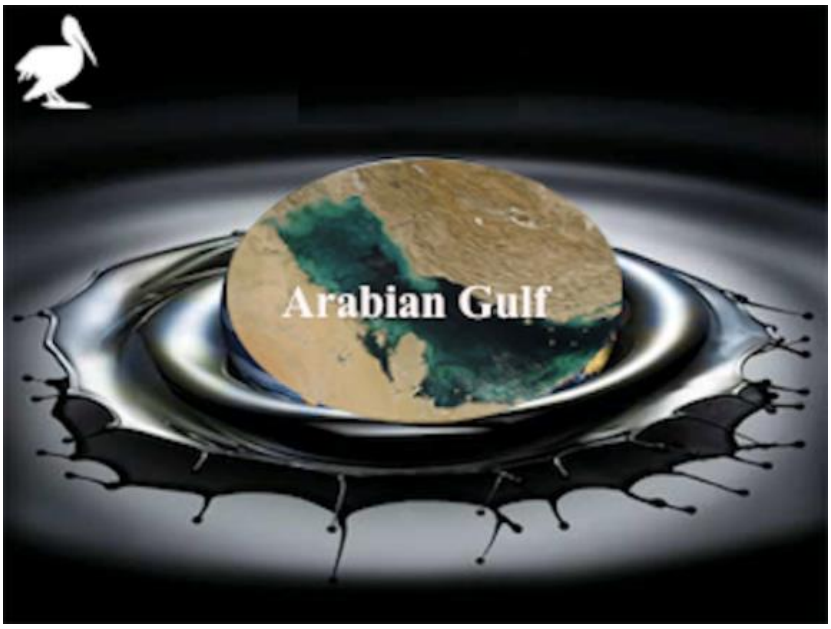

"Boil Model"

Back Tracking of Oil Slick Movements in Offshore of Arabian Gulf Marine Waters

Developed By

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April 2013

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KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH

Abstract:

A Numerical model has been developed based on the solution of the governing partial differential equations of flow and immiscible pollutants (BOil) for predicting the back track oil slick in Kuwaiti offshore territorial waters and Arabian Gulf waters. The model has been coupled with KGulf Model, a hydrodynamic numerical model (K. Al-Salem, 2012). KGulf gives the 2D velocity distribution on the surface of water body. In the case of transient analysis; the velocity distribution is calculated at each computational time step. This velocity distribution will be taken as the input for back tracking oil transport simulation model. The Lagrangian discrete parcel algorithm has been used to predict the back oil spills and the model consider Monte Carlo Statistical technique to overcome the random walk in Lagrangian discrete parcel algorithm. It can be used either as a real-time basis to predict the back movement of oil spill for unexpected accident of crude carriers in the Kuwait offshore waters or for Quick respond for decision marker on any oil spill accidents in the sea.

Introduction

Vast quantities of oil are used all over the world to meet the increasing human needs and demands. This requires extraction, storage, and its transportation. All these activities may cause pollution to the marine environment, thus endangering the marine resources and life. A contingency plan should be setup by every State to plan and prepare and to deal with any accidental or intentional oil spill in their marine environment. The prediction of the fate transport and back tracking of an oil spill is an important tool for decision makers in such cases. Numerical models are widely used for that purpose. Many oil spill models are commercially available and can be setup for the Arabian Gulf and for the Kuwaiti territorial waters. Such models however, require accurate data on the marine currents which are usually provided from a separate hydrodynamic model HD, such model were developed as in (Jen-Men Lo,K. Al-Salem. 1999)(Al-Salem K. 1993). In this paper, the different components of a system to deal with back tracking of oil spill prediction will be provided. There is a need for analyzing or predicting the back tracking movement of spilled oil slick to know the source of the spill location and the time of the spill. This paper will discuss the development of software 'Boil model', which developed for simulating the back track of oil spills in the sea. The back track oil slick is simulated by considering the mechanical spreading. The software can be used for assisting to know where oil spill location started for Kuwait offshore waters or Arabian Gulf.

Model Validation

Model Simulation for Off shore of Al-Ahmadi port Kuwait oil spill (Jan. 19, 1991)

(Case Study 1)

The 1991 Middle East war resulted in oil spills at Kuwaiti coast. The Oil spill start in January 19 1991 at Al-Ahmadi off shore at location (29°07' N, 48°20' E) . Figure X1 shows the observed locations of the oil spill on various dates. The observed locations of the leading edge of the spill on February 14 and March 18, 1991 are concentrated near the island of Abu Ali, Saudi Arabia at Location (27°36.3' N,

49°47.04' E) and north of Bahrain Island at location (26°59.04' N, 50°40.65' E) (Al-Rabeh,1992)(Walid Elshorbagy, 2007). The characteristics of the sea water hydrodynamics were simulated using the KGulf model (K. Al-Salem, 2012), which was embedded in BOil model. Grid used for this case is shown in Figure 2. The results from the back track oil spill (Boil model) simulations are evaluated with available observed of spill as in Figure 1 shows excellent agreement with the model simulated locations on these dates as shown in figure 2 and table 1 for oil spill sited at February 14, 1991 and Figure 3 and table 2 for oil spill sited at March 18, 1991. The implications of the lack of good meteorological data.

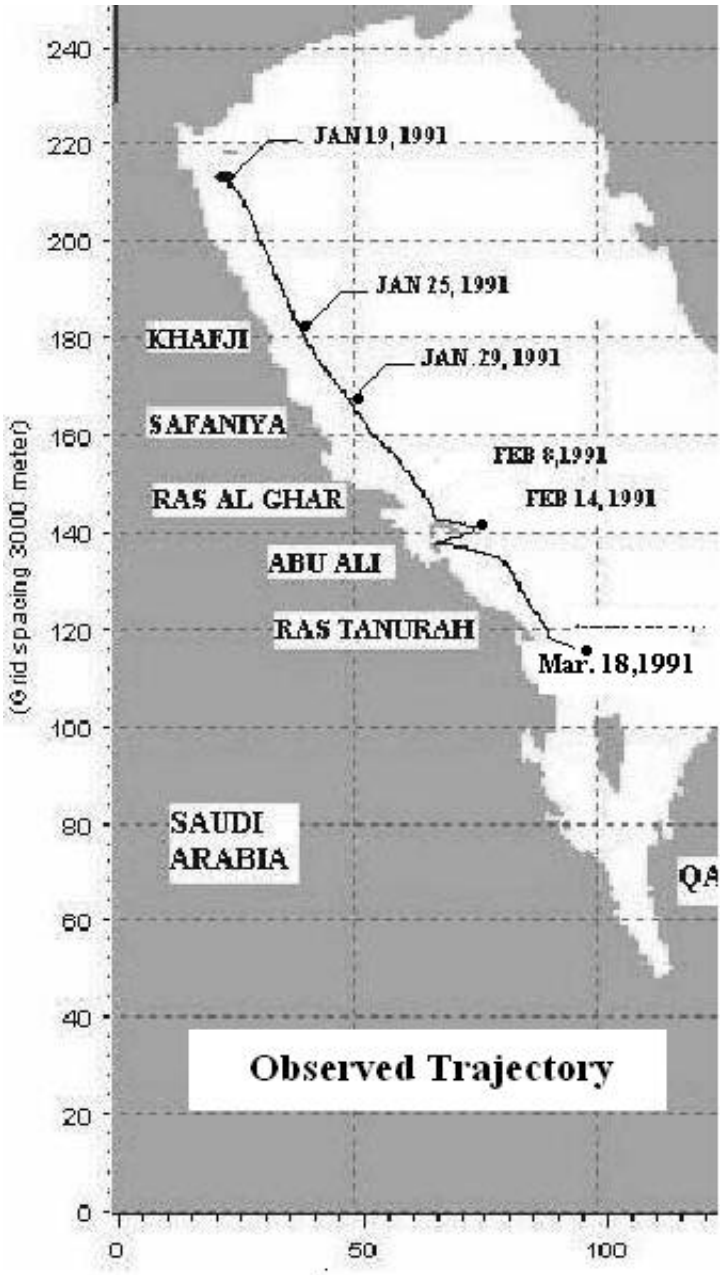

Figure 1. Observed Location Trajectory for Al-Ahmadi, Kuwait Oil Spill in January 19, 1991

Table 1. Simulation Summary for Sited Location in February 14, 1991

Output simulation List			
Simulation Results Summary			
Oil Spill Sited at Date: 14\ 2\ 1991			
Oil Spill Source Date : 19\ 1\ 1991			
Total Simulated Time 625 Hrs			
Total Simulated Test number: 20			
Delta x/y : 2000 m			
Oil Spill Sited Location			
Longitude: 49.7847488 deg			
Latitude : 27.605824 deg			
Monte Carlo statistical Probabilities of back Track Oil Spill Location			
Total Probabilities: 13			
NO	Longitude(deg)	Latitude(deg)	Probabilities(%)
1	48.2509301050808	28.97248	15
2	48.1910926073019	29.07823	15
3	48.1647904432161	29.00237	10
4	48.1585246280141	29.03351	10
5	48.2809276954386	29.01916	10
6	48.2419031106924	28.93168	5
7	48.1981272909885	29.01189	5
8	48.2421273320078	29.12227	5
9	48.215602532149	29.11985	5
10	48.270041967775	29.16493	5

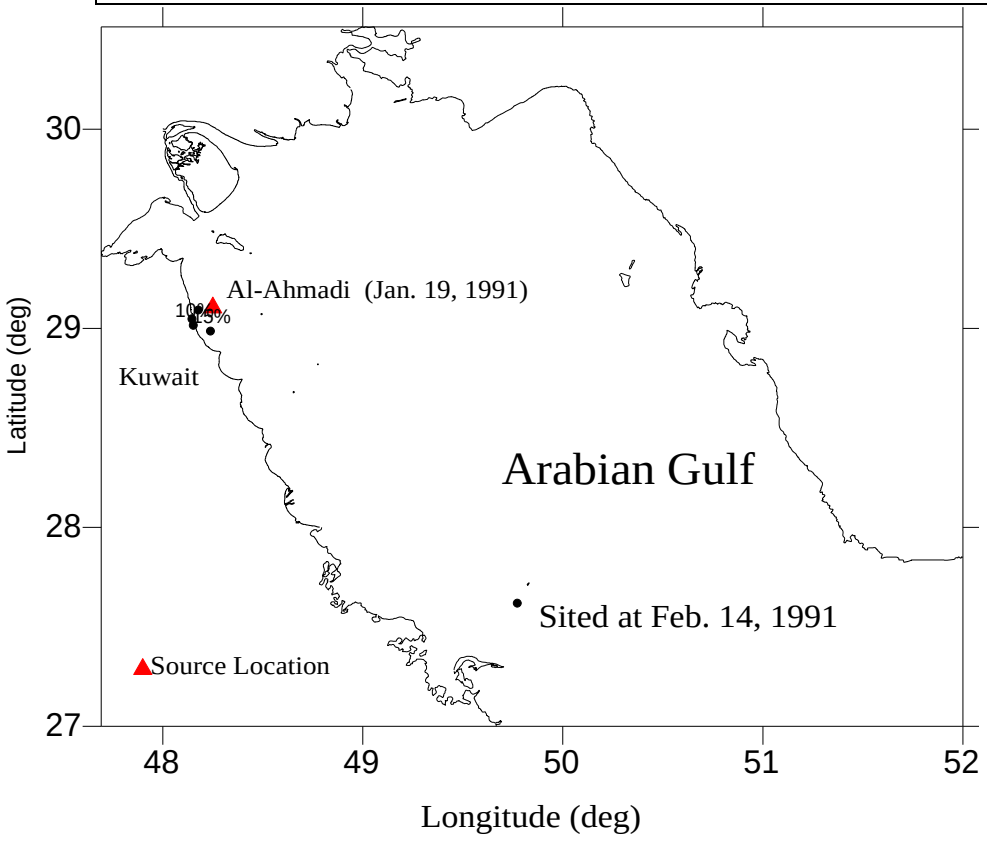

Figure 2. Simulation for Sited Location in February 14, 1991

Table 2. Simulation Summary for Sited Location in March 18, 1991

Output simulation List			
Simulation Results Summary			
Oil Spill Sited at Date: 18\ 3\ 1991			
Oil Spill Source Date : 19\ 1\ 1991			
Total Simulated Time 1393 Hrs			
Total Simulated Test number: 20			
Delta x/y : 2000 M			
Oil Spill Sited Location			
Longitude: 50.5151852 deg			
Latitude : 26.9151111 deg			
Monte Carlo statistical Probabilities of back Track Oil Spill Location			
Total Probabilities: 8			
NO	Longitude(deg)	Latitude(deg)	Probabilities(%)
1	48.1288372826076	29.15603	30
2	48.388430790514	28.62489	20
3	48.1028277007335	29.23663	15
4	48.1205221078382	29.18796	10
5	48.1374308873726	29.12458	10
6	48.3843183272265	28.71816	5
7	48.1407285774313	29.0918	5
8	48.1585909155314	29.03099	5

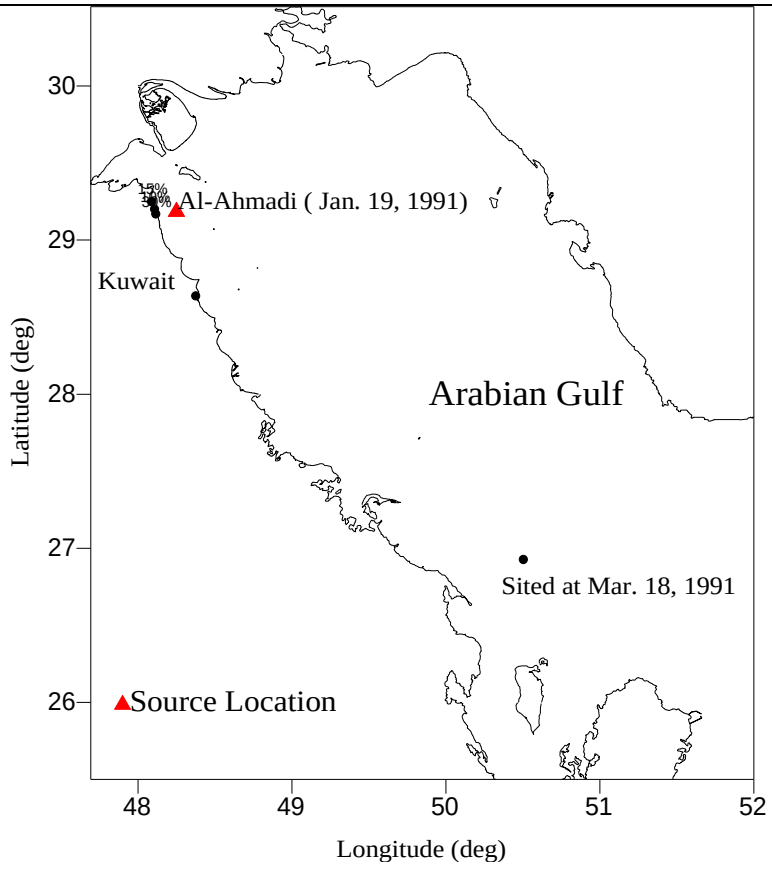

Figure 3. Simulation for Sited Location in March 18, 1991

Model Simulation for NOWRUZ oil spill (February 27, 1983) (Case Study 2)

In early 1983, a ship collided with a well platform at 29° 33'N. latitude 49° 25'E. longitude in the Iranian Nowruz oil field about 250 km. north of Jubail. This collision caused the well to cease production. On February 27, 1983, during high winds and seas, the well blew-out causing a spill of 1,500 to 2,000 barrels of heavy crude oil per day. On March 2, another two wells were started on fire following an Iraqi attack on the Nowruz oil filed area. Figure 4 shows the observed locations of the oil spill on various dates. The observed locations of the spill on March 23, 1983 at location (Longitude 49^o 43.87'E Latitude 27^o 46.21'N), April 16, 1983 at location (Longitude 50^o 16.3'E Latitude 26^o 25.89'N) and April 25, 1983 at location (Longitude 50^o 16.31'E Latitude 26^o 5.17'N) (Abdullah S. AI-Amirah, 1980). The results from the back track oil spill (Boil model) simulations are evaluated with available observed of spill shows excellent agreement with the model simulated locations on these dates as shown in figure 5 and table 3 for oil spill sited at March 23, 1983, figure 6 and table 4 for oil spill sited at April 16, 1983 and figure 7 and table 5 for oil spill sited at April 25, 1983. The implications of the lack of good meteorological data.

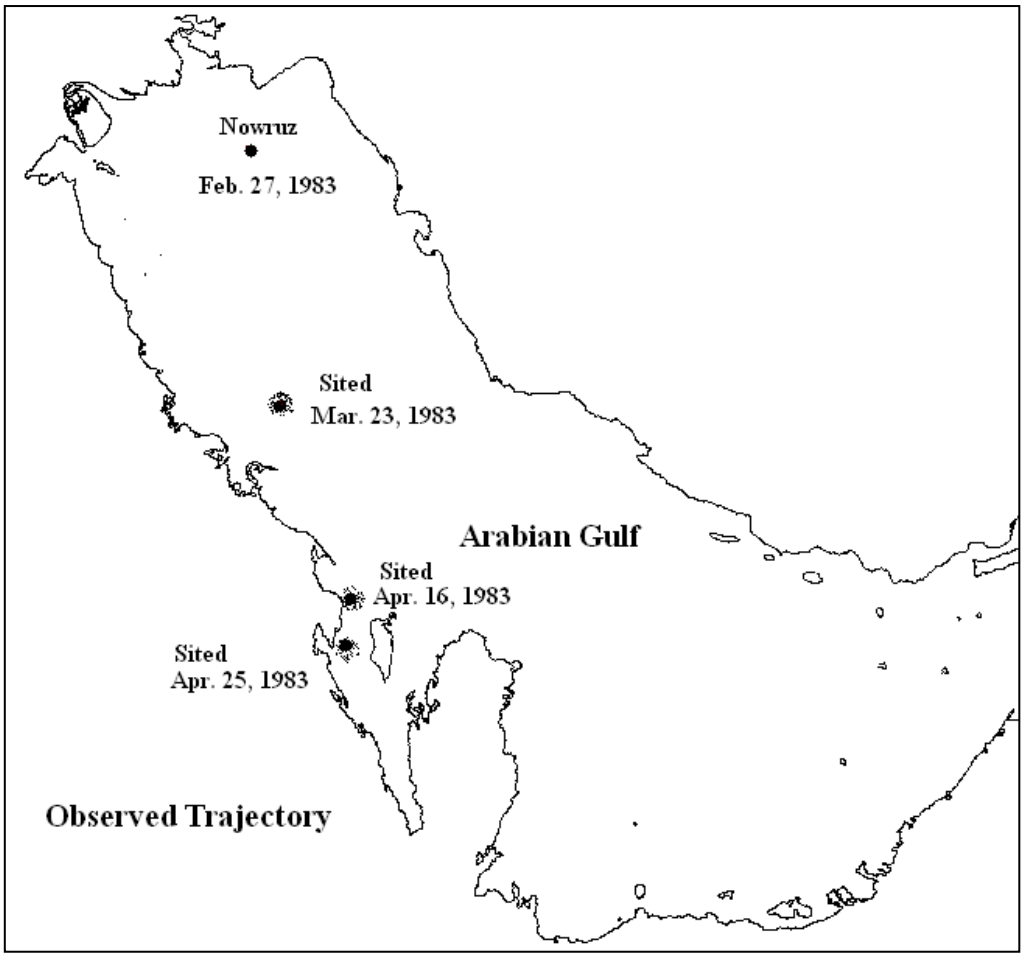

Figure 4. Observed Location Trajectory for NOWRUZ oil spill (February 27, 1983).

Table 3. Simulation Summary for Sited Location in March 3, 1983

Output simulation List			
Simulation Results Summary			
Oil Spill Sited at Date: 23\ 3\ 1983			
Oil Spill Source Date : 27\ 2\ 1983			
Total Simulated Time 577 Hrs			
Total Simulated Test number: 20			
Delta x/y : 2000 M			
Oil Spill Sited Location			
Longitude: 49.73125 deg			
Latitude : 27.77019 deg			
Monte Carlo statistical Probabilities of back Track Oil Spill Location			
Total Probabilities: 16			
NO	Longitude(deg)	Latitude(deg)	Probabilities(%)
1	49.5622159320275	29.65777	15
2	49.6249246398565	29.61024	10
3	49.5388920582331	29.58809	10
4	49.6535402152822	29.61438	5
5	49.5410593093487	29.54016	5
6	49.5812981399401	29.58181	5
7	49.5297234615593	29.73953	5
8	49.482894209549	29.71861	5
9	49.6049490245272	29.63738	5
10	49.5517932790184	29.68835	5
11	49.5382847526002	29.66228	5
12	49.5183236401936	29.61064	5

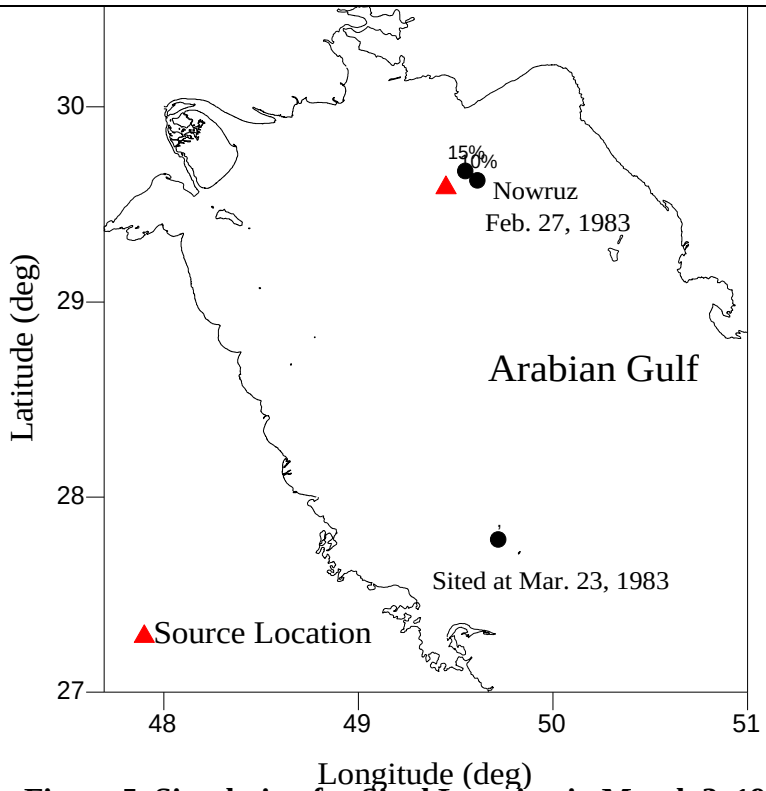

Figure 5. Simulation for Sited Location in March 3, 1983

Table 4. Simulation Summary for Sited Location in April 16, 1983

Output simulation List			
Simulation Results Summary Oil Spill Sited at Date: 16\ 4\ 1983 Oil Spill Source Date : 27\ 2\ 1983 Total Simulated Time 1153 Hrs Total Simulated Test number: 20 Delta x/y : 2000 M Oil Spill Sited Location Longitude: 50.26584 deg Latitude : 26.40053 deg Monte Carlo statistical Probabilities of back Track Oil Spill Location Total Probabilities: 14			
NO	Longitude(deg)	Latitude(deg)	Probabilities(%)
1	49.8586352218081	29.67701	25
2	49.9092776103814	29.68621	10
3	49.8784835173595	29.64284	10
4	49.9183833241339	29.49213	5
5	49.8738842142468	29.71492	5
6	49.8224562251308	29.65185	5
7	49.8390692621406	29.77754	5
8	49.8658962472293	29.55368	5
9	49.8833835431996	29.79653	5

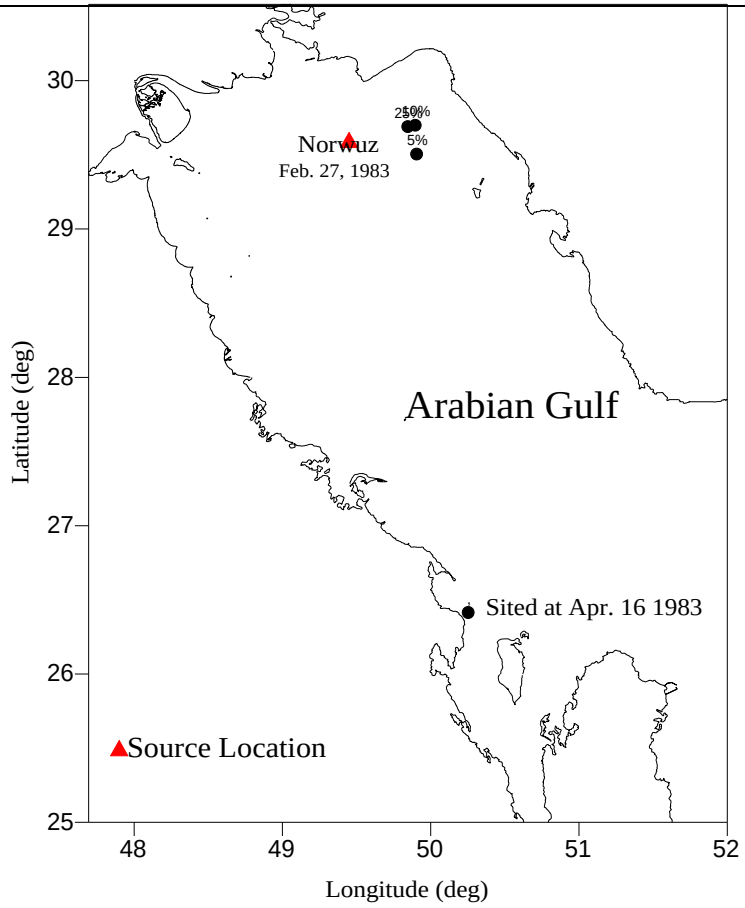

Figure 6. Simulation for Sited Location in April 16, 1983

Table 5. Simulation Summary for Sited Location in April 25, 1983

Output simulation List

Simulation Results Summary
Oil Spill Sited at Date: 25\ 4\ 1983
Oil Spill Source Date : 27\ 2\ 1983
Total Simulated Time 1369 Hrs
Total Simulated Test number: 20
Delta x/y : 2000 M
Oil Spill Sited Location
Longitude: 50.24644 deg
Latitude : 26.07701 deg

Monte Carlo statistical Probabilities of back Track Oil Spill Location
Total Probabilities: 15

NO	Longitude(deg)	Latitude(deg)	Probabilities(%)
1	49.7924226141374	29.90923	15
2	49.8519078573763	30.02788	10
3	49.8128937732108	30.00954	10
4	49.8068542607304	29.97519	10
5	49.8552371999063	29.97281	5
6	49.8507550291018	30.05098	5
7	49.8552372558942	29.93674	5
8	49.8131724614139	29.89933	5
9	49.8096044268741	30.03429	5

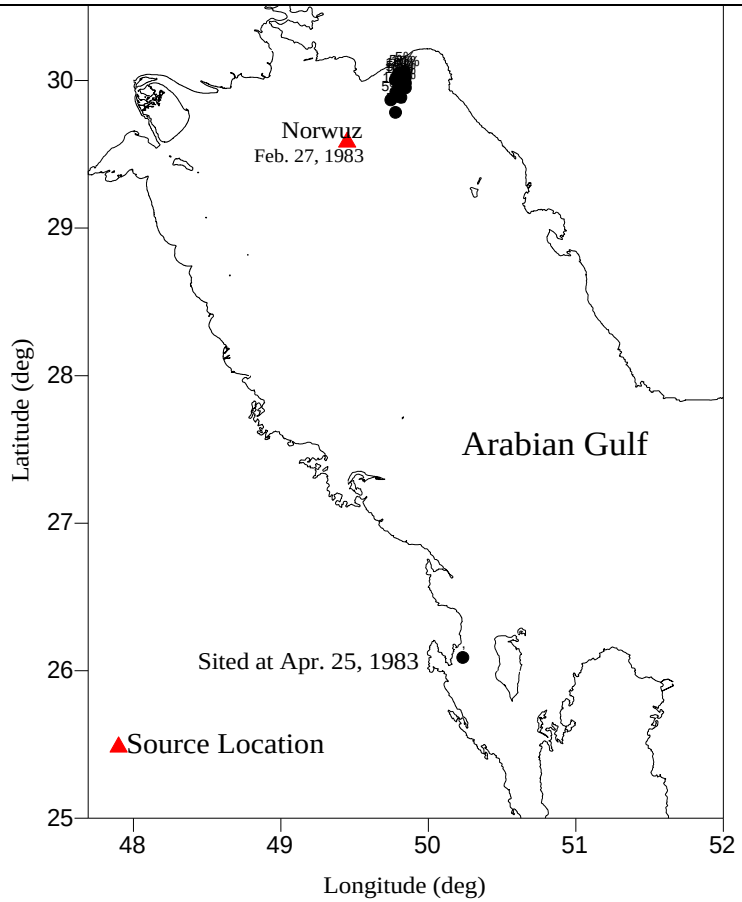

Figure 7. Simulation Summary for Sited Location in April 25, 1983

Model Simulation for Shuaba Port Kuwait oil spill (Aug. 2, 2010) (Case Study 3)

An oil spill of 50 Gal released at the Kuwait Sea at depth of 17 meters at location N 29 4.3' E 48 9.76' (August 2, 2010) is considered. The characteristics of the sea water hydrodynamics were simulated using the KGulf model, which was embedded in BOil model. Figure 8 shows the observed locations of the oil spill. The observed locations of the spill on August 7, 2010 at location (Longitude 48^{o} 7.72'E Latitude 29^{o} 11.321'N). The results from the back track oil spill (Boil model) simulations are evaluated with available observed of spill shows excellent agreement with the model simulated locations on this date as shown in Figure 9 and table 6 for oil spill sited at August 7, 2010.

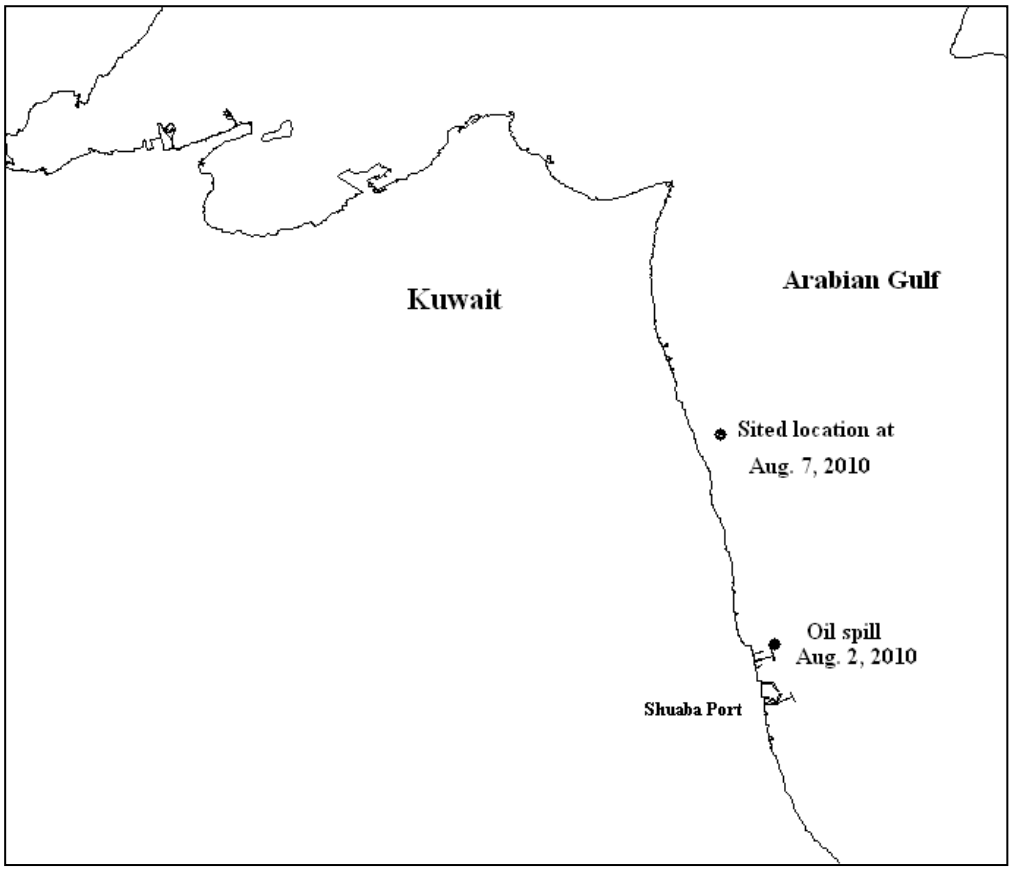

Figure 8. Observed Location Trajectory for Shuaba Port Kuwait oil spill (August 2, 2010).

Table 6. Simulation Summary for Sited Location in August 2, 2010

Output simulation List
Simulation Results Summary Oil Spill Sited at Date: 7/8/2010 Oil Spill Source Date : 2/8/2010 Total Simulated Time: 144 Hrs Total Simulated Test number: 20 Delta x/y : 2000 M Oil Spil Sited Location Longitude: 48.1287 deg Latitude : 29.1888 deg Monte Carlo statistical Probabilities of back Track Oil Spill Location Total Probabilities: 5 NO---Longitude(deg)----Latitude(deg)-----Probabilities() 1 48.164433 29.056879 45.000000 2 48.192749 29.044485 30.000000 3 48.179611 29.025148 10.000000 4 48.211781 29.030708 10.000000 5 48.185226 29.064556 5.000000

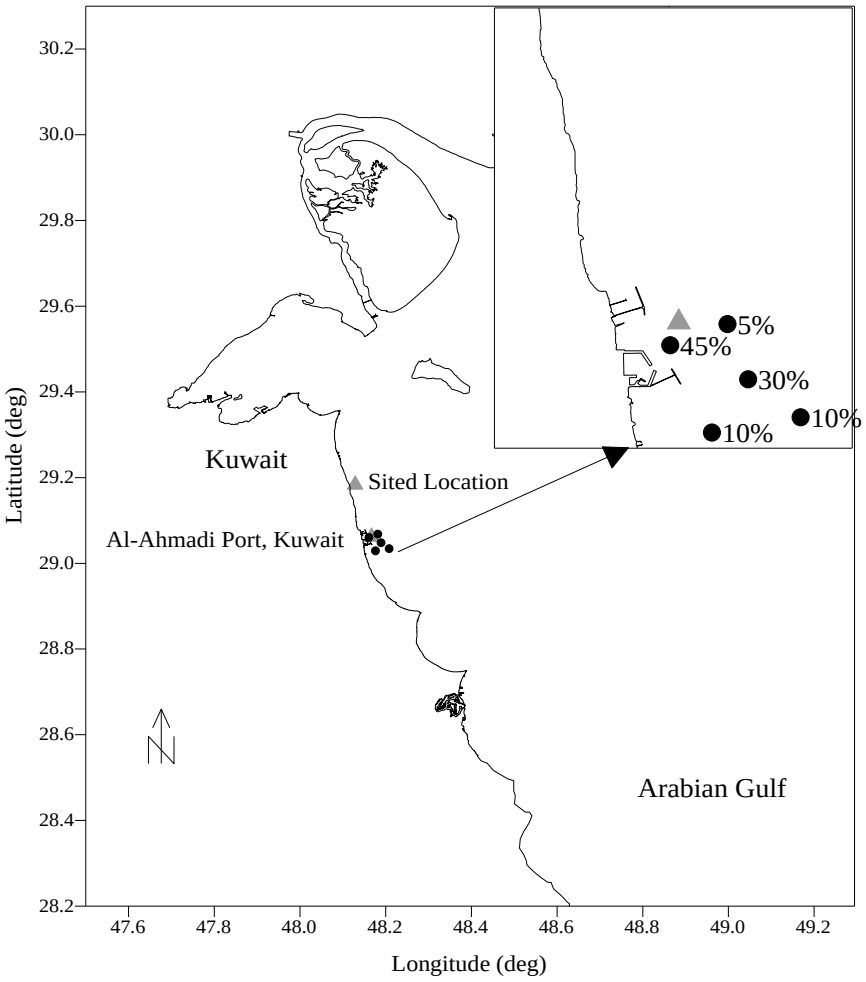

Figure 9. Simulation for Sited Location in August 2, 2010

Procedure for Stand-Alone Usage of Back Track Oil Spill Prediction model

"Boil Model"

The Offshore back Track oil spill model is an efficient and interactive model and easy to use for any user with a little experience in a computer usage. Although more advanced features are anticipated to evolve in the future, this version is sufficiently user-friendly and can provide the base information for prediction of the source of the oil spill present on the sensitivity map will provide important information for the decision makers on the actions necessary to deal with the source of the oil spill. Model was linked to website in the internet at address (http://www.hceatkuwait.net) for decision marker, public to use and for Quick respond on any oil spill accidents in the sea. In this section of the report, step-by-step instructions are given for user of Boil model. The procedure outlined here to run the model.

User must log in to the model at internet adders (http://www.hceatkuwait.net) as shown in Figure 10.

Figure 10. Internet Website Main Page for Boil Model

Figure 10 will display for user the main model options to start as:

1- 2D Hydrodynamics Setup
2- Wind Data Setup
3- Simulation Setup
4- Simulation Output Presentation

In the following section will explain each option setup.

Setup Option 1.

In this option we allow user to select the project domain option as

1- Select Grid Domain

The model has different Gird Domain for 2D hydrodynamic prediction for user to select as :

- Arabian Gulf Grid (coarse grid)
- Kuwait Bay Grid
- Al-Ahmadi Port Coast ,Kuwait Grid
- Al-Zour Coast, Kuwait Grid
- Ras Al-Kafjy and Ras Mushaab Coast, Saudi Arabia Grid
- Ras Laffan Port coast, Qatar Grid
- Arabian Gulf Grid (refine grid)

User can select **Help Option** for more detail on type of Grid domain.

2- Select Map

The has different map limits was per-stored for user the selected. But if user has custom map limit then user must select (**Selected MAP**) and the enter user map limite manually as (Longitude and Latitude in Degrees).

If user want to plot grid line on the map must select (**grid line on/off)**

If user liked to see the map selected is by press on (**MAP SHOW**).

3- Then user must save the entry by select **(UPDATE).** Data Will Store. User Can Reload per-stored data by select (**RELOAD MAP LIMITS**).

4- User must Select the simulation Date Limits as:

User must select the Expect spill source Date as (**Day/Month/Year**) and Sited Oil Spill Date as (**Day/Month/Year**). Then user must select (**SAVE**) to save the data entered.

At this point user has finished entry for option 1 as shown in Figure 11.

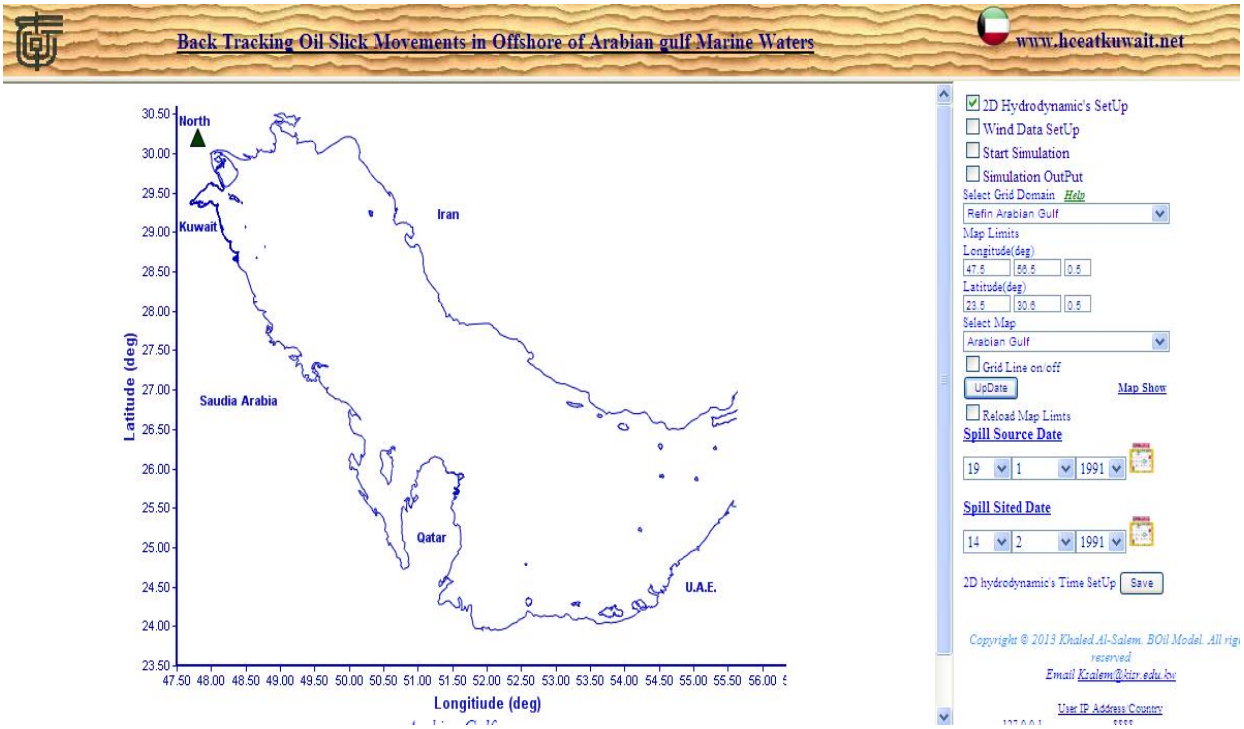

Figure 11. The Selection for Project Domain and Hydrodynamic Simulation Dates limits as in option 1.

Setup Option 2.

In this option we allow user to select the entry for Wind Data as in:

1- Constant wind data (Wind speed and Wind direction)

2- User can enter wind data manually for each hour in one day by select (**Wind Speed input for 24hr) as** shown in Figure 12. Then user must save the data entered or user can reload the entered data by select (**RELOAD INPUT**).
User can present the wind data Plot by select (WIND SHOW) as shown in Figure 13 for wind speed and direction plot.

User must press on (**Wind Speed SetUp File)** to save and set up wind data to the system.

Setup Option 3

User can start simulation section by select (**Start Simulation**) Figure 14 will display for user to enter the oil spill sited location then press (**check button**) to location the nearest grid to sited location entered inside the selected grid domain. Then when grid located water depth will display and grid index as shown in Figure 14.

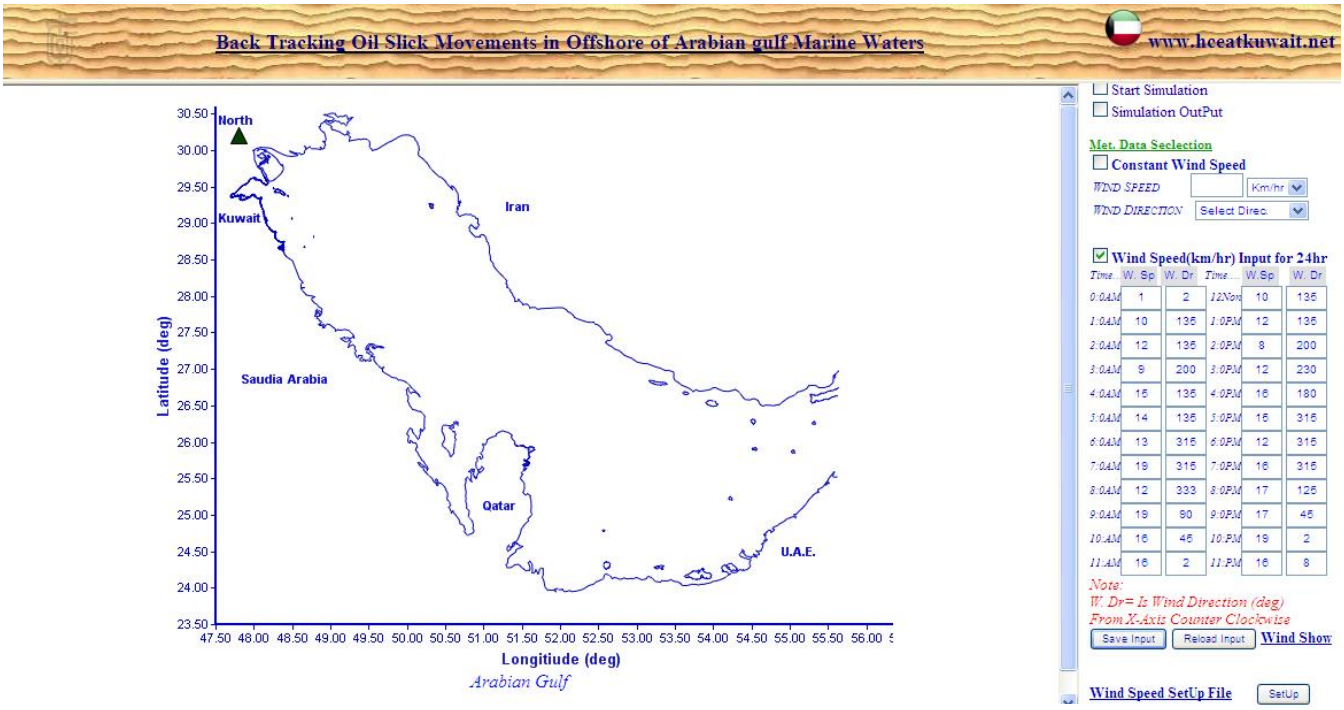

Figure 12. Wind data manually entered for each hour in one day selection

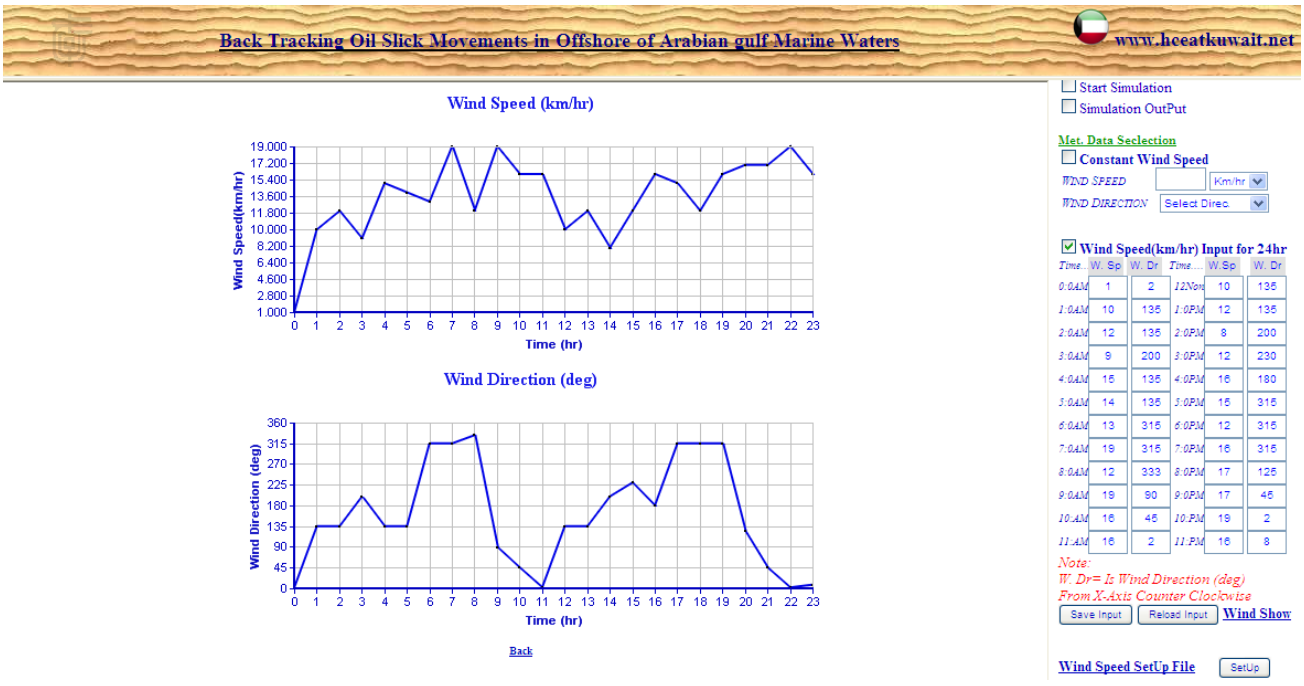

Figure 13. Wind Data Plot

Figure 14 also display data entry for:

- Time in a day of the sited oil spill (in hours)
- Number of simulated test number.
- Delta (dx/dy) in meter.

User need authorization password to start simulation. To get the password must contact model operator at Email address :(ksalem@kisr.edu.kw)

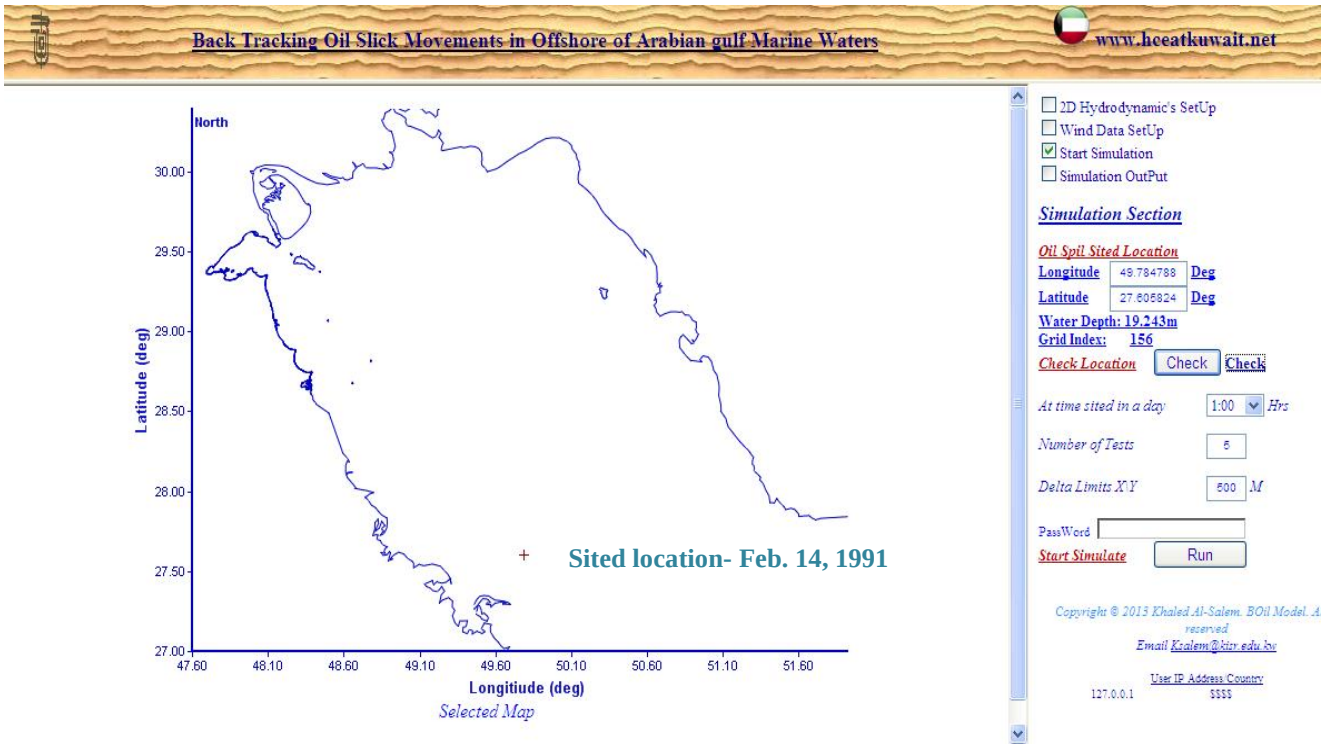

Figure 14. Start Simulation Option and Site Location Selection

Setup Option 4

This option is for simulation output presentation by selected (**Simulate Output**) Figure 15 will display for user to select the following:

- Total time simulated (hours)
- Number of probabilities for source location
- To present the probability of source location on the map by select (**Post probability number**). If user enters 0 is to display all probabilities location for source or user can select any number of the probabilities to post on map.
- After user select (post probabilities number) a table will display for the simulation results.
- User can download the simulation results by select the disk Image as in text file as shown in Table 7.

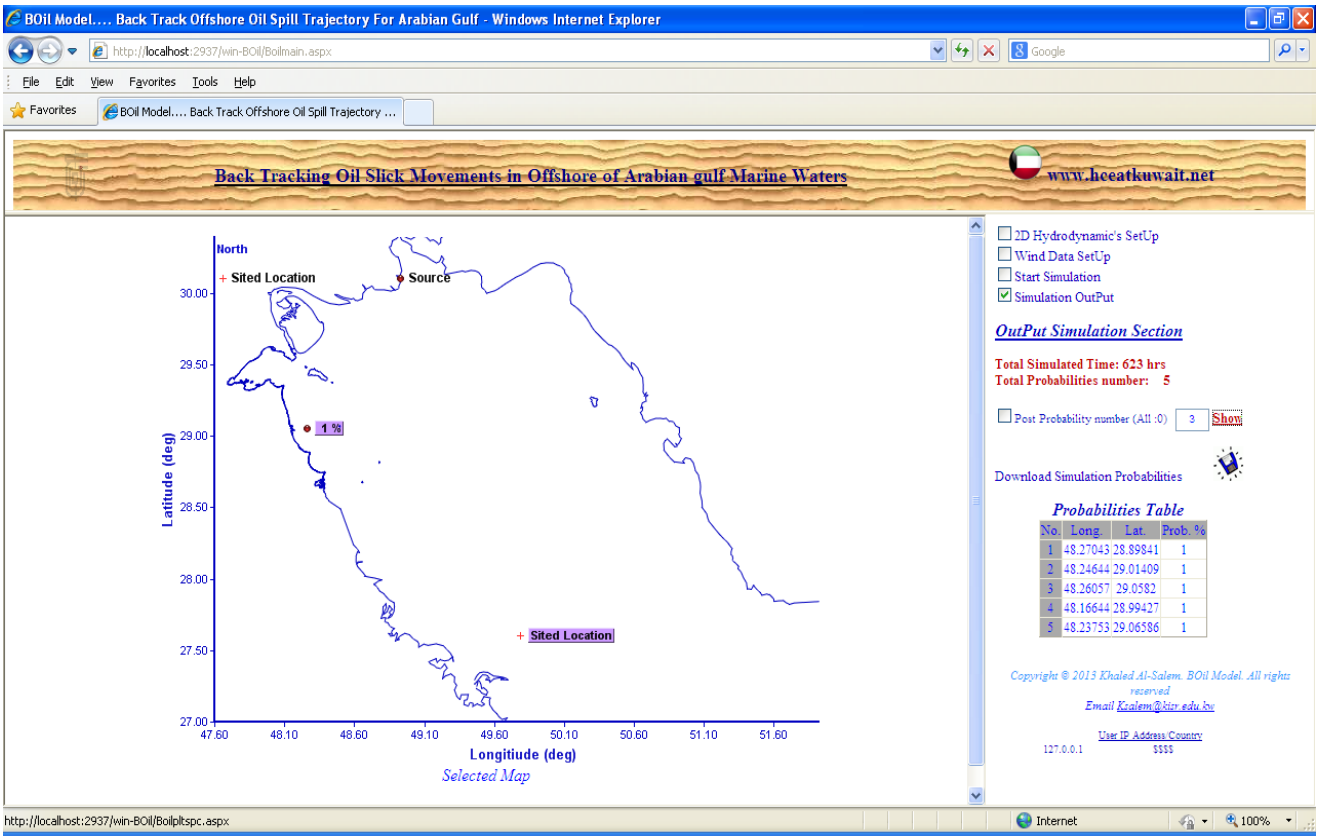

Figure 15. Simulation output Option presentation

Table 7. Model Website downloads Output Simulated File

OFF Shore Back Track Oil Spill In Arabian Gulf Water's (BOIL Model)
==========
---------- Developed By: Khaled Al-Salem (2013)----------
Simulation Results Summary
Oil Spill Sited at Date: 14/ 2/ 1991
Oil Spill Source Date : 19/ 1/ 1991
Total Simulated Time: 623 hrs
Total Simulated Test number:5
Delta x/y : 500m
Oil Spill Sited Location
Longitude: 49.784788deg
Latitude : 27.605824deg
Monte Carlo statistical Probabilities of back Track Oil Spill Location
Total Probabilities: 5

NO--	Longitude(deg)--	Latitude(deg)--	Probabilities(%)
1,	48.2375294892448,	29.0658641764257,	20
2,	48.1664361058232,	28.9942680893899,	20
3,	48.2605722839649,	29.0581979567513,	20
4,	48.2464424324459,	29.0140851440801,	20
5,	48.2704341238931,	28.8984094056705,	20