in the Southern coast of Iran. It is important to understand how brine is dispersed into the sea so that we can minimize its potential environmental impact. One factor that affects the mixing of brine discharges is the tidal current. The tidal currents transports brine plumes back and forth before eventually dispersing it into the sea. As a seawater desalination plant is continuously disposing of brines at a constant rate, unacceptably high salinity in coastal water on both sides of the outfall are created due to the flow reversals. Therefore, it is important to optimize the intake location. In this study, the effect of a tidally oscillating flow in dispersing brine waste discharge into the sea has been studied using a two-dimensional model, MIKE21 and results are presented graphically by plotting contours of concentration. It is found that not only are the plumes spreading far downstream of the outfall along the beach, but due to the flow oscillation, the plumes are also spreading towards the upstream side of the outfall. With attentive to results we forecast two fine positions for intake layout.

Key words: Desalinization plant, numerical model, MIKE21, tidal current, Kish Island

INTRODUCTION

Water, a limited finite resource, vital for the very existence of life on earth and a necessity for economic and social development and for environmental sustainability, is becoming a scarce commodity. This is caused by the population growth, the change of lifestyle, water pollution caused by human intervention, inefficient use of water and climatic changes with more frequent extreme events such as droughts and floods. Where, the availability of water cannot be increased by using conventional resources or by recycling or cannot be made available by demand management methods, the desalination of sea or brackish water offers an alternative solution (Tsiourtis, 2001).

According to the Bible, the first project of desalination was conducted by Moses at the place of Mei Mara in the Sinai Desert, where by introducing a piece of bitter wood into the bitter water Moses has turned the previously bitter fluid into potable water. The first scientific report describing a technology designed for the desalination of seawater was published by Thomas Jefferson, the American Secretary of State, in 1791 (Einav *et al*., 2002). Instructions for operation of the technology were posted on notice boards in every ship, for use in a case of emergency. During the Second World War, hundreds of portable desalination devices were used by the troops of the various armies. In the early fifties, research projects were initiated with the aim of lowering the price of the desalination process. The increase in the standard of living in the developing countries during the second half of the 20th century resulted in an increased demand for water for daily use as well as for industrial use. At the same time, clear water, regarded in the past as a natural resource, available and cheap, had turned into a precious commodity. At the beginning of the third millennium, we are facing a revolution in the desalination process, where reasonable costs and a continuous trend of further lowering the costs, will enable the supply of water of high quality at convenient prices, thus allowing expansion of residential areas as well as an improvement in the quality of life of people all over the world.

Desalination of seawater also produces brine, wastewater containing a high salt concentration to be disposed of into the environment. It is common practice for coastal seawater desalination plants to discharge the brine waste into the sea via an outfall at some distance from the beach (Purnama and Al-Barwani, 2006). One major concern is the potential environmental impacts caused by extensive brine discharge. The effect of the

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brines is mainly of a local nature and does not cause accumulated damage of the sea. The range of the effect of the brines on the marine environment depends on bathymetry and on the hydrological characteristics of the sea, i.e., the type of currents and waves (Meerganz von Medeazza, 2005). Characteristics of brines such as concentration, discharge rate, outlet pressure and planning of the pipe system also influence the extent of damage to the marine environment. Current know-how for evaluating the range of the effect is based mainly on mathematical models and a few field samples made in real time (Einav and Lokiecb, 2003).

Meanwhile, seawater desalination is the reliable solution to the water shortages in the arid Middle East and North Africa. Due to the prolonged drought conditions and the national rapid economic development with sharp growth of the population in the arid Persian Gulf countries of Iran, Kuwait, Saudi Arabia, Bahrain, Qatar and the United Arab Emirates (UAE) (Smith *et al*., 2007), limited underground water resources are being used faster than they can be replenished. Therefore, the construction of more seawater desalination plants along the coast of the Persian Gulf is to be expected. The total production capacity of all desalination plants in the Persian Gulf countries was estimated at 5.075 million m^3 of water per day, which accounts for more than 58% of the world's desalting plants' capacities (Smith *et al*., 2007).

In South coast of Iran, Kish Island seawater desalination plant has been constructed which has important role in purvey of potable water for region's people (Fig. 1). Whilst the desalination plants built along the west coast of the Persian Gulf are discharging their brine waste stream approximately of 3.4 million m^3 day^{-1}. Together these plants dispose of their brine waste in excess of 3.4 million m^3 per day into the Persian Gulf and it is therefore important to understand how brine is dispersed into the sea so that we can minimize its potential environmental impact (Smith *et al*., 2007). The Persian Gulf is a shallow marginal semi-enclosed sea situated in the northern-eastern Arabian Sea, with mean depth at only 35 m and less than 100 m in depth over its entire extent (Smith *et al*., 2007) (Fig. 1). It covers an area of about 240,000 km^2, with 1000 km in length and breadths ranging from 185 to 340 km. The main topographic features are a deep channel on its Northeast side off the coast of Iran and shallow areas on the west side off the coasts of Kuwait, Saudi Arabia, Qatar and the UAE. The Persian Gulf is connected to the Gulf of Oman via the narrow Strait of Hormuz, which is constricted to 56 km wide at its narrowest point by the Musandam peninsula. At the Strait of Hormuz the deep-water channel is at the southern side with the shallower water along the coast of Iran. The Persian Gulf is located between latitudes 24°N and 30°N (Fig. 1). In those latitudes, descending dry air produces arid conditions and is where most of the Earth's deserts are located. The mean annual net evaporation rate for the Persian Gulf is equivalent to the sea surface lowering at a rate of 1.5 m year^{-1} (Smith *et al*., 2007). By contrast, the freshwater inflows from the Tigris, Euphrates and Karun at the delta of the Shatt al Arab are only equivalent to a 0.2 m year^{-1} rate of rise. The Persian Gulf acts as an inverted estuary with salinity greater than the Arabian Sea e.g. salinity values exceeding 40 ppt (parts per thousand) around the island of Bahrain and the coasts of Qatar and the UAE (Smith *et al*., 2007). Dense, saline water formed by evaporation tends to sink and eventually flows around the tip of the Musandam peninsula through the deepest part of the Strait of Hormuz into the Gulf of Oman. Along the shallower coast of Iran, there is a replacement surface inflow with the salinity 37.5 ppt (Smith *et al*., 2007).

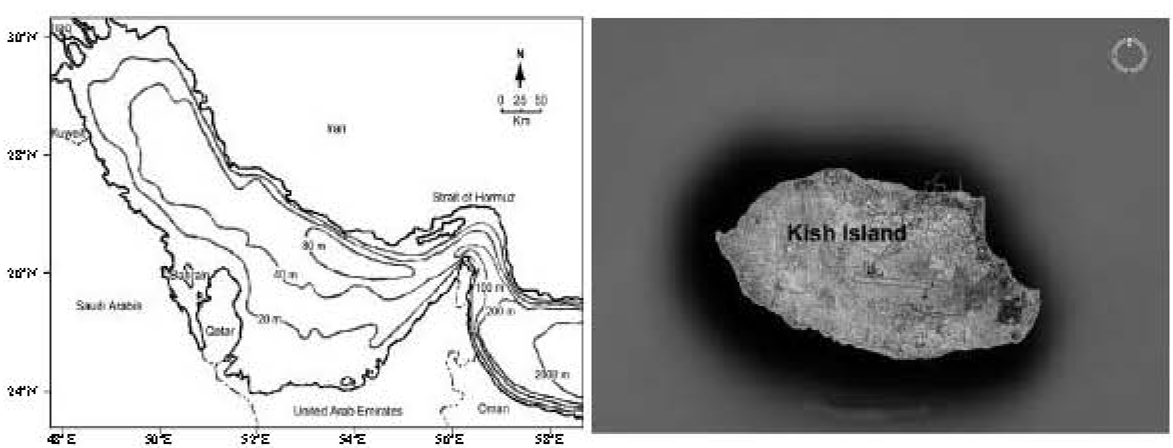

Fig. 1: Bathymetry of Persian Gulf and location of Kish Island

As, the brine waste is produced daily in large volumes, it is important to understand how the long-time brine plumes is dispersed into the sea so that we can minimize its potential environmental impact. The brine outfall location is chosen to ensure a rapid dilution and mixing process and in particular, the brine plumes should have been dissolved by the time they reach the intake location. One way to reduce the salt concentration levels at the intake location is by building a so far away sea outfall from intake location (Al-Barwani and Purnama, 2008). This seems to be impractical for an existing desalination plant, as it will change the original design of the plant. Therefore, if the sea outfall is fixed and the salt concentration of the sea water due to brine outfall is increased under the hydrological characteristics of the sea, how can we be sure that the salinity around the outfall with respect to environmental criterion is met; also the salinity in intake location still remains on standard rang? In an attempt to answer this question, with consideration several layouts for intake location, we discuss about the optimum place for intake in order to minimize the salt concentration levels in intake location, using a two-dimensional advection-diffusion model.

In this study, we present the modeling dispersion of brine waste discharge into the sea from Kish Island Seawater Desalination Plant with numerical model MIKE21. The effect of a tidally oscillating flow in dispersing brine waste discharge into the sea is investigated using a two-dimensional advection-diffusion equation. As a seawater desalination plant is continuously disposing of brines at a constant rate, unacceptably high salinity in coastal water on both sides of the outfall are created due to the flow reversals (Purnama and Al-Barwani, 2006). According to the results, the maximum water salinity increment in intake location with respect to initial water salinity is less and the environmental criterion is met.

HYDRODYNAMIC MODELLING

Here, it is focused on the numerical simulation of salinity dispersion around Kish Island seawater desalination plant and its main goal is the analysis of discharged brine waste effects from outfall on the intake position and dispersion pattern of effluent water under existent environmental conditions. The seawater is transferred to the desalination plant by pipelines and then brine discharged into water body on the sea to formation of hydrodynamic mixing process. The mixing behavior of any wastewater discharge is governed by the interplay of ambient conditions in the receiving water body (consist of water body's geometric and dynamic characteristics in water body) and by the discharge characteristics (related to the geometric and flux characteristics of the submerged outfall installation). The hydrodynamics of an effluent continuously discharging into a receiving water body can be conceptualized as a mixing process occurring in two separate regions. In the first region, the initial jet characteristics of momentum flux, buoyancy flux and outfall geometry influence the jet trajectory and mixing. This region will be referred to as the near-field and encompasses the buoyant jet flow and any surface, bottom or terminal layer interaction.

As, the turbulent plum travels further away from the resource, the source characteristics become less important. Condition existing in the ambient environment will control trajectory and dilution of the turbulent plume through buoyant spreading motions and passive diffusion motions and passive diffusion due to ambient turbulence. This region will be referred to here as the far-field. Far-field processes are characterized by the longitudinal advection of the mixed effluent by the ambient current velocity.

NEAR-FIELD AND THE APPLIED MODEL

Outfall structure shape, high flow velocity of outfall jet and saline difference between ambient and discharged water, causes stratified flow pattern formation in area around and near the outfall. In this region which called Near field zone flow velocity and water salinity do not have a homogeneous distribution in depth and then, 2D models would not be applicable. In other words within the near field velocity, salinity and density gradient in depth are much more and applying the 2D depth averaged models will cause considerable errors. In this study saline dispersion analysis inside the near field region is being evaluated separately and its outputs will be the input data for source point in far field applied model.

Description of used software for near field analysis: In this study Cornell Mixing Zone Expert System, CORMIX, has been applied for near field analysis. It computes the plume characteristics in the initial mixing zone within which the fluid motion, turbulent field and saline dispersion are dominated by the discharge properties such as the mass flux and buoyancy flux of outfall jet. Results of Cormix will be extracted at the end of near field which can be defined where saline plume characteristics are fully vertically mixed. It is assumed that local wind has negligible effects on the discharged flow pattern in the near filed zone.

Depending on type and shape of outfall, there are 3 different models in the CORMIX software:

- CORMIX 1 for submerged single port discharges
- CORMIX 2 for submerged multi port discharges
- CORMIX 3 for buoyant surface discharge

In this study, regarding to outfall shape which is surface channel discharge, CORMIX 3 has been applied for near field analysis. Required input data for near field studies by Cormix, are geometry, discharge, salt concentration of discharged flow in outfall position and depth of outfall.

Specifications of jet plume including width and depth of diffused plume, its trajectory and also salt concentration along the centerline trajectory of plume will be some major outputs of Cormix. Dilution parameter, S, is defined as a representative for pollutant material concentration (water salinity in this study) in Cormix outputs and is calculated as below:

$$S = \frac{D_0}{D} \tag{1}$$

In which, D_0 is salt concentration of discharged flow in outfall position and D is salt concentration in the end of near field zone, where depth of diffused plume is equal to water depth, along the plume centerline.

In this study, D and S is extracted at the end of near-field zone (where the plume depth has been developed in all of water depth) and then plume velocity and discharge is calculated there and applied as the input data for far field model.

Results of near-field model: It should be noted that returned water is discharged through one open surface channel with 2 m width, 1.5 m depth and 30 m length. Discharge of outflow is 10929.6 m^3 h^{-1} and its salt concentration is 15400 mg L^{-1} higher than the intake water concentration. Water depth in outfall position has been considered 2.5 m which occurs in CD level.

Using CORMIX 3, near field analysis has been performed. Results of Cormix as variation of salinity and distance from outlet have been shown in Fig. 2. Based on Cormix results in distance of 70 m from the outlet (which is considered as the horizontal coordination origin), thickness of saline plume would be extended in all over the depth and water salt concentration has been decreased to 5280 mg L^{-1}. This position is assumed as the end of near field zone at which the plume specifications should be calculated as input data for far field region.

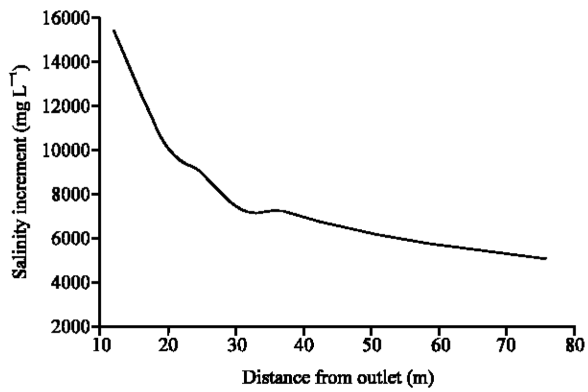

Fig. 2: Variation of salinity increment (due to ambient water salinity) along the centerline of plume trajectory

NEAR FIELD-FAR FIELD COUPLING

As mentioned before, because of using the 2D hydrodynamic-dispersion model for far-field modeling and assuming no vertical gradient in far-field region, end of near-field zone is considered where saline plume has been vertically fully mixed.

Salt concentration at the end of near-field is one of the Cormix outputs and can be applied directly for far-field model inputs. But, discharge and velocity has not been determined in near-field model outputs. Then following the mass, momentum and buoyancy fluxes conservation (for a volume control between outfall and end of near-field zone), discharge and velocity of source term which will be forced to far field model, can be calculated. Following parameters are input data (Qo, Vo, Do) and outputs (D, S) of Cormix:

- Q_o : Discharge flow in outfall = 10929.6 m^3 h^{-1} = 3.036 m^3 sec^{-1}
- V_o : Discharge velocity in outfall = 1.01 m sec^{-1}
- D_o : Salt concentration increment of discharged water (due to the ambient water salinity) = 15400 mg L^{-1}
- D : Salt concentration increment at the end of near-field zone = 5280 mg L^{-1}
- S : Dilution parameter = D_0/D = 2.91

Regarding to the Fig. 2 and above mentioned parameters, plume characteristics at the end of near field are calculated based on conservation equations:

$$Q_o D_o = QD \rightarrow Q = Q_o \times S \tag{2}$$

$$Q_o V_o = QV \Rightarrow V = \frac{Q_o \times V_o}{Q} = \frac{V_o}{S} \tag{3}$$

The salt concentration increment at the end of near-field zone is D = 5280 mg L^{-1}, therefore Q = 8.835 m^3 sec^{-1} and V = 0.35 m sec^{-1}.

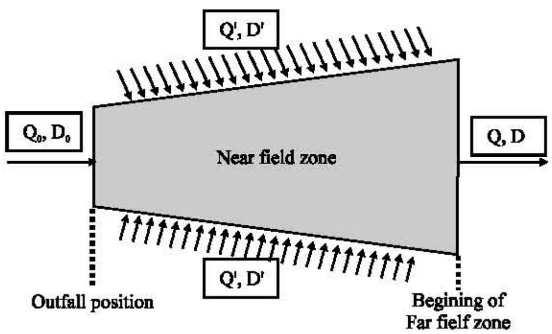

Fig. 3: Volume control between the outfall and first of far-field zone

For the mass conservation, as shown in the Fig. 3, laterally inflow with salinity of environmental water should be entered to the control volume. Then in far-field modeling some artificially sinks with a total strength of (S-1)Qo should be imposed in two sides of the source point.

$$Q' = Q - Q_0 = (S - 1)Q_0 \tag{4}$$

According to mentioned explanations about transmission of near-field plume data to far-field, the specifications of source point and the strength of artificial sinks, are calculated as $Q' = 5.799\ m^3\ sec^{-1}$.

FAR FIELD AND THE APPLIED MODEL

As the turbulent plum travels further away from the outfall location, the jet characteristics become less important and three-dimensional treatment of salinity dispersion is nearly changed to two-dimensional treatment. Then, in order to simulate the current phenomena, it is possible to use two-dimensional models. MIKE-21 FLOW MODEL has been used for hydrodynamic and salinity dispersion simulation in model and far field region. The hydrodynamic model is dynamically coupled with the temperature and salinity modules, which are resolved by advection-dispersion processes.

MIKE21 Hydrodynamic Module (HD) is a general numerical modeling system for the simulation of water levels and flows in estuaries, bays and coastal areas (Siegle *et al*., 2002). It simulates unsteady two dimensional flows in one layer (vertically homogeneous) fluids in response to a variety of forcing functions. The water levels and flows are resolved on a rectangular or triangle grid covering the area of interest. The main inputs to the model are bathymetry, bed resistance coefficients, wind fields and water level and/or flux boundary conditions. The model allows flooding and drying over the computational grid during the simulation (Siegle *et al*., 2002).

MIKE21 HD solves the vertically integrated equations of continuity and momentum in two horizontal dimensions. The equations are solved by implicit finite difference techniques with the variables defined on a spatially staggered grid. The equation matrices that result for each direction and each individual grid line are resolved by a Double Sweep (DS) algorithm (Siegle *et al*., 2002).

Data inputs and setup: With regard to set-up of the model, bathymetry is of prime importance. In this study, the relevant data has been obtained from the Admiralty map of Persian Gulf and bathymetry data from Kish Island. The bathymetry used for the model is mainly based on the Admiralty map of Persian Gulf and has been refined and adjusted by the more accurate local maps (Fig. 4). In order to have a proper examination from salinity dispersion in the vicinity of Project site, mesh resolution has been increased around intake and outfall locations. The unstructured mesh for the model was generated using 4668 elements and 2611 nodes applying Mike Zero Mesh Generator. Figure 4 shows the simulated area and mesh near the Kish island site.

Simulation period was set to 35 days, which covers two neap and spring periods. Basically if the model is calibrated for a period of 14 days, which covers one neap and one spring period, additional simulation time can be used for the verification of the model. The time integration of the equations is performed using an explicit scheme. Due to the stability restriction using an explicit scheme the time step interval must be selected so that the C_R is less than 1. In the present module, the time step interval equal to 0.5 sec, so that the maximum Courant number is 0.35.

Tidal constituents of Kish Island station has been used to construct the tidal fluctuation driving force of the model along the open boundary of the hydrodynamic model. Admiralty Tide Table was considered in identifying the values of M2, S2, K1 and O1 (Table 1) as they gave the most accurate tidal elevation response.

Water elevation predictions available from Tide Tables are an appropriate set of data for model boundary condition. Utilizing the Iranian Tide Tables 2007, one station at Hormoz Strait was chosen. Figure 5 shows Hormoz tidal elevation series for 19 April to 24 May 2007 based on the four main tidal constituents M2, S2, K1 and O1 obtained from the above references.

Bed resistance controls water surface elevation and current speed for each point and can be introduced to

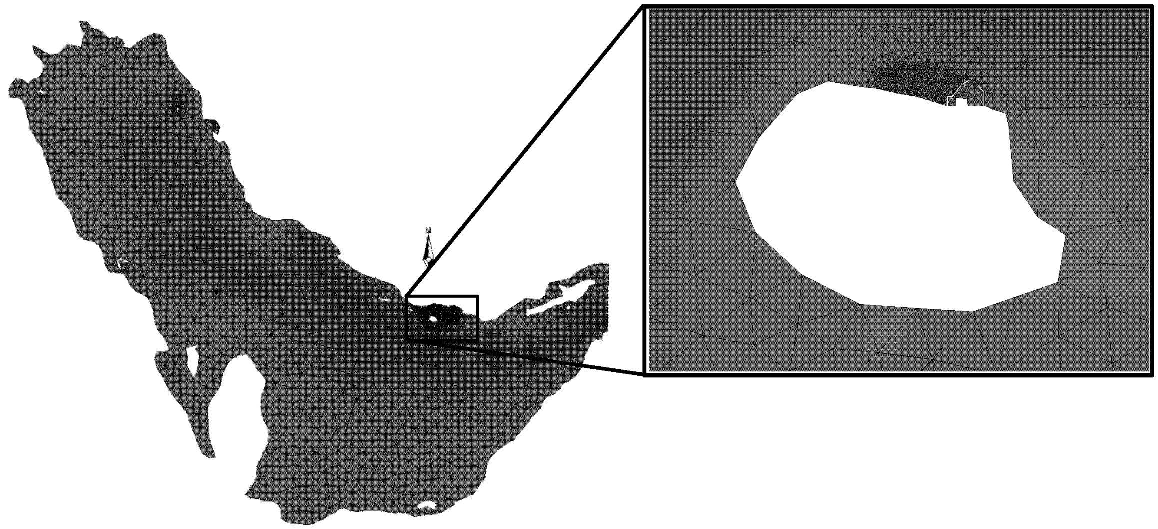

Fig. 4: Computational mesh and bathymetry for Persian Gulf regarding to fine mesh around the Kish Island

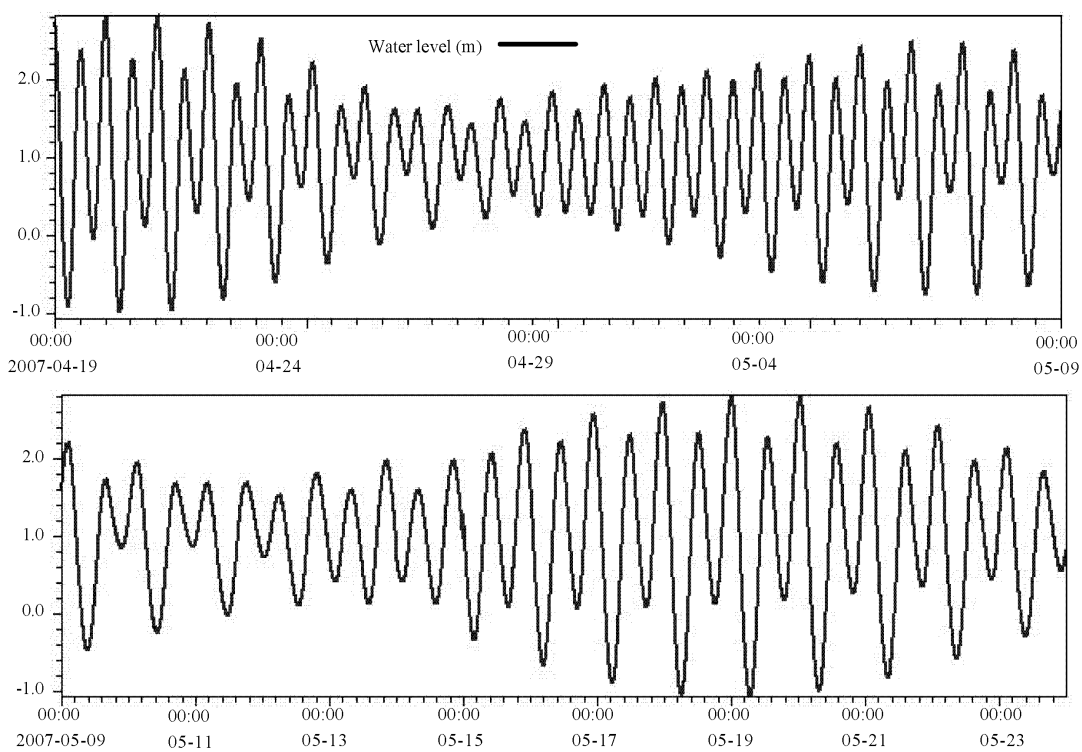

Fig. 5: Tidal elevations of Hormoz Strait as open boundary for the model

Table 1: Kish Island station tidal constituents

Tidal constituent	M2	S2	K1	O1
Phase (H in m)	0.31	0.14	0.26	0.20
Amplitude (deg)	58.40	93.60	144.50	111.00

model through both Chezy and Manning formula. Although, there are some laboratory based relationships for calculation of bed resistance considering the type of bed materials, they present only an approximation of this parameter and the best method to get an appropriate value for this parameter is model calibration using field measurement of current speeds and tidal elevations. For present modeling studies value of 32 was used for bed resistance in the form of Manning number. As it is supposed to have some field measurements into the local

Table 2: Relevant hydrodynamic and salinity modules parameters adopted in models simulations

Variable	Description	Units	Default	Reference
M	Manning Number	$m^{1/3}sec^{-1}$	32	Calibration
C_s	Smagorinsky Coefficient	-	0.28	Calibration
T	Reference Temperature	°C	10	MIKE21 Manual
S	Reference Salinity	PSU	32	MIKE21 Manual

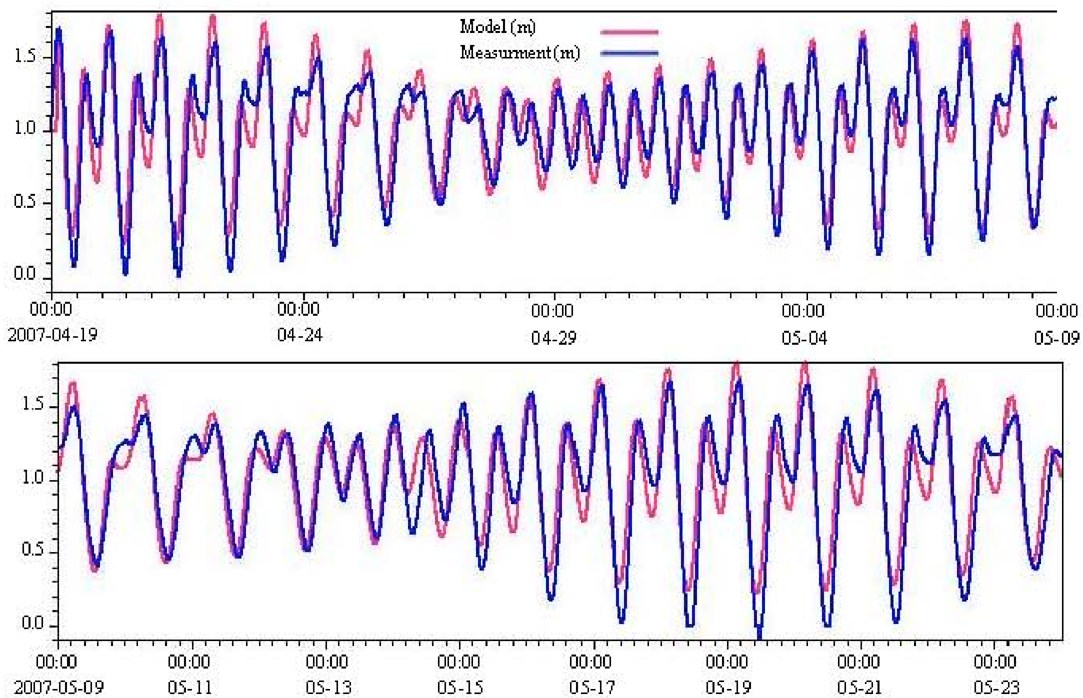

Fig. 6: Comparison of measured water levels at Kish Island with modeled water levels

model area, it will be possible to determine bed resistance through a calibration procedure.

Model calibration: To get enough confidence about model results, models should be calibrated against reliable field measurements including tidal elevation, current speed and direction. If needed, using a reasonable change of proper parameters in model, differences between model results and measurements should be decreased as much as possible. This difference can be due to the empirical parameters in model which can be improved by changing them or can be a result of special approaches or assumptions made for modeling which should be adjusted by taking other reasonable assumptions. Other subject that can be effect on above mentioned different are the accuracy of vehicle that is used in measurements and the other phenomena affect on the data measurements.

In order to control or calibrate tidal model, various data can be used. Field measurements of water level and current speed and direction are the most applicable data and can be usefully used for model calibration. Such measurements had been performed that can be used for the present study.

Bed resistance factor and eddy viscosity coefficient are parameters which can be used in calibration process as variable parameters regarding to the basic equations of hydrodynamics model. Model Calibration was performed by changing bed resistance (Manning coefficient) and the Smagorinsky coefficient, *CS*, for the horizontal eddy viscosity within a recommended ranges and model executed for each of them. Reaching the least difference between model results and measurements was the main criteria of calibration. The values tested in model ranged from 20-50 $m^{1/3}$ sec^{-1} for bed resistance and 0.25-1 for Smagorinsky coefficient while the recommended range is 20-40 $m^{1/3}$ sec^{-1} and 0.25-1 for bed resistance and Smagorinsky coefficient, respectively. The values of 32 $m^{1/3}$ sec^{-1} and 0.28 had good results for these factors in Kish Island model. Table 2 shows the values of kinetic coefficients and parameters adopted in the hydrodynamic and salinity modules.

Figure 6 shows a comparison between simulated water elevations and Kish Island admiralty tide table. This

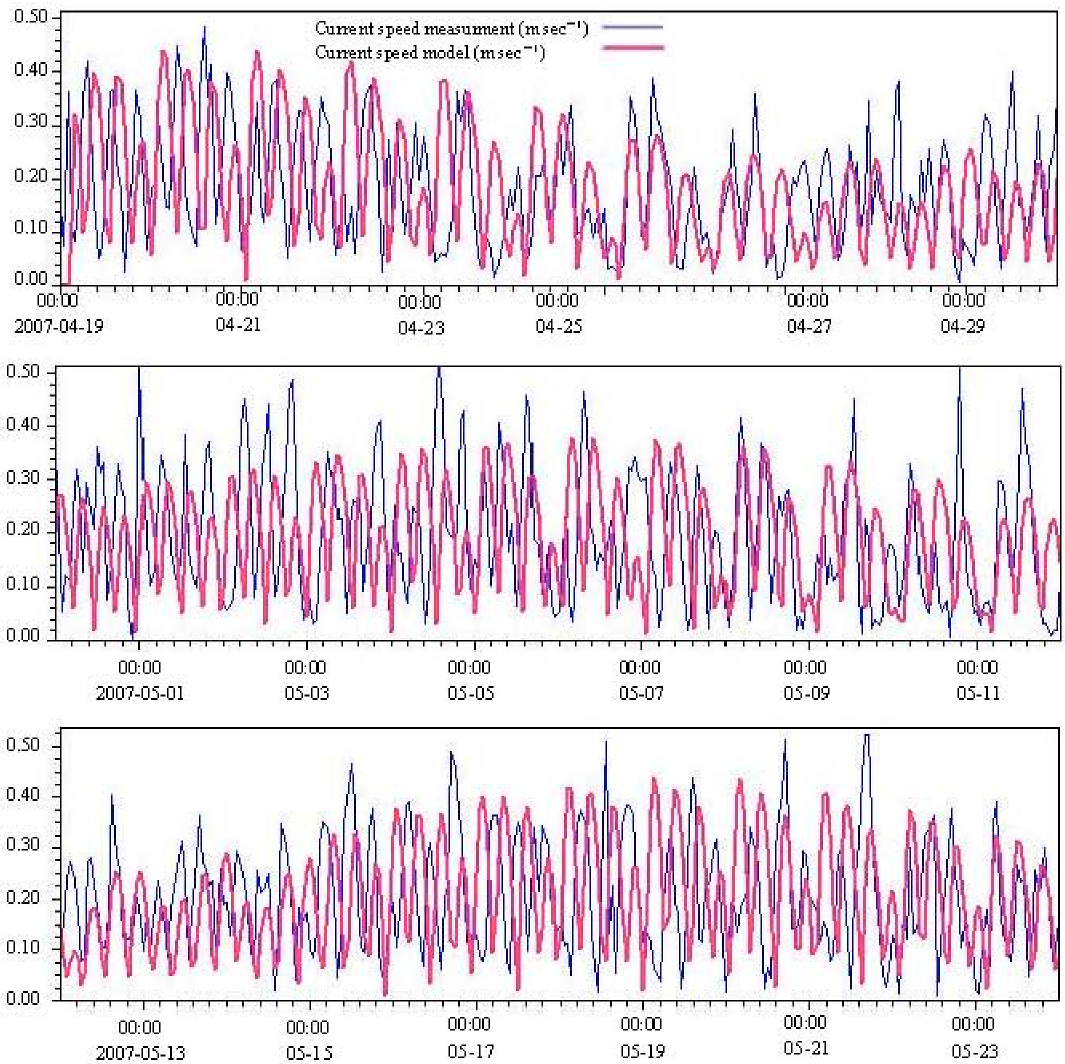

Fig. 7: Comparison of measured current speeds at Kish Island station with modeled current speeds

Fig. 6 shows that the ebb peak of tides was simulated by the model in a very high degree of accuracy, however small discrepancies can be seen for floods. In addition, in the spring tide minor discrepancies can be seen in both ebb and flood values, though they have a very slight effect on the velocity magnitudes.

Figure 7 shows a comparison between measured and simulated velocity magnitudes, in a one-month period approximately. Computed velocity magnitudes present excellent agreement with the measured data in some periods. In these periods, the peak of the velocities is simulated in high degree of accuracy and phase errors are very low. However, in some periods, small errors in the velocity peak values and phase can be seen. It is thought that the occurrence of these discrepancies could be due to some environmental effects such as wind variation for the whole of Persian Gulf and storms, which they are not considered in the model.

Figure 8 shows good agreement between simulated and measured velocity directions for both neap and spring tides.

RESULT

Result of hd module: Running the model was performed for 35 days (on a Pentium 4.0 with 3 G.HZ CPU and 3.0 G.HZ RAM) that it took 14 h. Figure 9 shows velocity vectors field and current speed in Persian Gulf for flood and ebb, respectively.

Flow pattern shows two stagnation areas for neap and spring tides. Water elevations vary along the Persian Gulf as the tidal wave lengths are less than the length of

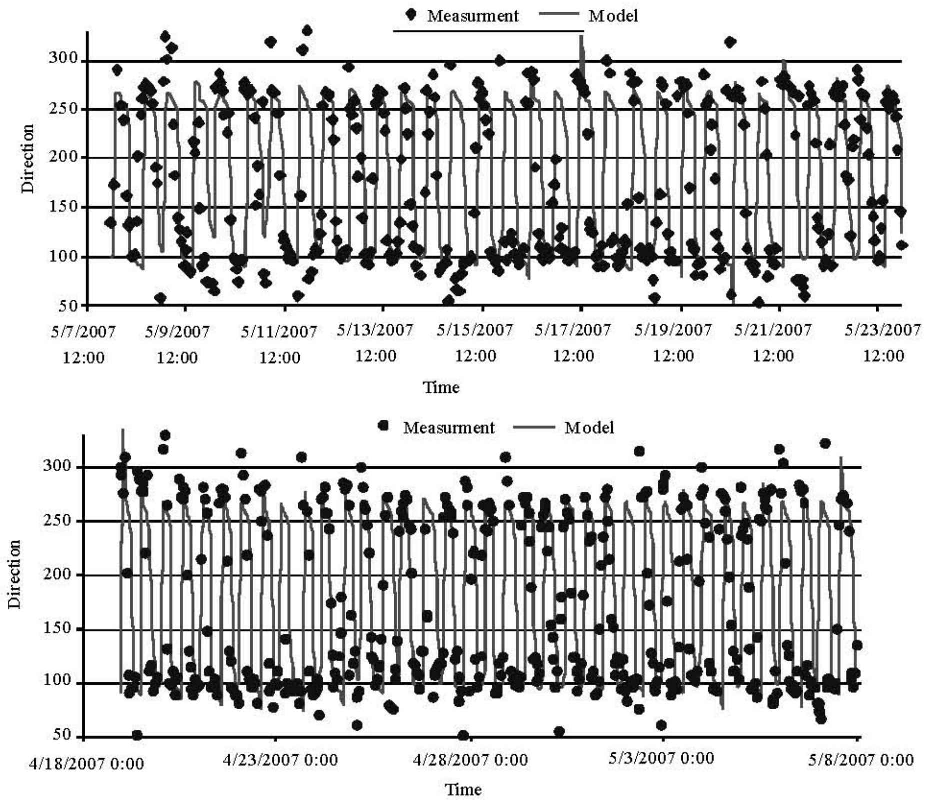

Fig. 8: Comparison of measured velocity directions at Kish Island station with modeled current directions

Persian Gulf. Also, Fig. 10 shows velocity vectors field and current speed in a specific time in the Kish Island region as a sample.

Result of kish island salinity dispersion simulation: The location of outfall and intake suggestion positions (points 1, 2 and 3) of Kish Island desalination plant has been shows in Fig. 11. According to the received information from the project management, the outfall location hasn't changed but the intake location transferred to point 1 or 2 or 3 according to simulation results.

Figure 12 shows salinity dispersion around outfall location at the flood and ebb times in Kish Island as a sample. It shows that the spread of salinity lies along the coastline and in the direction north east. The results show the maximum salinity increment obtains 0.33 PSU. In the next section, the time series of salinity at the points 1, 2 and 3 present and discuss the salinity dispersion around the outfall and intake locations suggestion.

DISCUSSION

Analysis of results show salinity increment covers more area in flood times than area in ebb times, while in this time salinity increment covers western region of the desalination plant.

Al-Barwani and Purnama (2008), through a model simulation of the long-time brine plumes steadily discharged into the seawater based on a two-dimensional advection-diffusion equation obtained that the brine stream discharged will be transported away from the outfall and then afterwards as the flow reversal, the plume is returned back towards the outfall, which is the same as in present study.

Our finding is in agreement with Al-Barwani and Purnama (2008), who found that within two tidal periods after being discharged, the plume may have returned to the outfall 3 times before eventually leaving it.

As shown in Fig. 13, the maximum water salinity increment in point 1 with respect to initial water salinity (36.8 g L^{-1}) obtains 0.33 g L^{-1} which is less than land the environmental criterion is met. Furthermore the average of water salinity increment in this point is 0.18 g L^{-1}.

Also as shown in Fig. 14 and 15, the maximum water salinity increment in points 2 and 3 obtain 0.28 and 0.22 g L^{-1}, respectively which are less than 1% of initial water salinity. Moreover the average of water salinity increment is 0.14 g L^{-1} for point 2 and 0.10 g L^{-1} for point 3.

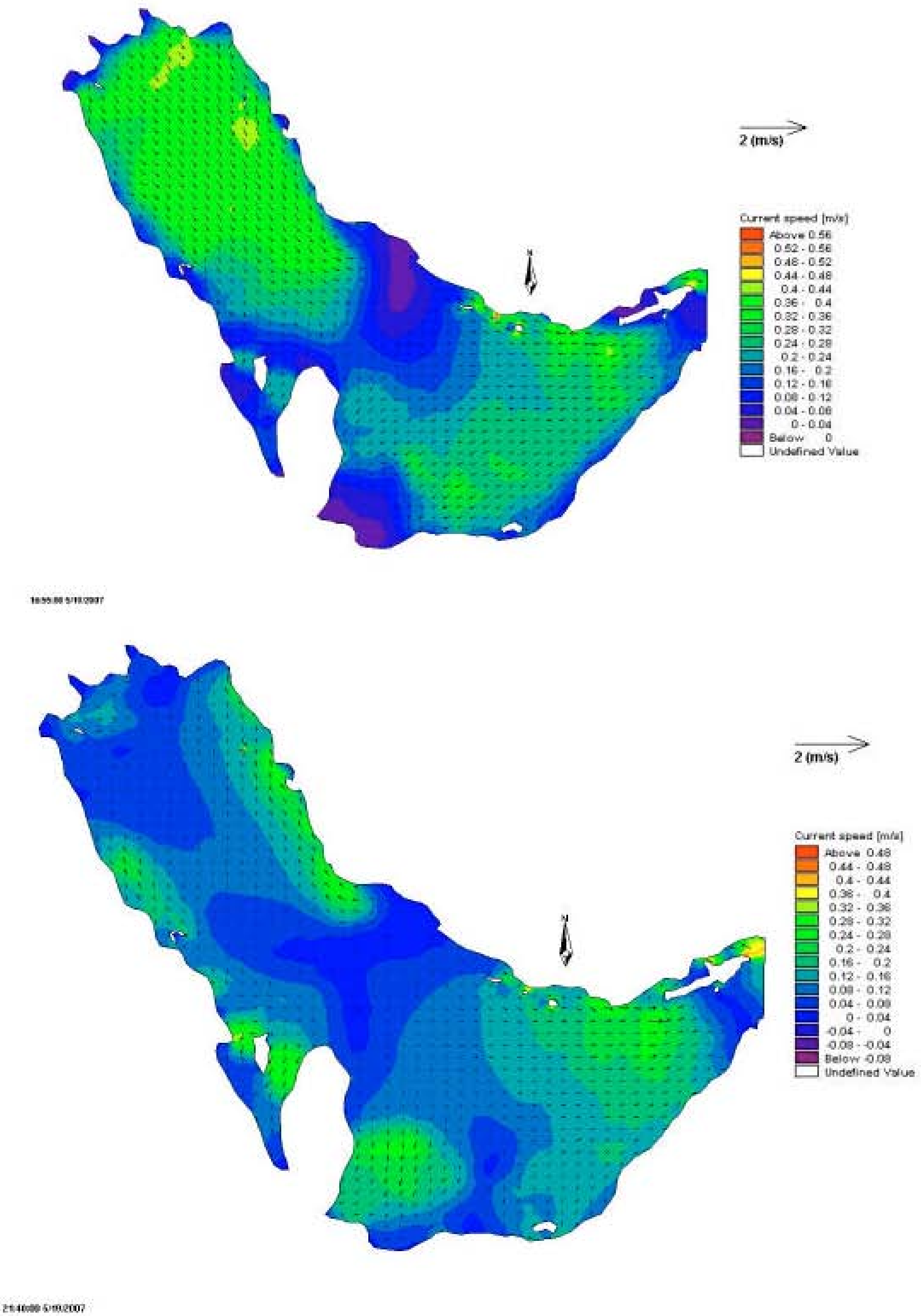

Fig. 9: Velocity vectors field and current speed in Persian Gulf for flood (up) and ebb (down)

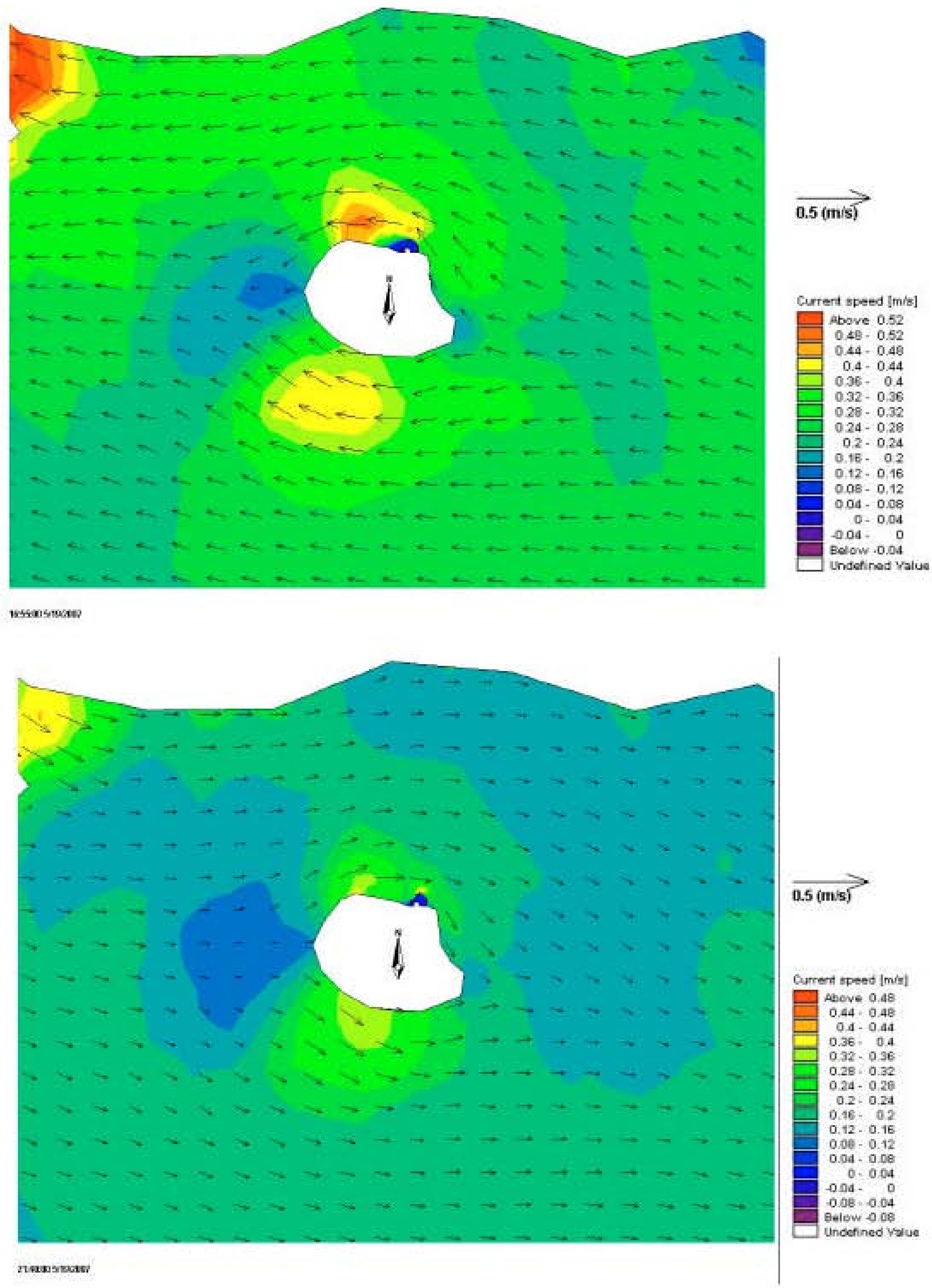

Fig. 10: Velocity vectors field and current speed in Kish Island for flood (up) and ebb (down)

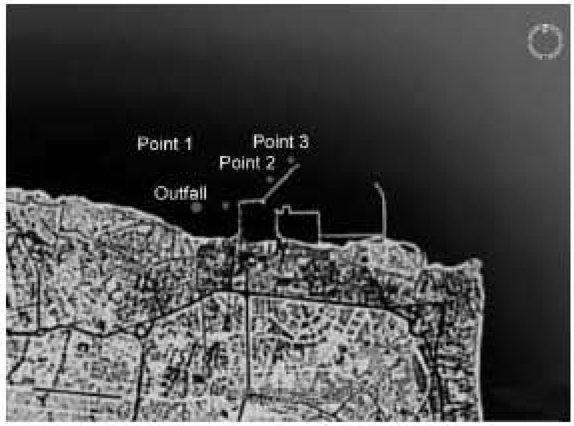

Fig. 11: Position of outfall and intake locations suggestion for Kish Island desalination Plant

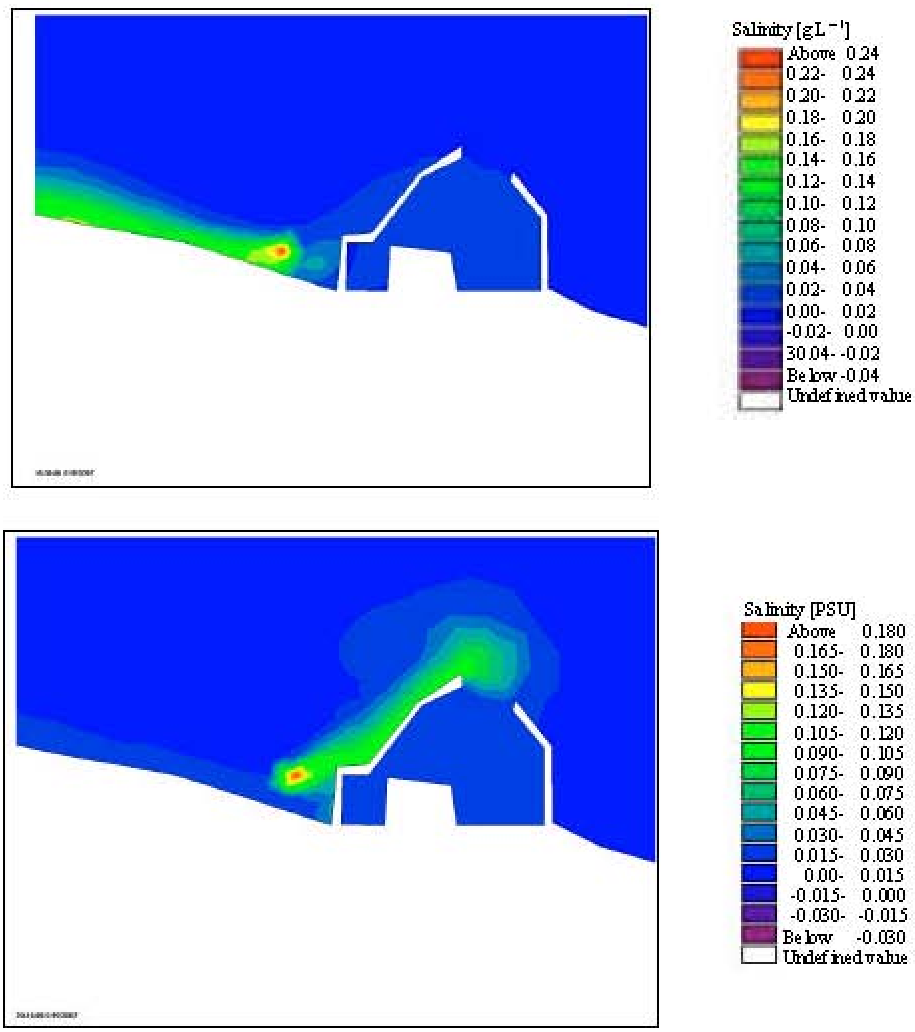

Fig. 12: Salinity dispersion around output location in a flood (left) and ebb (right) times at Kish Island

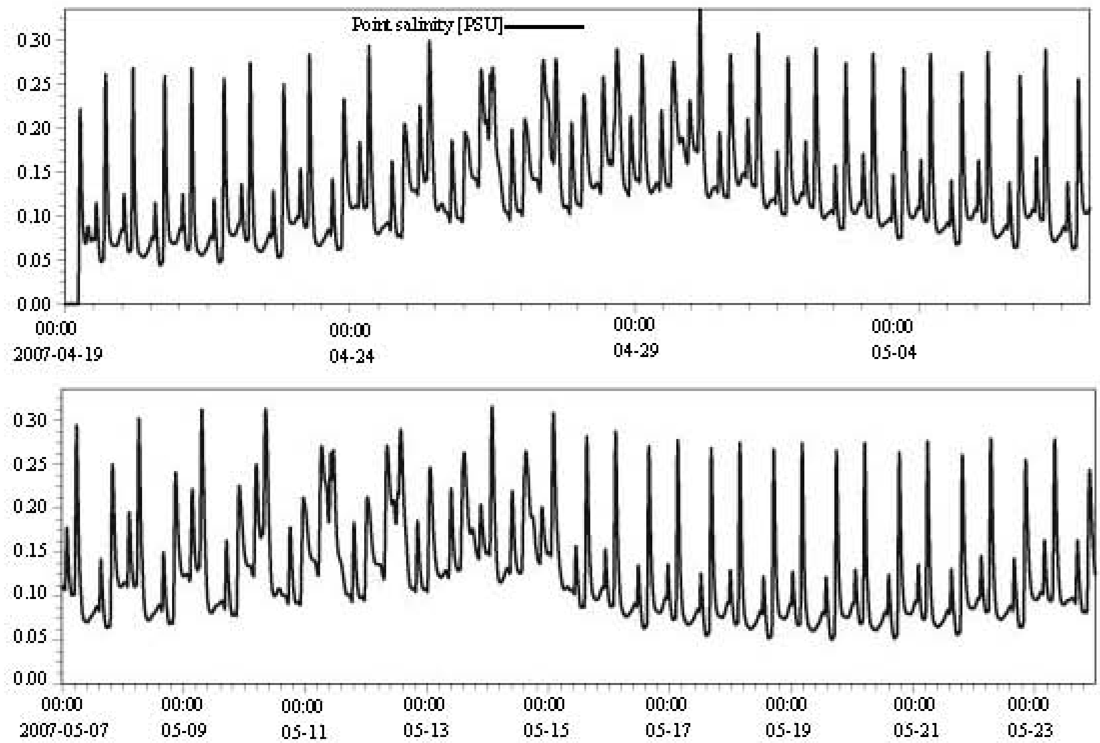

Fig. 13: Time series of salinity at the point 1 at the depth of 12 m during the representative month

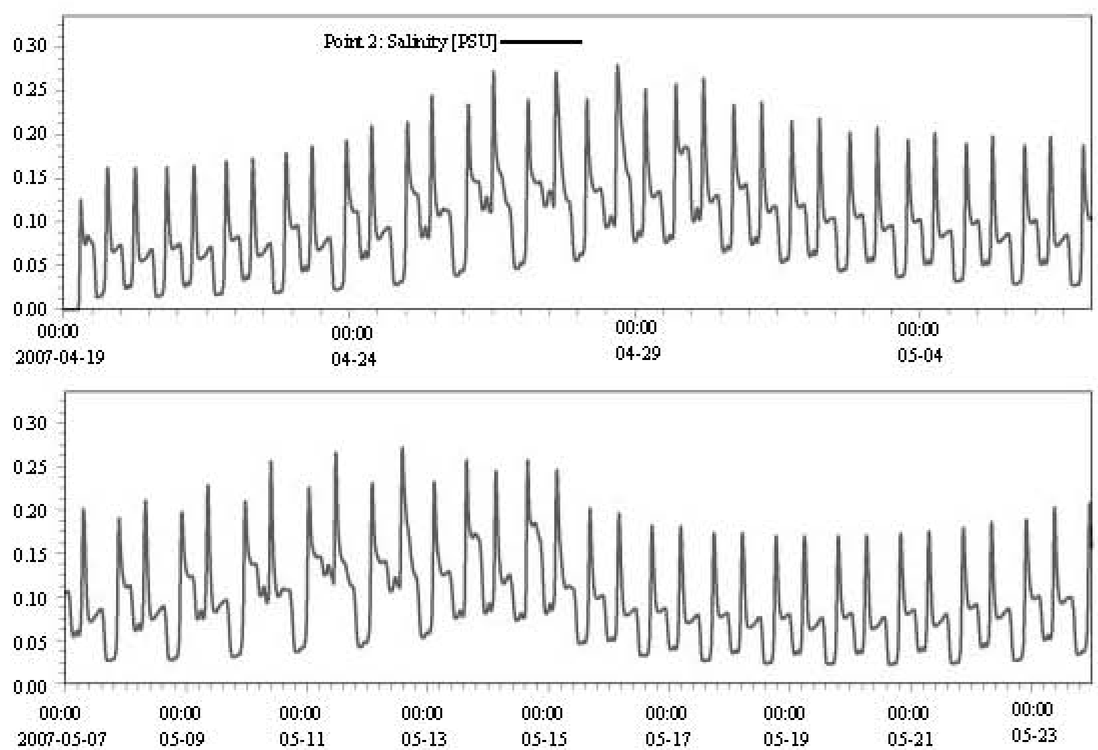

Fig. 14: Time series of salinity at the point 2 at the depth of 20 m during the representative month

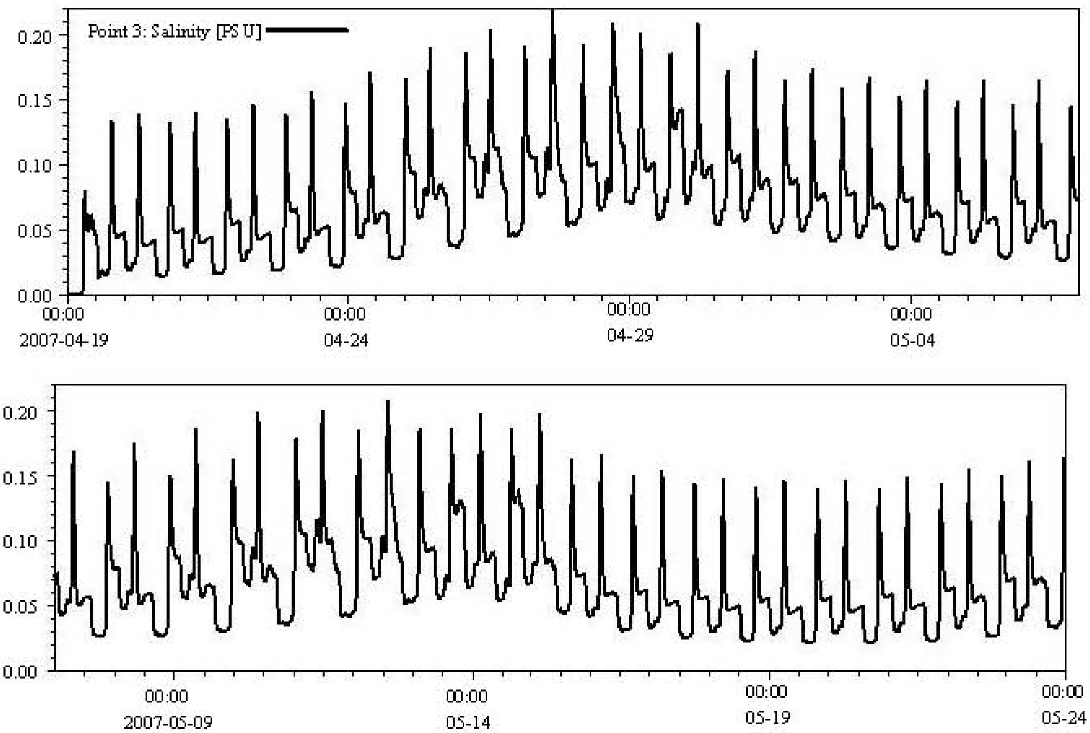

Fig. 15: Time series of salinity at the point 3 at the depth of 25 m during the representative month

The model results of present study show that if brine waste stream is continuously discharged at a constant rate, then the coastal water which is closed to the outfall at the time of flow reversal, where the flow speed drops to zero and there is no dispersion, will be carrying an undesirably high salinity, which has also been reported by Al-Barwani and Purnama (2008).

Overall, comparison the results of different cases of intake layouts shows that by transferring of intake location toward the sea, the effect of jetty on marine hydrodynamic currents around outfall location decreases and the distribution of salted water increases, thus water salinity around the study area will be lower with respect to the other points.

Also, results of this study show that by employing intelligent planning and the appropriate technologies, it is possible to minimize the adverse effects of seawater desalination plants on the environment, which has also been reported in Einav *et al*. (2002).

Totally, according to substantial discharge of outfall which would not create environmental and recirculation problems, positions 2 and 3 can be considered for intake locations.

CONCLUSION

Seawater desalination plants is a solution to grow demand for fresh water, but the technical processes used could damage the environment, with impacts such as the global warming by the increases use of energy, noise pollution, negative effects on land use and adverse effects on the marine environment. As desalination, plants carry a large volume of brine wastewater into the sea, environmental impact studies are required to define regulatory strategies on protection and conservation of the marine environment in a sustainable way. Higher salinity or fluctuations in salinity is expected near the outfall and a long outfall's plume is often observed drifting along the coast.

In searching for the maximum concentration in the coastal waters, using a two dimensional advection-diffusion model, the long-time effect of a tidally oscillating flow on mixing brine discharges into the sea is investigated. 2D model of MIKE-21 is applied for large-scale simulation of hydrodynamic tidal current in Persian Gulf. Current speed and circulation have been simulated and the model has been calibrated against the tide table and measured water elevations and velocities. An unstructured grid is deployed. The computed water elevations shows good agreement with both of the measured data and data from admiralty tide table data. The computed velocities generally show acceptable level of agreement with the measurements.

The hydrodynamic model is dynamically coupled with the salinity module, which is resolved by advection-dispersion processes. With consideration the location of outfall and suggestion intake locations for Kish Island desalination plant, the effect of tidally oscillating flows on the mixing and dispersal of brine waste discharge into the sea has been presented graphically by plotting the results of numerical model. According to the results the maximum water salinity increment in intake locations with respect to initial water salinity is less than 0.34 g L^{-1} and the environmental criterion is met. Overall, because of substantial discharge of outfall which would not create environmental and recirculation problems, positions 1 and 2 can be considered for intake locations.

Finally, as it is observed the brine plumes could be rapidly dispersed and dissolved before they reach the intake location.

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