Available online at **www.pelagiaresearchlibrary.com**

Pelagia Research Library

Advances in Applied Science Research, 2012, 3 (4):1963-1977

ISSN: 0976-8610
CODEN (USA): AASRFC

The application of two dimensional model on oil spill movement in Khor AL-Zubair, north west, Arabian Gulf

Samer A. R. Al-Taei[1], Abdul R. H. Subber[2] and Faris J. M. Al-Imarah[1]

[1]*Marine Science Center, University of Basrah, Basrah, Iraq*
[2]*Department of Physics, College of Education University of Basrah, Iraq*

ABSTRACT

The present work used a simulation model to track the movement and fate of oil pollutants, which takes into consideration all the factors of hydrographic and hydrological conditions. The experimental part includes; collect in the bathymetric and topographic data for the study area, measurements of the tides, climate variables, measurements of water velocities, field testing process for a synthetic oil spill and following-up the presence of slicks. The theoretical part simulated the experimental data using MIKE12 HD package for 26 days with the division of semi-dimensions Δx=200m and Δy=200m with time step Δt=80s. This yields to have a number of network j=322 and k=105 equivalent to (6762 km^2). The matching between the field data and the calculated results was up to 90% approximately. The tidal ranges were 4.5m and 4m in Umm Qasr and Khor Al-Zubair, respectively. The speed of the currents during the ebb phase is greater than the speed of the flood in Umm Qasr and Khor Al-Zubair, reaching its greatest value of 1.85m/s at Khor Al-Zubair. By using MIKE12 SA it is concluded that the oil spill of the Fuel type has a significant impact on the marine environment for spot thickness (>20mm) and the area of spread (28km^2) and dwell time spot is farther from the simulations (>10days). The model used in this study was successful in the study of hydraulic properties as well as the transport and fate of oil spills and leaks.

Keywords: Khor Al-Zubair, Oil spill, Numerical modeling, MIKE12 SA, Spot thickness

---

INTRODUCTION

During the last three decades, the prime source of pollution in NW Gulf area came mostly from wars activities. So, it is one of the most marine polluted zones in the world. The Gulf has been suffering from oil pollution associated with a large number of oil spill accidents caused by substandard ships and/or oil smugglers. Moreover, military actions associated with regional wars were the main contribution for such accidents [1].

Within the area of this study, there are 4 plants; the petrochemical, steel, Umm Qaser cement, and fertilizer plants. All of them are close to the gulf coast, which means that they should throw their crap directly in Shatt Al-Basrah canal and Khor Al-Zubair, which in turn to Khor Abdulla and NW Gulf. There are three crude oil ports for loading and discharging oil. The presence of such large quantities of oil in the Khor Al-Zubair region clearly demonstrates the geographical and political importance of this enclosed water passage, which increases the risk of pollution. Khor Al-Zubair is classified as an estuarine lagoon [2-3], with lower boundary located near Warba Island, about 8km south-east Umm Qasr. The total length of Khor Al Zubair is about 40km from the upper boundary and reaches to the lower boundary at Khor Shetana, as shown in Figure 1, and the width of the channel varies between 1km and 2km at high water on an average spring tide. The depth of the navigational channel ranges between 10m and 15m, with a tidal range of 5m. At high water on an average spring tide, the area covered by water is approximately 60km^2. In 1983, an artificial channel (Shatt Al-Basrah, see Figure 2) was opened to connect the Euphrates river (in Karmat Ali), after it emerges from Al-Hammar marsh, to Khor Al-Zubair. Before this channel was opened, the environment of Khor Al-Zubair was a lagoon environment or what is called a 'negative estuary' because the evaporation exceeds the freshwater inflow plus precipitation, and the salinity reaches as much as 47‰ in summer months[4].

Figure 1. Satellite image for Khor Al-Zubair

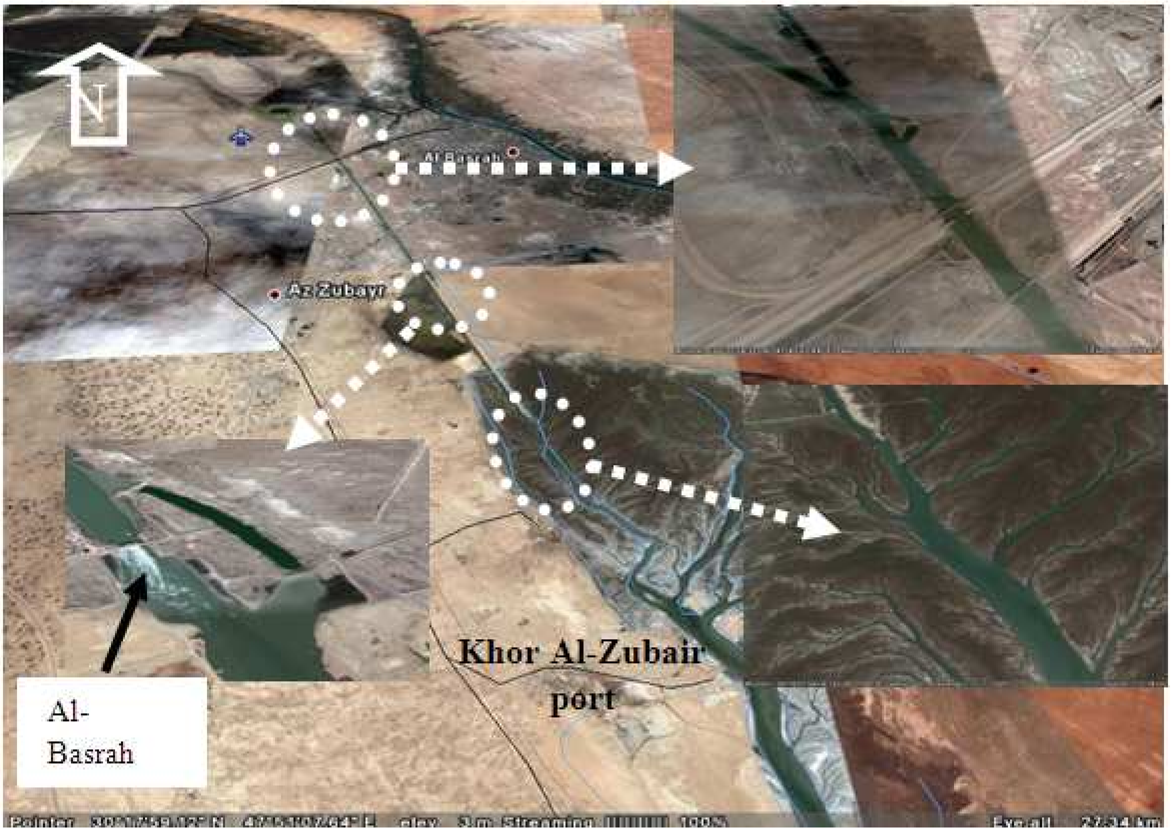

Figure (2): Image satellite for the whole Shatt Al-Basrah canal

After the opening of Shatt Al-Basrah channel, the environment of Khor Al-Zubair completely changed to form a positively estuarine environment (estuarine lagoon), with a well-developed longitudinal salinity gradient. In 1993, MOD (Main Outfall Drain) was connected to this canal at km 10 from the canal head and the connection with Karmat Ali river was closed. This caused an increase in the flow rates which vary between 100-200m^3/s [5]

This work aims to provide a useful working tool for the local authorities, in case of an oil spill hazard within Khor Al-Zubair lagoon confined space.

MATERIALS AND METHODS

The climatic information compiled from 40 years of observations showed that at March, the mean highest temperature is 34^{0}C and the mean lowest temperature is 20^{0}C. Though average humidity varies from 65 to 80%, March is a fair weather month with no rainfall and clear sky. Winds were measured continuously at Dona Paula (close to the oil spill regions) using Autonomous Weather Station. In general, winds along the coastal region varied between north and northwest at the morning hours and between west and northwest at the evening hours. This can be done by entering the data in an ASCII file (using normal editor) and then reading this file into the standard data file format using the MIKE Zero Time Series Editor as shown in Figure 3. The wind data must cover the complete simulation period.

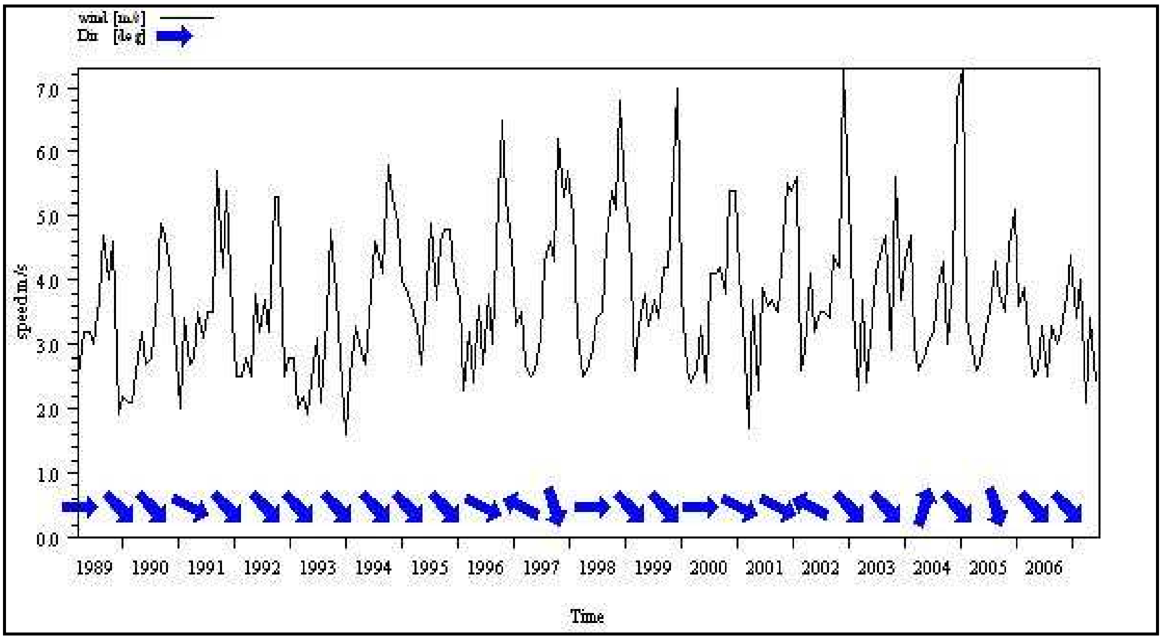

Figure 3. Wind speed and direction (1989-2007)

Table 1. Tidal gauge details

No.	Station	Position (GPS)		Gauge type	Zero level (relative to LLW)	Period
		Lat.	Long.			
St1	Khor Al-Zubair port	30° 12' 16.69″N	47°52' 46.95″E	Valeport 740	- 1.15 m	10/12/2007 to 2/12/2008
St2	Umm Qasr port	30°01'N	47°57'E	Valeport 740	-1.3 m	11/12/2007 to 15/12/2008
St3	Khor Abdulla (Iraq)	29°50'N	48°25'E	TotalTide Software	Predicted heights are in meters above Chart Datum	Any time
St4	Umm Al Aseed (Kuwait)	29°56'N	48°02'E	TotalTide Software	Predicted heights are in meters above Chart Datum	Any time
St5	Shatt Al-Basrah (upstream)	30° 31' 57.7″N	47°42' 56.77″E	Tide staff	Heights are in meters above M.S.L.	24/12/2007 to 6/12/2008

2.1. Bathymetry Survey

Depth survey performed eight cross sections along Shatt Al-Basrah canal levering about (30Km) of the courser during 2008. DGPS (Differential Global Position System) technical type Trimble 5700 device was used to transport the Bench Mark (B.M.) value of the canal banks datum for 3 meters near each canal bank. The main canal cross-sections were surveyed by using Echo-Sunder type HTDRTRAC ODEM. Accrual data were corrected for the Lowest Low Water (LLW) or Chart Datum (CD) level and after that they were plotted.

2.2. Water Level Recording

Data of water level recordings were collected for the study area by two ways for different as periods shown in Table 1. Figure 4 shows the location of the stations.

2.3. Flow and Discharge measurements

Two methods were used in flow and discharge measurements; 1- During December 2007, the flow and discharge for upstream of Shatt Al-Basrah canal were measured in the form of time series for 15 days continuously, at 12:00 AM. Current meter model CM-2 was used to measure speed and direction of flow. Measurement was along the water column (1m, 2m, 3m…etc) [6,7] and retrieved the main velocity of the canal. Discharge was calculated by speed in the area of cross-section in unite m^3/s.

2-An advanced flow meter is used within the study area. It is a so-called ADCP (Acoustic Doppler Current Profiler) type Rio Grande 600 Hz. Two methods were used to measure ADCP flow and discharge:-

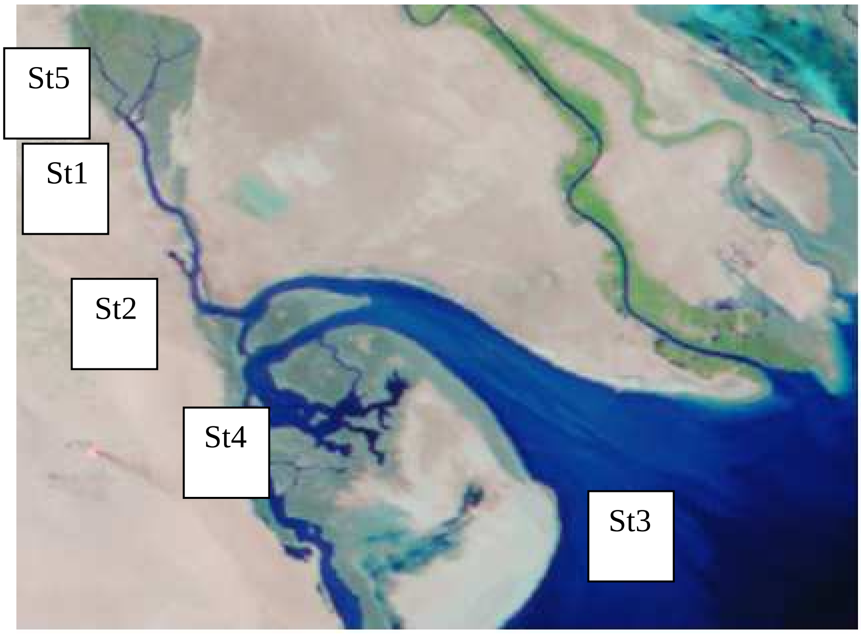

Figure 4. The location of measurement stations

A-Transect lines measurements: The cruise lines indicated speed and direction along a cross-section figure 5. The total distance is about 2.8 Km, which is expected to be sailed in 12hr.

B-Time series measurements:- Time series measurements represent measurements over a certain period where the boat is fixed in space (anchored, moored). On the contrary to transect, these measurements are conducted over relative long time (12hr) but on a fixed location. Time of measurement is a 10min. for all (time series 12hr). Table 2, gives details of the data availability for the present investigation.

2.4. Water Properties

The water sampler type Niskin Sampling Bottle model 1080 is used for collecting samples from four cross-sections (Shatt Al-Basrah canal, Umm Qasr, and Khor Al-Zubair,). The measurements were conducted during a tidal session (13hr), samples of water were collected from water surface (below 0.5-1 meter) in four sites along the study area during 2008.

Field salinity, conductivity, and temperature of water were measured using portable YSI model 556 MPS and Digital Thermometer after calibration with standard sea water. Thirteen water samples (at an interval of one hour during a tide cycle) were collected from the surface water in each station for the determination of salinity in the laboratory by Digital Salinometer model E-202.

2.5. Oil Spill Experiments

Two field experiments were carried out (Crude Oil / Basrah Light) with 7.5 and 40 liters during 18th and 22nd August 2008 in Shatt Al-Basrah canal. These experiments were conducted during flood and ebb tidal phases. We used a small boat, Camera with the specifications a high-precision 10.1 pixel, and GPS type Germen 152 for precise location.

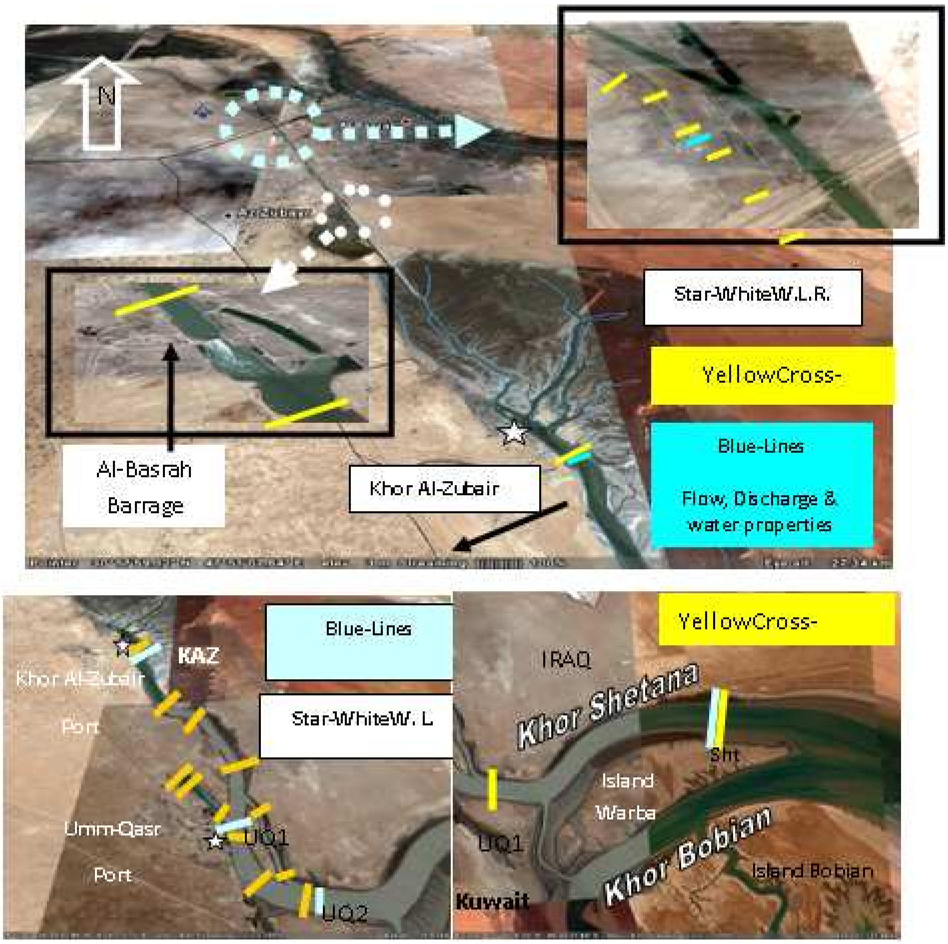

Figure 5. Satellite image showing approximate Locations of the selected cross sections in Shatt Al-Basrah canal and Khor Al-Zubair to be measured (depth, position, water level, water properties, discharge, speed, and direction)

Table 2. Measurements of current and discharge details

Station	Position (GPS)		Type of device	Date
	Lat.	Long.		
Khor Al-Zubair KAZ	30° 12' 16.69″N	47°52' 46.95″E	ADCP technique	10/5/2008 & 2/1/2008
Umm Qasr UQ1	30° 2' 14.23″N	47°57' 1.68″E	ADCP technique	1-4/1/2008 & 8/5/2008
Umm Qasr UQ2	30°00'N	47°59'E	ADCP technique	1/1/2008 & 8/5/2008
KhorShetana Sht	29°50'N	48°25'E	ADCP technique	9/5/2008 & 3/1/2008
Shatt Al-Basrah (upstream)	30° 31' 57.7″N	47°42' 56.77″E	MC-2	24/12/2007 to 6/1/2008

On 9/5/2009 5:00 pm the following-up dispersion of the remnants of engines for ships, oil spill from a ship anchored in the port of Umm Qasr (GPS=Lat. 30° 11' 00″ N and Long. 48° 52' 00″ E) happened. The remnants of oil spills after 0.5 hr and a slick, completely disappeared in the northern coast of the port.

On 28/5/2009 4:00 pm the following-up an oil slick spilt from a vessel approximately 200 liters near the port of Khor Al-Zubair (GPS= Lat. 30° 12' 00″ N and Long. 47° 52' 40″ E) took place. Oil spill area has estimated approximately at 50m^2 and was irregular. The condition of the tide was ebb with light northwesterly wind speed up to 1 m/s, and has the process (oil spill disappeared completely) at 5.00 pm.

2.6. Boundary Condition

Two types of boundary conditions are applied in this work; flow and solid wall boundary conditions. The tidal flow boundary condition is considered by imposing of water surface level fluctuations at Khor Al-Zubair.

The fluctuations of water surface elevation are from tidal predictions at Khor Abdulla and Umm Al-ASeed in Kuwait, which can be obtained by application of the calibrated constants of the harmonic analysis, for any arbitrary period of time (Admiralty Tide Tables, 2008). Figure 6, represents the area of study indicated by the sites of open boundary conditions.

2.7. HD Model Calibration

The purpose of the calibration is to tune the model in order to reproduce satisfactory results comparable to the measured conditions for a particular period known as the calibration period. It is rare that the first few simulations will provide good results as model instability can result in the simulation ending prematurely, commonly called a blow up. These usually become unstable and end the simulation prematurely in what is usually called a blow up.

Figure 6. Locations of boundary conditions

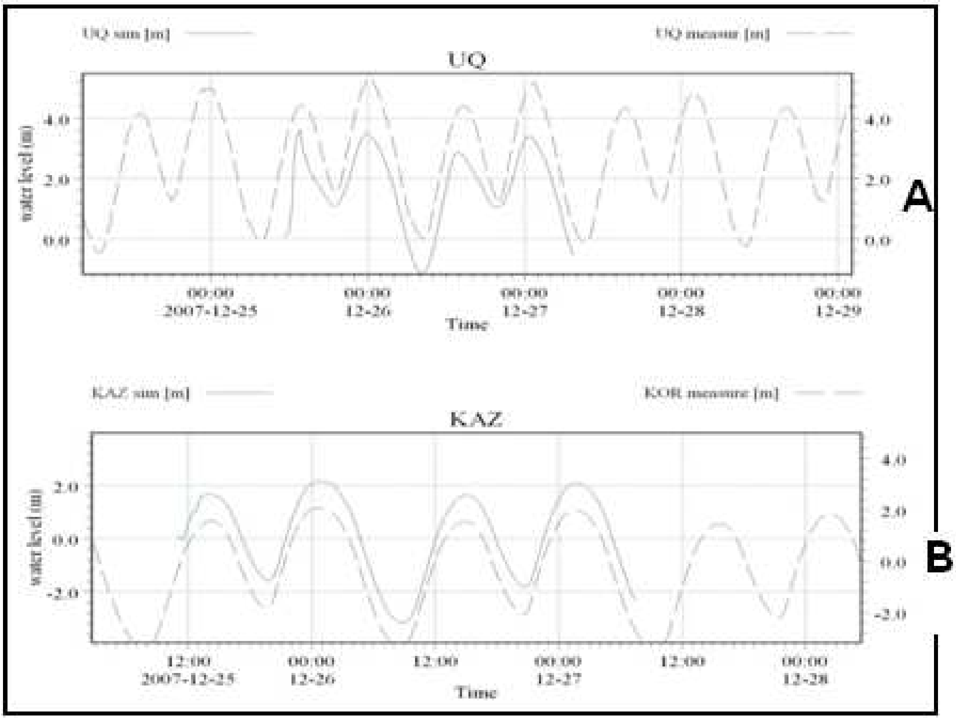

Figure 7. Comparison between water levels for simulation and measured. A- WL computed and measured in Umm Qasr site; B- WL computed and measured in Khor Al-Zubair site

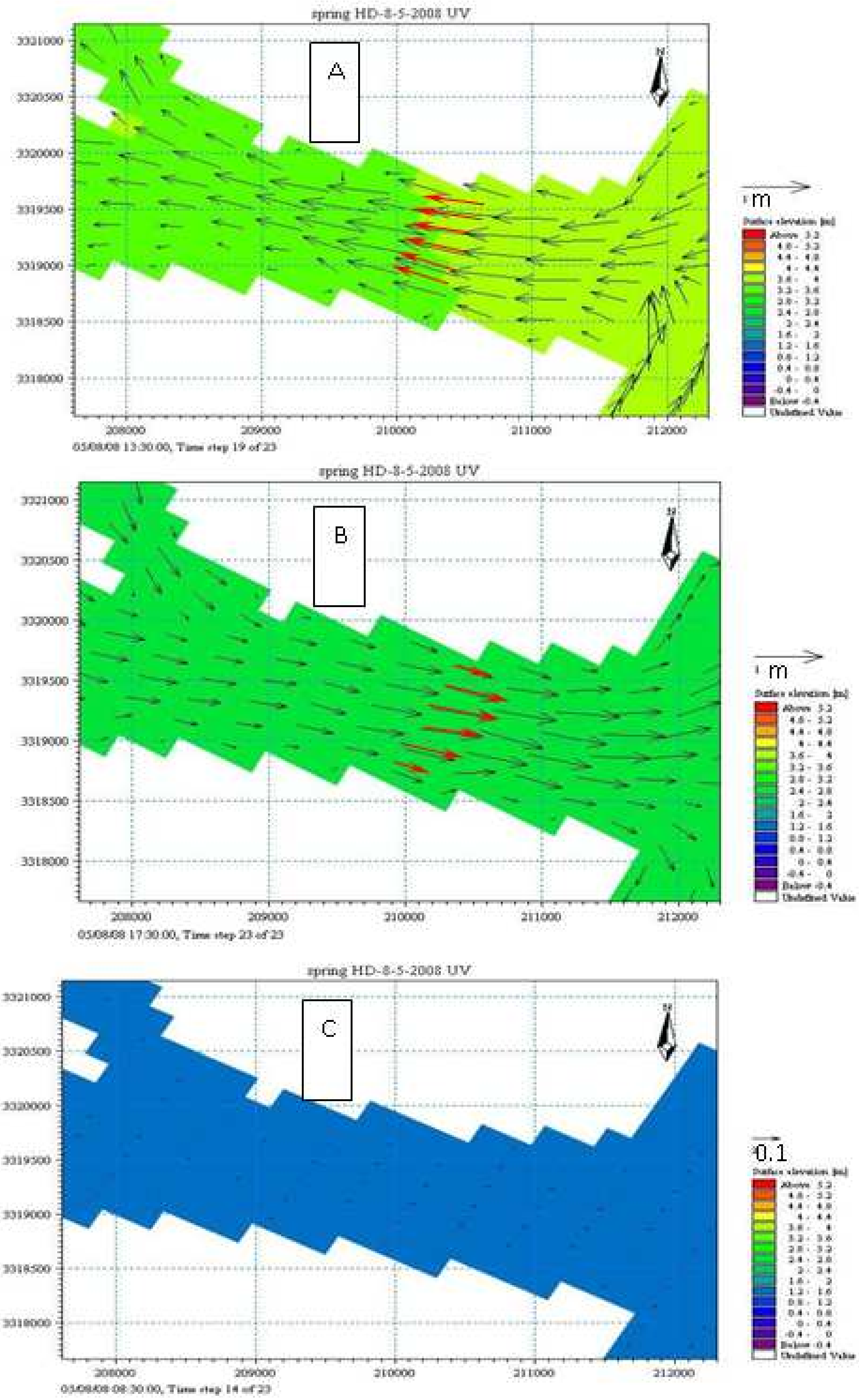

Figure 8. Simulation (black arrow) and measurements (red arrow) of currents in Umm Qasr during the spring tide phase on 8-5-2008 A-flood B-ebb C-slack

The results of the model after the calibration are presented in Figure 7. A comparison between the values of simulation tidal rises and measured in the area of the ports of Umm Qasr, Khor Al-Zubair and Warba, showing an agreement with the simulation parameters. Figure 7, shows the comparison of speed shapes (using tidal constituents) and model predicted surface elevations for Umm Qasr, Warba and KAZ. The coefficient of fitting is 90% for this and hence, it assured that the HD model is well calibrated.

Figures8, 9, and 10 show the results of calibration model for currents to the areas of Umm Qasr, Khor Shetana, and Khor Al-Zubair during spring phase. It was developed for entire period calibration flooding of 10, 9 and 8-5-2008 to coincide with the field measurements of the areas of Umm Qasr, Khor Al-Zubair, and Khor Shetana. As well as for comparison between the cases are the floods and ebb tide for each region as shown in Forms (A and B). Once these parameters are specified, as shown in Table (3), some simulations can be run. The exact values of the parameters given for each simulation and calibration will be present.

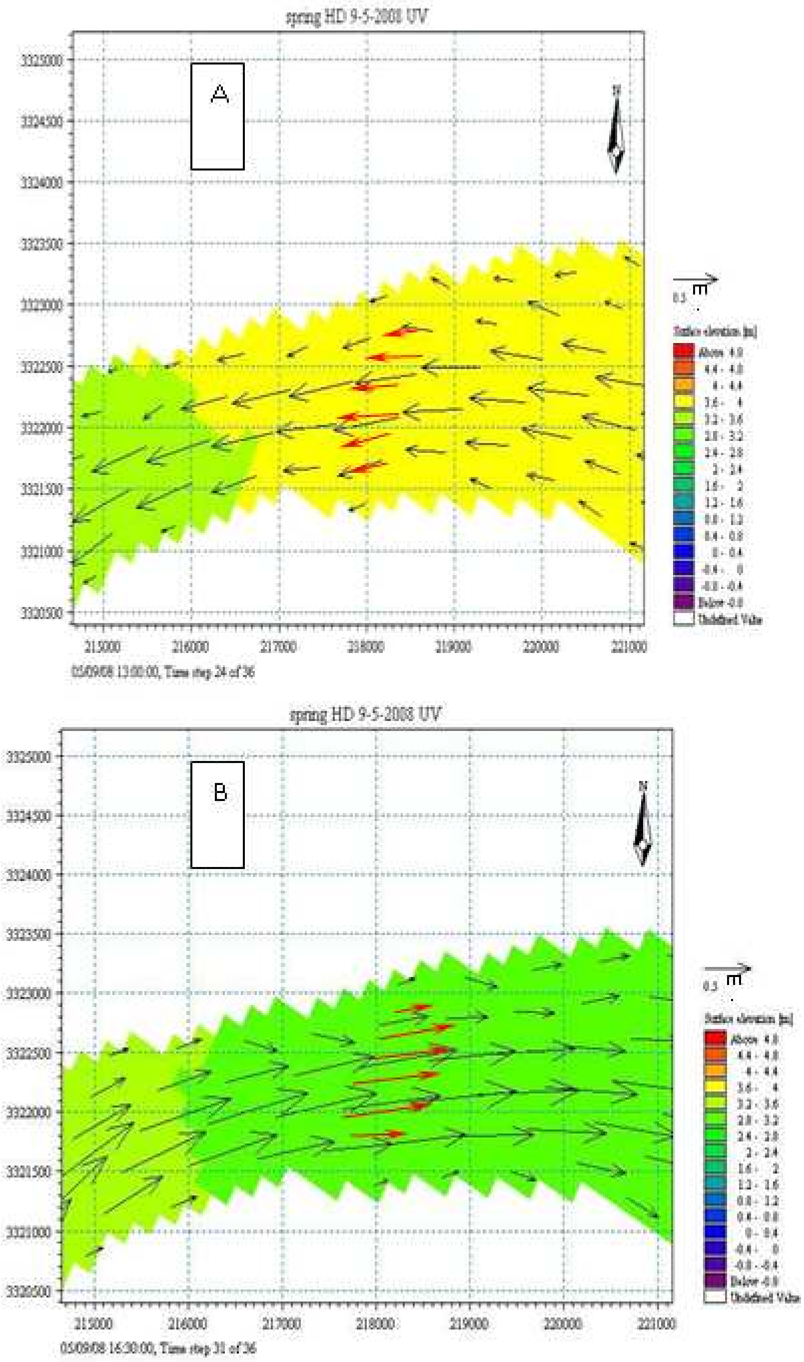

Figure 9. Simulation (black arrow) and measurements (red arrow) of currents in Khor Shetana during the spring tide phase on 9-5-2008 A-flood B-ebb

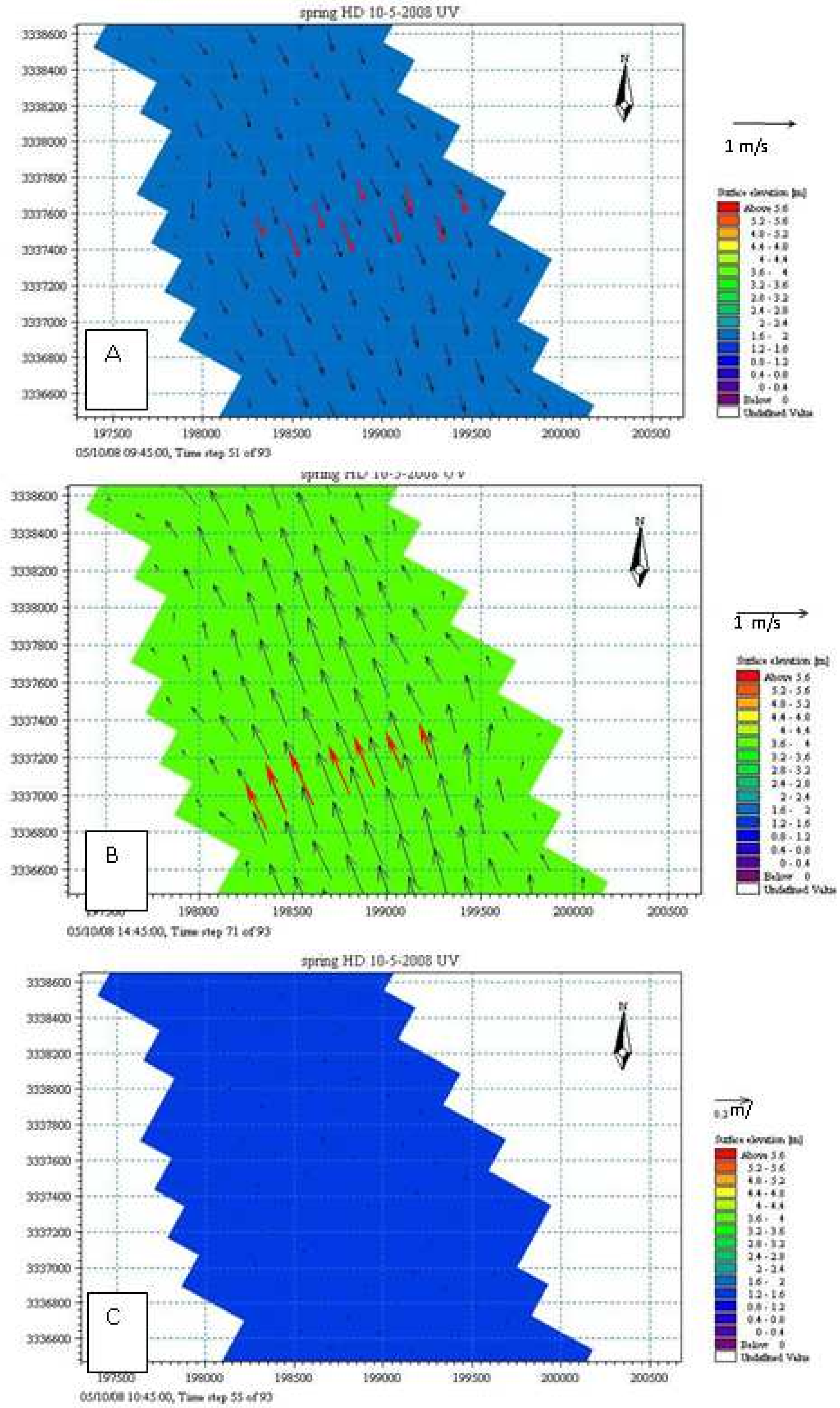

Figure 10. Simulation (black arrow) and measurements (red arrow) of currents in Khor Al-Zubair during the spring tide phase on 10-5-2008; A- ebb; B- flood; C-slack

Table 3. Input parameters for the HD model simulations

Parameter	Value
Module	Hydrodynamic only
Bathymetry	Bathy 200m*200m
Simulation period	2007-12-24 11:00AM to 2008-1-20 04:00PM (26days)or any time period
Time step	80s
No. of time step	3456
Enable Flood and Dry	Drying depth 0.2m Flooding depth 0.3m
Initial surface level	0.40m
Wind	Varying in time, constant in domain: wind.dfs0
Wind Friction	Varying with Wind Speed: 0.0015 at 0.1 m/s, 0.01 at 20m/s
KAZ boundary	(105,316) - (105,321) along line 105
KAZ boundary	Water level
KAB boundary	(1-104) along line 0
KAB boundary	Water level
KAW boundary	(179-185) along line 0
KAW boundary	Water level
Eddy viscosity	Smagorinsky formulation, velocity based constant 0.5
Resistance	Manning number, coefficient 40 $m^{-1/3}/s$
Result file	HD.dfs2

RESULTS AND DISCUSSION

3.1 HD model

The movement of sea currents varies in severity and direction during the tidal cycle as well as difference between the spring and neap phases. Simulation results were reviewed for a period of 10 days in both seasons, the cold (December, 2008) and hot (August, 2008) for KAZ.

Figure 11 shows the form of the surface currents for a full tidal cycle (24 hours) from 31-12-2007 at 17:00 pm until 1-1-2008 at 17:00 pm for the neap phase, where A-represents the highest value of the flood, B-slack water, and C-the highest value of the ebb of the KAZ area, respectively.

Figure 12 and 13 show the water level for Umm Qasr (UQ), Khor Al-Zubair (KAZ), and Khor Abdulla (KAB) on points (j=34, k=223), (j=76, k=284), and (j=83, k=113) for two seasons (Hot and Cold), respectively. We note that the rising tide for UQ area reaches 5.5m, while the value of the highest tide in KAB area is 3.5m, due to the form of bottom topography.

3.2 Oil Spill Model

In this simulation three types of oil [Gas Oil, Crude Oil (Basrah light), and Fuel] were chosen. Table 4 shows the properties of the 6 different oil types. Oil is a mixture of hundreds of hydrocarbon compounds, whose individual chemical properties are widely different. The properties of the oil as a whole depend on the properties of the individual constituents. Because these constituents are in different rates, the slicks properties will change with time.
Table 5 shows the fraction of different compounds for each of the pre-coded oil types in the model. The data of oil properties have been collected from laboratories in the South Refineries of the Company (SRC) [8] in Basrah. Table 6 shows the characteristics or parameters of the oil spill model.

Table 4. Some of the oil types and their physical/chemical characteristics[8,9]

Oil type	Basrah Heavy	Basrah Light	Fuel	Gas oil	Gasoline	Kerosene
Oil classification	**Heavy crude oil**	**Light crude oil**	**Heavy oil**	**Light refined oil**	**Light volatile refined oil**	**Light volatile refined oil**
Density (at 15ºC)	893.8	856.2	941.0	825.6	725	776.6
API	26.8	33.8	18.9	39.85	63.6	50
Flash Point ºC	74	72	78	70	20	44
Vis. 40 ºC CST	20.27	7.361	30.47	2.7		
Colour	Black	Black	Black	0.5 ASTM	Red	(Saybolt) +26 min
Carbon Residue	5.36	3.16	2.89	1.3	0.1	0.5
Sulphur content %wt	3.78	1.87	2.4	0.9	0.03	0.09
Pour pointºC	20	20	23	-9		
Asphalten content %wt	0.75	0.45	0.84	-	-	-

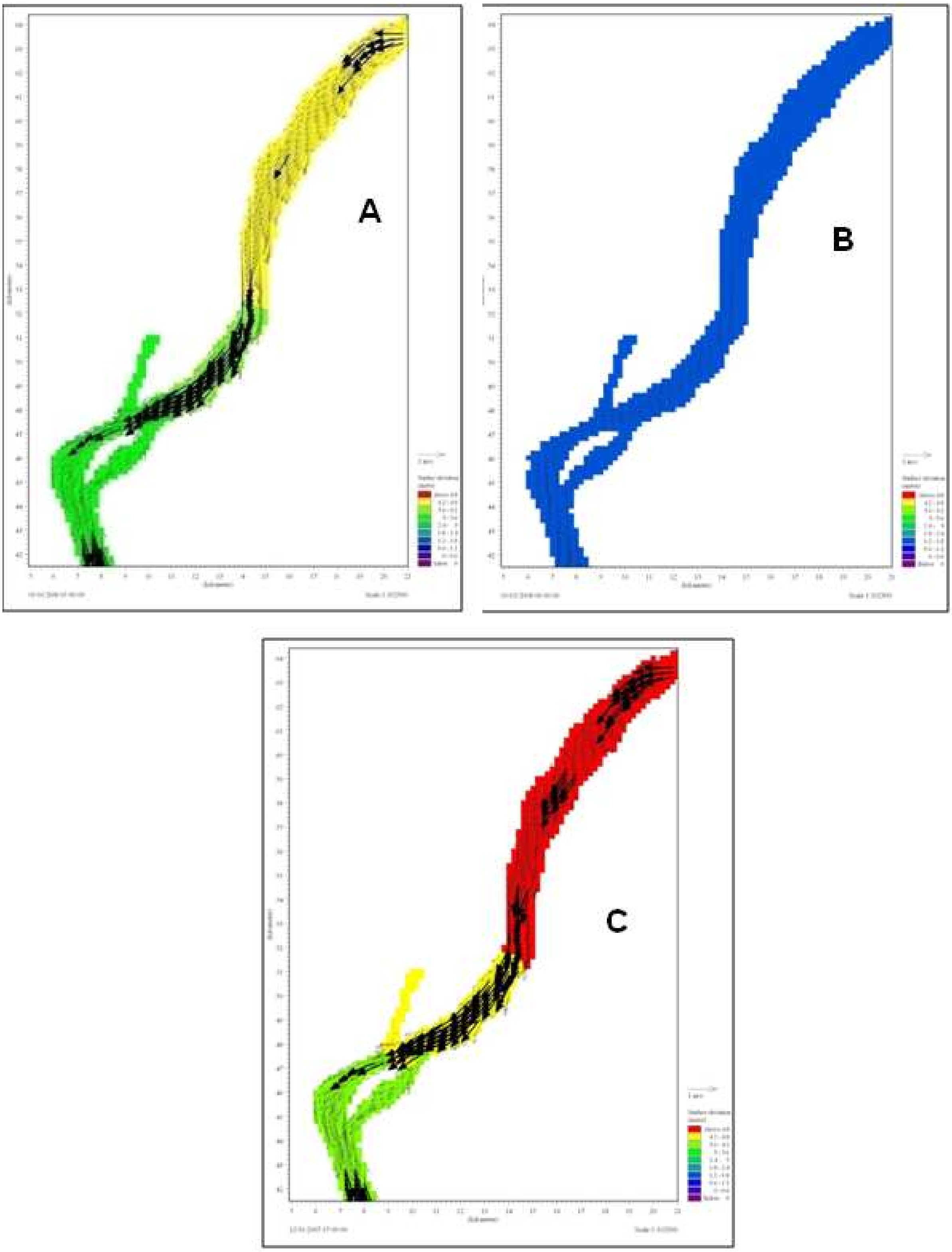

Figure 11. Tidal currents field in surface layer (surface currents) of the KAZ at the neap phase from 31-12-2007 to 1-1-2008: A-Flood B-Slack C-Ebb

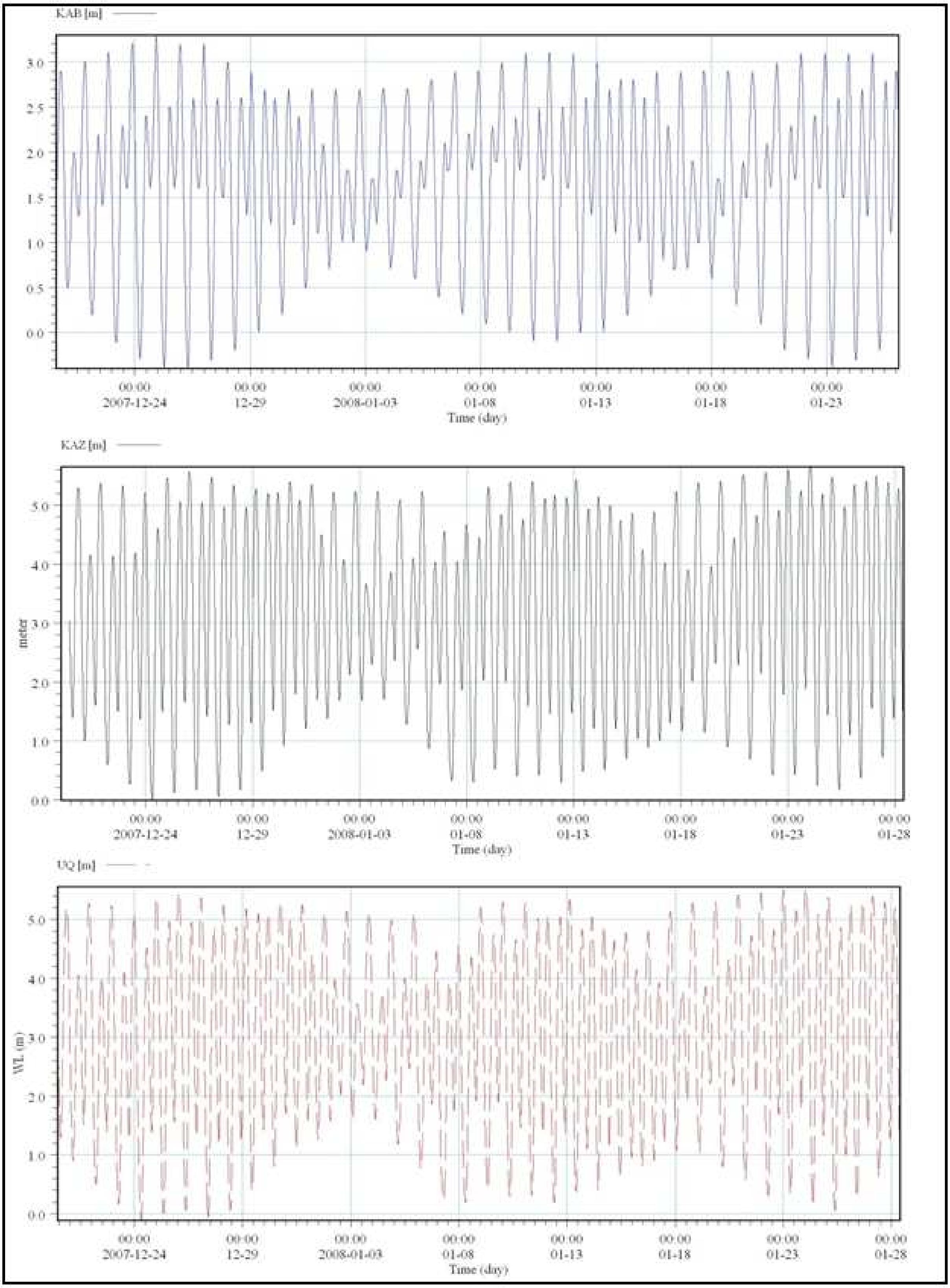

Figure 12. Computed tide heights for the Cold season for 38 days from 21-12-2007 to 28-1-2008in 1-KAB 2-KAZ 3-UQ

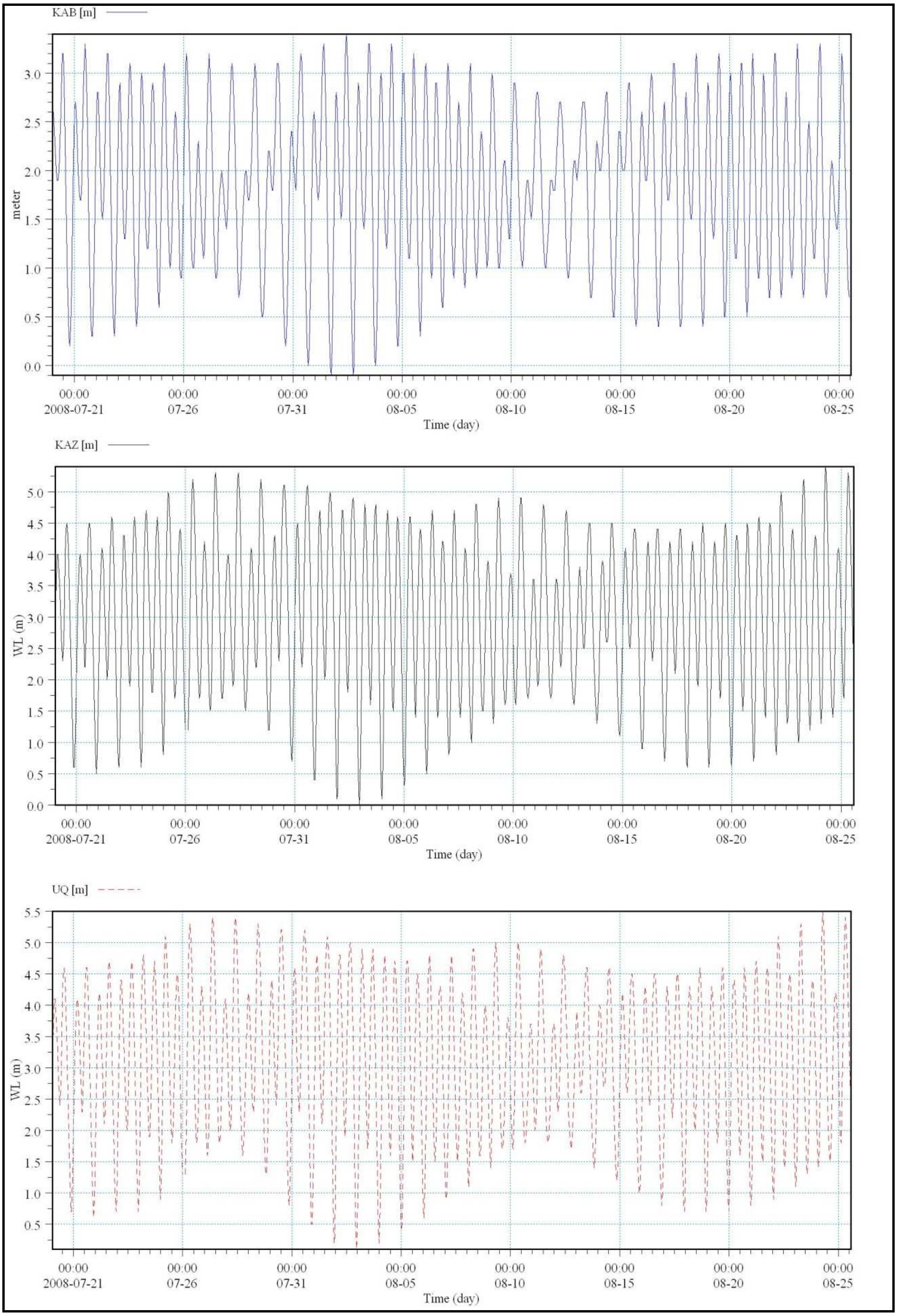

Figure 13. Height of tide in 33 days of the Hot season from 12-7-2008 to 25-8-2008 on 1-KAB 2-KAZ 3-UQ

Table 5. Fractions of different compounds for each of the pre-coded oil types in the model

Fraction	Description	Boiling range	Fuel	Basrah Light	Gasoil
1	C6-C12 (Paraffin)	69-230°C	0.15	0.15	0.1
2	C13-C25 (Paraffin)	230-405°C	0.13	0.15	0.25
3	C6-C12 (Cycloparaffin)	70-230°C	0.14	0.20	0.15
4	C13-C23 (Cycloparaffin)	230-405°C	0.12	0.20	0.15
5	C6-C11 (Aromatic)	80-240°C	0.07	0.05	0.15
6	C12-C18 (Aromatic)	240-400°C	0.035	0.03	0.05
7	C9-C25 (Naphteno-aromatic)	180-400°C	0.035	0.07	0.15
8	Residual (incl. heterocycles)	>400°C	0.32	0.15	0.00

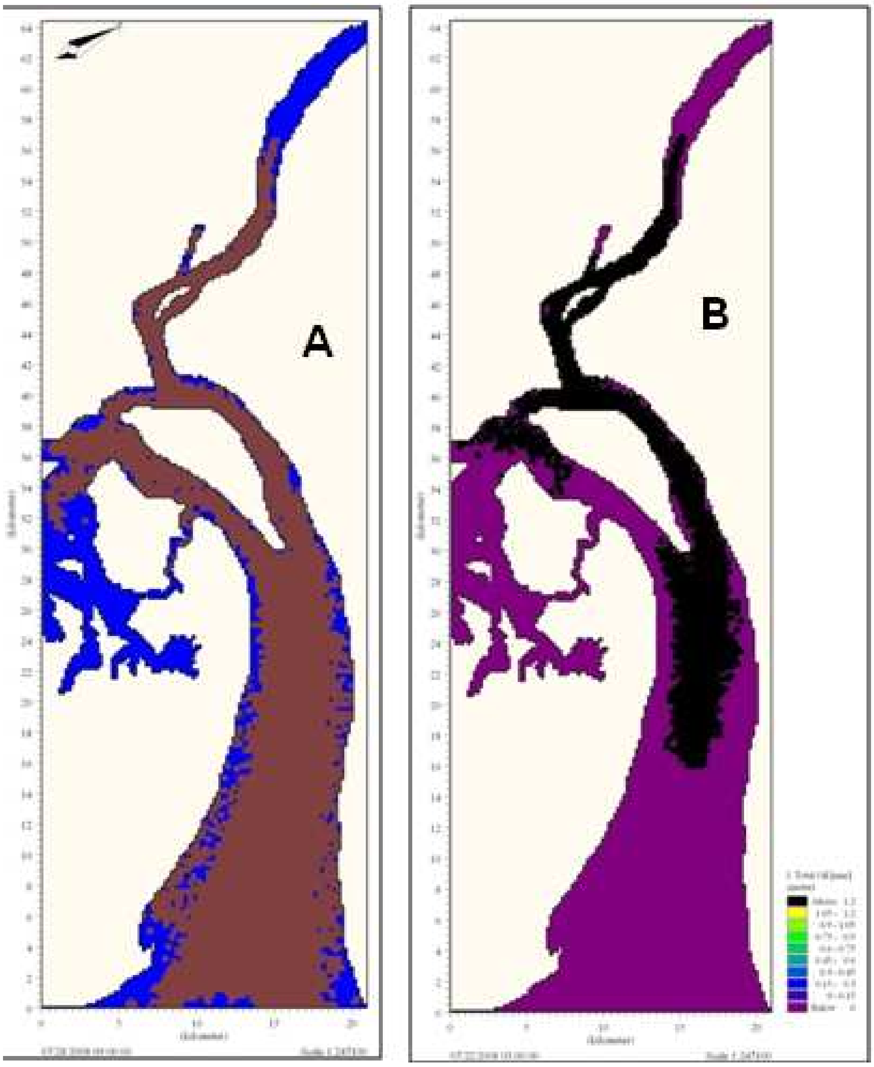

Figure 14. Result of oil spill model A-Gas Oil spilled, B- Fuel Oil spilled

Figure (14-A) shows the simulation results in KAZ of Gas Oil spill to locate the size of the spread area of oil pollution which is estimated at 40km^2. The thickness of the slick is very thin because its contents are highly volatile chemicals which interact very quickly, and they evaporate heavily up to the extent of combustion. The total time of survival is 1 to 2 days according to the season (this leakage is out of control because of the weather).

Figure (14-B) shows the simulation results of Fuel oil spill which has a very big impact on the marine environment because of its chemical constituents, whereas an estimated area of spread 28km^2, which is less than Crude Oil (Basrah light) due to the heavy specific weight. The time of the survival of a slick oil pollution is longer than the time of simulation (>10 days). Pollution slick is moving longitudinally with the channel and graduates beyond the limits of the study area.

Researchers [10,11,12, and 13,] studied the impact of the air temperature (seasons) and wind on the dispersion and spread of oil slick spilled into the sea in different locations in the world. They found that the influence was very large and increases with the surface area of the oil spill, while the wind has its main role in dispersing the oil. Alvarez–Salgado et. Al[14] studied the impact of the oceanographic conditions during spring 2003 on the transport of oil spill in the sea and concluded that physical factors are directly affecting the movement of oil slick between the coasts. This confirms our result in the spill model in the study area.

Table 6. Input parameters for sample simulations

Item	Number / Value
Simulation Time (day)	10
Spill time step Δt (min)	15
Initial oil particle number, *N*	Release 100 at 1hr intervals during duration
Spill quantity	17,000 ton
Emulsification coefficient, $\gamma(s^{-1})$	10^{-6}
Resurfacing coefficient, α	1
Buoyant velocity $V_b(m.s^{-1})$	0.00254
Air temperature (ºC)	20 ºC
Water viscosity υ_w $(m^2.s^{-1})$	1.311×10^{-6}
Spill volume (m^3)	300
Oil type	Fuel, Crude light, Gas oil
Wind velocity	Data for August 2008
Spill location	KAZ (j=76, k=284)
Spill condition	Continuous spill duration= 10hr
Oil viscosity υ_o $(m^2.s^{-1})$	8.6×10^{-4}
Surface tension σ $(N.m^{-1})$	0.02
Salinity	35.5 psu

CONCLUSION

The Climate of the region is one of the key factors affecting the dispersion of oil spill, an arid desert, where the hot season which runs from May until October, is characterized by high temperatures, increasing wind speed, and the high values of evaporation.

High values of the surface currents, are at low tide compared with the tidal stream in Khor Al-Zubair and Umm Qasr, and are close in Khor Abdullah.

The marine environment of the studied area is affected by the area spreading, thickness, and the survival time of the oil spill pollution.

Quantity of oil spilled and durations of the spill have a direct correlation with the increase in the volume of oil spilled in the study area.

REFERENCES

[1] SOMER, *State of the Marine Environment Report*, ROPME/GC-11/003, Kuwait, **2003**.
[2] Alramadan B M, " *Introduction in marine physics in Khor Al-Zubair*", mar. Phys. Conf., Barah, **1986**,
[3] Emery K O , and , Stevenson R E, *The Geological Society of America*, **1999**, New York, Memoir, 67, 673-750.
[4] AL-Ramadhan B M, *Coastal and Shelf Science*, **1988**, No.26, 319-330.
[5] DOM, *Main Outfall Drain, Ministry of Water Resources*, Main Outfall Drain Office, Baghdad, Iraq. **2008**,
[6] Bowden K F and Din Sharif S H , *Geophy. Jour. Roy. Ast. Soc.*, **1966a,**10, 383-400.
[7] Bowden K F and , Din.Sharif S H, *Geophy. Jour. Roy. Ast. Soc.*, **1966 b**,11, 279-292.
[8] SRC South Refineries Com. (S.C), *Oil properties. Laboratory Dept., Al-Shaiba site*, Ministry of Oil, Basra, Iraq, **2008.**
[9] SOC South Oil Com. (S.C) **(***Oil properties. Laboratory Dept., NahranAmer site*, Ministry of Oil, Basra, Iraq. **2008**.
[10] Shen H T, and Yapa P D, *Journal of Hydraulic Engineering*, **1988**,ASCE, 114 (5), 529-543.
[11] Tkalicj P, Huda M K and Gin K Y H, *Journal of Hydraulic Research*, **2003**,41 (2), 115 –125.
[12] Chao X, Shankar N J and Wang S S Y , *Journal of Hydraulic Engineering*, **2003,**129, No. 7, 495-503.
[13] Al-Rabeh A H, Lardner R W and Gunay N, *Arabian Gulf Environmental Modeling & Software*, **2000**, 15, 425–442.
[14] Alvarez–Salgado X A, Herrera J L, Gago J , OteroSoriano P, Pola J and Garcia- Soto C , *Marin Pollution Bulletin*, **2006,** 53, 239-249.