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College of Science

**Environment and Sustainable
Development Program**



Integration of Efforts to Enhance the Oil Spill Response in the Kingdom of Bahrain

Thesis submitted in partial fulfillment of the requirement for the Degree of M.Sc.
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Abstract

Oil spill can be considered as one of the ecological disasters on marine environment. It has become a global concern because of its adverse effects on marine environment, society and economy. The oil spill incidents that occurred in the Kingdom of Bahrain caused damage to marine environment and threatened the vital coastal facilities along Bahrain's coastlines.

The objectives of the present study are to examine the oil spill management in the Kingdom of Bahrain and determine the exposure level of the coastal facilities to oil spills which eventually strengthen the preparedness and enhance the response to oil spill incidents in Bahrain.

In this study the national legislations, the conventions related oil spill managements, the reports of the oil spill incidents occurred in the last ten years in Bahrain and the correspondent oil spill contingency plans were reviewed and evaluated using a compliance index. To determine the exposure level of the coastal facilities to oil spills, GNOME model was validated and applied to forty hypothetical oil spill scenarios.

The modeling results showed that the coastal facilities in Al-Hidd and Sitra is more probable to be hit by oil spills than other coastal facilities. The coastal facilities in the northern coastlines are vulnerable to receive more quantity of oil than other coastal facilities. However, the time required for oil to reach the northern coastline is longer, compared to the other coastlines. It is recommended to utilize the modeling results to enhance oil spill response, by using them in contingency planning, setting the protection priorities and allocation and mobilization of response resources both in government and private sectors. The review of the national legislations and conventions related to oil spill management revealed a need to update the current national legislations to incorporate the obligations and requirements of the reviewed conventions into the national legislations. The evaluation of the oil spill incidents reports and the oil spill contingency plans showed that the compliance of the coastal facilities to the requirement of the oil spill management was good during 35% of the reviewed incidents reports. Therefore, it is recommended to enhance the available response capabilities and the communication among the competent parties by developing a national communication system to enhance the notification and reporting processes during oil spill incidents.

Dedication

To my beloved mother for her prayers,

To my beloved wife for her patience,

To my little kids,

To my friends and all those who have supported, encouraged and inspired me.

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Table of Content

Subject	Page
Defense Committee's Approval	A
Abstract	B
Dedication	C
Acknowledgement	D
Table of Content	E
List of Tables	G
List of Figures	H
List of Appendices	H
Chapter One Introduction to the Study	
1.1 Introduction	2
1.2 Research Problem	5
1.3 Research Questions	5
1.4 Research Objectives	6
1.5 Research Significance	6
1.6 The study's setting	6
1.7 Research terminology	7
Chapter Two Theoretical Framework and Literature Review	
Theoretical Framework and Literature Review	9
Chapter Three Methods and Procedures	
3.1 Oil Spill Management in Bahrain	30
3.2 Exposure of the Coastal Facilities to oil Spill	37
Chapter Four Results, Discussion and Recommendations	
4.1 Oil Spill Management in Bahrain	44
4.1.1 Results of Reviewing the National Legislations and Signed Conventions	44

4.1.2	Discussion of Reviewing the National Legislations and Signed Conventions	45
4.1.3	Results of Examining the Compliance of the Coastal Facilities with the Requirements of the National Contingency Plan	52
4.1.4	Discussion of Examining the Compliance of the Coastal Facilities with the Requirements of the National Contingency Plan	58
4.2	Quantifying the Exposure Level of the Coastal Facilities to Oil Spills	61
4.2.1	Results of Quantifying the Exposure Level of the Coastal Facilities to Oil Spills	61
4.2.2	Discussion of Quantifying the Exposure Level of the Coastal Facilities to Oil Spills	77
4.3	Conclusion and Recommendations	83
	References	
	Abstract Translated to Arabic	

List of Tables

No.	Subject	Page
1	Examples of Oil Spill Incidents in the Gulf Region 1965 – 2002	11
2	Oil Spill Incidents Occurred in Bahrain 2006 – 2015	14
3	Oil Spill Response Equipment Available in Central Stores	21
4	Summary of the Literature Review	26
5	The Issued Laws and Regulations Related to Oil Spill in Bahrain	33
6	The Conventions Related to Oil Spill that Signed by Bahrain	33
7	Questions Indicating the Attributes of the National Plan Requirements	36
8	The Coastal Facilities within Segment A	38
9	The Coastal Facilities within Segment B	38
10	The Coastal Facilities within Segment C	39
11	The Coastal Facilities within Segment D	39
12	The Coastal Facilities within Segment E	40
13	Evaluation Results for the Availability and Activation of oil Spill Contingency Plan	53
14	Evaluation Results for Notification and Reporting	54
15	Evaluation Results for Response Resources	55
16	Evaluation Results for Response Management	56
17	Evaluation Results for Waste Management	57
18	Data of 2003 Incident which Fed to GNOME Model	61
19	Modeling Result of the Incident Occurred in 2003	62
20	Comparison between the Actual and the Simulated Trajectories	65
21	The Modeling Results of Oil Spill Scenarios which Hit Segment A	66
22	The Modeling Results of Oil Spill Scenarios which Hit Segment B	68
23	The Modeling Results of Oil Spill Scenarios which Hit Segment C	70
24	The Modeling Results of Oil Spill Scenarios which Hit Segment D	72
25	The Modeling Results of Oil Spill Scenarios which Hit Segment E	73
26	Results of the Average Exposure Metrics Obtained from Gnome	74
27	The Compliance of the Coastal Facilities during the Incidents Occurred between 2006 and 2016	78

List of Figures

No.	Subject	Page
1	Organizational Structure of Incident Command System	21
2	Methods and Procedure Utilized to Achieve the Study Objective	31
3	Dividing Bahrain's Shorelines into Five Segments	40
4	Screenshot of the Geodatabase Created by Using ArcGIS	42
5	Compliance Index of the Coastal Facilities with the National Requirements	52
6	The Trajectory of the Oil Slick in 2003 Incident	63
7	The Path of the Oil Slick in 2003 Incident	64
8	Some Oil Spill Scenarios which Hit Segment A	69
9	Some Oil Spill Scenarios which Hit Segment B	69
10	Some Oil Spill Scenarios which Hit Segment C	71
11	Some Oil Spill Scenarios which Hit Segment D	72
12	Some Oil Spill Scenarios which Hit Segment E	74
13	Number of Hits	75
14	Average Time to Hit	76
15	Average Oil Concentration	77

List of Appendices

No.	Subject
1	The Conventions Related to Oil Spill That Signed by Bahrain
2	Articles and the Requirements Related to Oil Spill Managements
3	The Articles in the National Legislations Related to Oil Spill Managements
4	Incorporation of the Conventions in the National Legislations
5	Evaluation Sheet for the Compliance Index
6	Modeling Results
7	Metrological Data for 2016
8	Metrological Data For March and April 2003
9	Maps of Bahrain Navigational Channels and Ships Anchorage

Chapter One

Introduction to the Study

1.1 Introduction

Oil spill can be considered as one of the most severe ecological disasters on marine environment (Liu, 2010). Oil has a destructive nature; therefore, if an area has been contaminated by oil, the characters of the environment in that area is totally changed (Al Malek and Mohamed, 2005). Oil spill has become a global concern because of its immediate and adverse effects on marine environment, it has also potential long-term negative impact on ecosystems and marine habitats (Lee and Jung, 2013). Spilled oil also damages eco-sensitive resources and harbour facilities and causes social and economic losses (Dwarakish et al., 2015). Seabirds are highly vulnerable to the impact of oil spill because of their breeding behavior, foraging and distribution (Troisi et al., 2016). Feathers are important for birds in buoyancy, insulation and flight; small quantity of oil can affect the feathers and lead to loss of bird's buoyancy and insulation and that cause an immediate death by drowning or hypothermia (Fritt-Rasmussen et al., 2016).

When oil deposits on the surface of sensitive plants it causes sublethal impact and death of the marine life that depends on these plants. Mangroves are example of habitats that are highly vulnerable to oil spill, disruption of these habitats could affect their services such as fish production and shoreline protection (Duke, 2016).

Oil spill results in economic losses by disturbing the tourism sector, fishing industry, maritime navigation, ... etc. Tourism sector is extreme sensitive to oil spill, because beaches are considered as an important production factor during holidays (Cirer-Costa, 2015). Therefore, a few tons of oil could cause heavy losses to tourism firms. For example, in July 2007 the merchant vessel (Don Pedro) released 20 tons of oil to the sea and affected 107 hotels and apartment blocks in island of Ibiza (Cirer-Costa, 2015).

Oil spill could cause severe economic impact and damages, including the losses in fishing industry, property losses and expenses of cleaning operations and protection measures.

Kingdom of Bahrain is one of the small island countries in the world consists of 40 islands, with a diverse coastal and marine environment. Oil pollution related to transportation and military actions is considered as one of the major sources of marine pollution in the Kingdom of Bahrain (Zainal et al., 2008). The oil spill incident which occurred in August 1980 in the Kingdom of Bahrain resulted in a severe damage to the fishing industry due to the destruction of fishing equipment and suspension of fishing during the spill and cleanup operations (Linden, 1981). The oil spill incidents occurred in Bahrain during the second Gulf War led to an adverse environmental impact on the fishery. Bahrain's economic losses in 1991 and 1992 were estimated at 3.5 million US dollar (Price et al., 1994). On 15 March 2003, Ministry of Interior in the Kingdom of Bahrain reported an oil spill 20 miles off the north coast of the main island. After two days the oil reached the northern coastline. According to claim submitted by the government of Bahrain to the International Oil Pollution Compensation Funds (IOPC Fund), the preventative measures, cleanup operations, economic losses and property damages had cost the government around 2.7 million US dollar (IOPC Fund, 2004).

During that incident, the General NOAA Operational Modeling Environment (GNOME) was used to simulate the trajectory of the oil slick (PCPMEW, 2003). GNOME is a numerical model Developed by the US National Oceanic and Atmospheric Administration (NOAA) to predict the behavior and the fate of oil slick in marine environment. It has been validated by observation during many oil spill incidents worldwide (Kankara et al., 2016).

To provide a safe, timely, effective and coordinated response to oil spill incidents, Bahrain prepared the National Oil Spill Contingency Plan in February 1993. This plan was updated and approved by the Cabinet of Ministers in the Kingdom Bahrain in August 2013. The plan was integrated with Regional Oil Spill Contingency Plan. It identifies the roles and responsibilities for the concerned authorities in the public and the private sectors. According to the national plan, each coastal facility is required to prepare its local oil spill contingency plan and integrate it with the national plan (SCE, 2013).

Bahrain had issued the Law No.3 of 1975 on Public Health and Legislative Decree No.21 of 1996 with Respect to the Environment which aim in some articles to protect the marine environment from oil pollution, and to develop preventive measures for minimizing marine pollution by oil (Official Gazzete, 1975, Official Gazzete, 1996). Bahrain had also ratified many regional and international conventions related to oil pollution such as Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution, the International Convention on Civil Liability for Oil Pollution Damage, the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), and the International Convention on Oil Pollution Preparedness Response and Cooperation (OPRC Convention) (Official Gazzete, 1995, Official Gazzete, 2005, Official Gazzete, 2010).

Several national authorities and many regional organizations are involved in the management of oil spill incidents in Bahrain such as The Supreme Council for Environment, Coast Guard, Sea Port Affairs, Directorate of Marine Resources, the Regional Organization for the Protection of Marine Environment (ROPME), Marine Emergency Mutual Aid Center (MEMAC), Regional Clean Sea Organization (RECSO),.... etc. (SCE, 2013). The communication and cooperation among these authorities and organizations is highly important to maintain an adequate level of preparedness and response to oil spill incidents. In

addition, exercising the contingency plans through conducting of oil spill exercises helps in strengthening the liaison among the concerned authorities and organization.

1.2 Research Problem

Failure in providing timely and coordinated response to oil spill incidents may lead to adverse impact on the marine environment, society and economy. The oil spill incidents that occurred in the Kingdom of Bahrain in 1980s, 1990s and 2003 caused severe damage to the marine environment and threatened the vital coastal facilities along Bahrain's coastlines such as desalination and power plants, fishing harbors, marinas, palaces and tourist facilities. This was probably due to the lack of timely, effective and coordinated response to these incidents by the concerned authorities in the public and private sectors. In addition, the possible inadequate communication and level of preparedness among these authorities contributed to oil spill damages.

1.3 Research Questions

This research is an attempt to answer the following questions: what are the capabilities currently available in the government sector and the private sector to respond to oil spill incidents? Is the private sector in Bahrain capable to execute its roles assigned to it in the National Oil Spill Contingency Plan? What is the current practice in both sectors to respond to oil spill incidents? What are the measures required to enhance the response to oil spill in the two sectors? What are the necessary arrangements required to integrate the efforts of government sector and private sector?

1.4 Research Objectives

The objectives of this research are:

1. To examine the oil spill management in the Kingdom of Bahrain and the adequacy of the communication and coordination among the concerned parties in the government sector and the private sectors by utilizing the available resources.
2. To determine the exposure level of the coastal facilities to oil spills by using the General NOAA Operational Modeling Environment (GNOME) model and Geographical Information System (GIS).

1.5 Research Significance

Many studies have been conducted to investigate the impact of the oil spill incidents occurred in the Arabian Gulf and Kingdom of Bahrain on the marine environment and its organisms (Brown and James, 1985, Lehr and Belen, 1983, Linden, 1981, Massoud et al., 1998, Michel, 2011). However, enhancing the response to oil spill incidents in the Kingdom of Bahrain has not been tackled before. Therefore, this study examines the oil spill management and determines the exposure level of Bahrain's coastlines to oil spills. The modeling results and the exposure maps produced in this study will aid in oil spill contingency planning, setting the protection priorities, allocation of response resources, and mobilization of response equipment which eventually enhance the oil response in the Kingdom of Bahrain.

1.6 Study Setting:

The national laws and orders are available on the official website of the legal affairs, the regional and international conventions, the reports of the oil spill incidents occurred in the Kingdom of Bahrain in the last ten years and the correspondent oil spill contingency plans were investigated and evaluated to examine the oil spill management in the Kingdom of Bahrain.

The General NOAA Operational Modeling Environment (GNOME) is an oil spill model had been developed by NOAA to simulate the trajectory and the fate of oil spills. This model was used in this study to predict the trajectory and fate of oil during the proposed scenarios. Geographical Information System (GIS) is a useful system used to store, manage and present spatial data. Arc GIS is one of the GIS applications, it is was utilized in this study to determine and present the exposure level of the coastal areas and facilities to oil spill.

1.7 Research terminology

Oil spill means the accidental released of liquid hydrocarbons such as petroleum products or crude oil to the environment (Gundlach, 2014).

Oil spill response is defined as any action or measure that is taken before, during or after oil spill incidents, to prevent, monitor or combat pollution by oil (Sydnes and Sydnes, 2013).

Oil Spill weathering is defined as the processes that occur after oil spill and cause changes in the chemical and physical properties of the spilt oil. Examples of these processes are evaporation, natural dispersion, emulsification and dissolution (Fingas, 2010, Parker, 2008).

Oil Spill Modeling is a technique used to simulate the weathering processes, trajectory and fate of the spilled oil. Oil Spill Modeling also assists in determining the age and possible source of the spilled oil by reversing trajectory forecast models (Wang and Stout, 2010).

ROPME Sea Area is defined according to the Kuwait Regional Convention as the sea area that is surrounded by the coastlines of the eight ROPME's member states. It includes the Arabian Gulf and the Gulf of Oman (ROPME, 2016, Richardson, 2011).

Chapter Two

Theoretical Framework and Literature Review

Over the past forty years many large spills of oil in the marine environment from different sources have been recorded and resulted in disastrous impact on the environment. The Exxon Valdez oil spill took place on March 24, 1989, resulted in a spillage of 10.8 million gallons of crude oil into the Gulf of Alaska (Leacock, 2009). It caused massive acute effects on aquatic organisms and their communities such as bald eagles, sea otters and sea birds (Rice et al., 2007).

Another massive oil spill occurred on November 13th, 2002 when the tanker Prestige suffered a severe structural failure in its cargo tanks and released more than 60,000 ton of oil near the Spanish coastline (Albaigés et al., 2006). Several studies (Loureiro et al., 2009, García Negro et al., 2009) demonstrated the environmental impact and estimated the economic losses of Prestige oil spill.

Deep Horizon oil spill is considered as the largest offshore spill in the history, it occurred on April 20, 2010 and resulted in a spillage of nearly five million barrels of crude oil (Farrow et al., 2016). The impact of this incident on the marine environment was summarized by Beyer et al. (2016) and Dietrich et al. (2014).

The Arabian Gulf Sea suffered from many oil spill incidents that resulted in massive environmental impact. In the last 35 years, more than 140 medium to major oil spill incidents occurred in the Arabian Gulf (Elhakeem et al., 2007). Hasba oil spill incident occurred when the exploratory well Ron Tapmeyer blew out on October, 2nd 1980 and released an estimated quantity of 50,000 barrels of thick crude oil into the Arabian Gulf. By November 8 the oil reached Qatar and polluted around 70 miles of its northern and western coastline. When oil reached Qatar coastline it was emulsified and that made the cleaning operation difficult (Lehr and Belen, 1983).

The other massive oil spill incident in the Arabian Gulf was the Nowruz oil spill, which occurred on February, 4th 1983 during the Iraq-Iran war. Nowruz field is an Iranian off-shore oil field, about 270 km north of Al-Jubail. The total quantity of the released crude oil to the environment is unknown. However, the crude oil flowed for several months with an estimated rate of 4000 barrels per day (Fayad, 1986). The Nowruz oil spill resulted in severe biological impact, 31 of 50 individuals of Dugongs were found killed on the Saudi shorelines. More than 100 sea turtles, many Sea Snakes, hundreds of birds and many thousands of other species have been found dead after this disaster (Amirah, 1983).

The largest oil spill incident in the Arabian Gulf history occurred on January, 23rd 1991 during the Gulf War, about 11 million barrels of crude oil intentionally released into the Arabian Gulf, about 1.16 million barrels of oil were recovered from the surface water (Michel, 2011). The oil was released from different sources including the sunken ships in the war zone and the export terminal in Kuwait. This spill is 30 times larger than the Exxon Valdez disaster (Proctor et al., 1994). According to MEMAC (2003), since 1965 until 2002 more than 140 oil spill incidents occurred in the Arabian Gulf. Table 1 shows examples of these incidents.

Table (1)
Examples of Oil Spill Incidents which Occurred in the Arabian Gulf
Region 1965 – 2002 (MEMAC, 2003)

No.	Source	Name	Date	Location	Quantity (US Gallons)
1	Ship (Japanese)	Kaizo Maru	30/10/1965	Long 28 31.48 N Lat 48 34.18 E	Unknown
2	Ship (KSA)	Hejaz	15/04/1967	Long 26 06. 24 N Lat 050 46.24 E	Unknown
3	Ship	Sea Star	19/12/1972	Gulf of Oman	Unknown
4	Storage Tanks	Shuaibah Refinery	20/08/1981	Kuwait	31,175,660
5	Ship (Greece)	Assimi	11/01/1982	Oman	15,440,775
6	Oil Field	Nowruz	04/02/1983	Iran	85,882,352
7	Ship (Liberia)	Prim Rose	26/05/1987	Kuwait	735,275
8	Ship (Panama)	Texaco Caribbean)	08/10/1987	Fujairah	2,283,470
9	Ship (Britain)	Gas Enterprise	13/04/1989	Kuwait	73,528
10	Ship (Liberia)	Tropical Lion	25/04/1989	Abu Dabi	420,168
11	Export Terminal	Mina AlAhmadi	--/01/1991	Kuwait	25,210,084
12	Export Terminal	Mina Al-Baker	02/02/1991	Iraq	29,411,764
13	Ship (Iran)	Tabriz	12/07/1998	Bander Abbas Iran	29,411
14	Ship (Georgia)	Zainab	08/09/2000	26 50N, 052 53E	411,600
15	Ship (Honduras)	Doaa	13/07/2002	29 14N 049 19E	323,529

In the Kingdom of Bahrain oil pollution is one of the stressor on the coastal and marine environment. There are many sources of potential oil spills in the Kingdom of Bahrain including oil tankers, offshore oil well, oil terminals and underwater pipelines. Minor oil spills occur frequently in territorial waters of the Kingdom of Bahrain and there is a potential risk of large oil spills in ports and oil terminals (Naser, 2011).

Other oil spill incidents occurred in the Kingdom of Bahrain due to industrial activities, transportation and military actions in 1983, 1991 and 2003 (Zainal et al., 2008). On 25th August, 1980 Bahraini fishermen and residents notified the authorities about large quantities of oil in sea; the investigation carried out by Bahrain Petroleum Company (BAPCO) showed that approximately 20,000 bbl of crude oil were spilled into the sea from unidentified source (Brown and James, 1985). The oil had reached the coast of Bahrain from the north and northwest, deposited in the upper tidal zone and penetrated into the sand to around 1.5 feet. Because of the weathering processes, oil emulsified and accumulated in sand and other materials and became heavy enough to sink into the seabed (Lehr and Belen, 1983). On 25th September 1980, a mission from the United Nations visited Bahrain to study the impact of the oil slick and gave advice. According to the study, the oil slick caused the death of several hundred birds and total kill of beach fleas and crabs (Lehr and Belen, 1983). The study also concluded that the major biological impact of the oil spill was the mortality of marine life due to the smothering of organisms by oil. The oil spill resulted in a severe damage to the fishing industry due to suspension of fishing during the spill and the destruction of fishing equipment (Linden, 1981).

During the Gulf War II, the oil released in the marine environment caused an adverse impact on the fishing industry in Bahrain and caused a severe detriment to the marine life, including water fowl, coral reefs, shrimp beds and numerous fish species (Metz, 1994). Due to the environmental impact of the oil spill on the fishery, Bahrain's economic losses in 1991 – 1992 only were estimated at 3.5 million US dollar (Price et al., 1994).

On 23rd November 1993, around 4000bbl of light Arabian crude oil was released into the sea from one of the two under-sea crude oil pipelines between Bahrain and Saudi Arabia. The spill occurred when a piling barge struck and damage the pipeline; the crude oil was released, reached the sensitive beach and caused a serious damage. The oil spill contingency plan of Bahrain Petroleum Company (BAPCO) was activated to respond to the incident; the response which was taken by BAPCO in cooperation with the governmental authorities continued for 10 days and resulted in the total clean-up of the damaged beach (Brown, 1995).

On 15th March 2003, an oil spill incident was reported, oil slicks were noted in the north of the Kingdom of Bahrain, 20 miles off the coast. An estimated 100 tons of oil reached Bahrain's coast and polluted around 18 kilometers of shoreline. On March 18 the slick reached the north coast of the kingdom and after three days oil covered the west and east coasts of Muharraq Island causing damage to fishing vessels and gear. According to claim submitted by the government of Bahrain to the International Oil Pollution Compensation Funds, the preventative measures and cleanup operations had cost the government around 1.1 million U.S. dollar, 434 fishermen suffered economic losses and property damage estimated 1.6 million U.S. dollar. The estimated cost to protect

the water intakes of two desalination plants was 283,000 U.S. dollar (IOPC Fund, 2004). Over the last 10 years, Bahrain faced twenty three minor oil spill incidents in different locations. Table 2 shows the minor incidents occurred in the Kingdom of Bahrain.

Table (2)
Oil Spill Incidents Occurred in Bahrain 2006 – 2015 (SCE, 2016)

Year	No. of Incidents	Location	Spill Mount (liter)	Covered Area (m ²)
2006	3	ASRY Ship Yard -	Not estimated	-
		Near Financial Harbor (2)	-	225
2007	1	King Fahad Causeway	Not estimated	-
2008	1	King Fahad Causeway	Not estimated	-
2009	2	Manama Fishing Harbor	-	10
		Asker	Not estimated	-
2010	5	BAPCO Wharf	-	150
		Arad Bay	-	10
		Royal Marina	1000	-
		AWALCO	-	45
		Manama Fishing Harbor	20	-
2011	2	Muharraq Coast Guard Base	Not estimated	-
		UCO Engineering	-	12
2012	4	AWAL Company (2)	5 liters	-
		Mina Salman	Not estimated	-
		Reef Islands	Not estimated	-
2013	1	Sitra Fishing Harbor	3 liters	-
2014	2	BAPCO Pipe lines - Maameer	320	-
		Hidd Industrial Area	-	240
2015	2	Sitra Fishing Harbor	-	10000
		East Sitra Housing Project	160	-

Oil causes serious damage to the marine environment and its organisms like fish, plankton, marine mammals, reptiles, sea birds, coral reefs, seagrass, mangroves and saltmarshes. It causes also severe impact on the fishing and mariculture industries by contaminating fish stock, fishing equipment and disrupting fishing and business activities. The severity of the impact can be determined by many factors like the type and the quantity of oil, weather conditions and the sensitivity of the impacted organisms to the oil (ITOPF, 2011a, ITOPF, 2011b). According to IOPC Fund (2004) during 2003, oil spill in Bahrain 434 fishermen suffered economic losses and property damage estimated at US\$ 1.6 million. Cleaning-up and restoration cost is another factor to determine the economic impact of oil spill. According to Garza-Gil et al. (2006) during the Prestige incident the estimated cost for cleaning-up and restoration of 1000 kilometers of Galician coast was 559 million Euros while the cost of tourism loss was 133.8 million Euros. On the social side, oil spill incidents adversely affect communities, the impact of oil on sea water, fisheries and aquatic life leads the coastal residents to change their behavior in seafood consumption.

A survey had been conducted over three years (2012-2015) in southeast Louisiana, showed that the consumption of local seafood decreased by 50% during Deep Water Horizon Oil Spill (Simon-Friedt et al., 2016). When oil reaches the water intakes of the desalination plants, they must be shutdown to prevent the contamination of the produced water, and to avoid the damage of the equipment used in the plant. Suspending water production for long period may cause adverse impact on the community (Al Malek and Mohamed, 2005). Oil spill could cause other social and community impacts by affecting the recreational

facilities, aquarium, agriculture, marinas, fishing harbours, heritage sites and cultural artefacts (ITOPF, 2011c).

Oil spill management is essential for improving the response to oil spill incidents. It includes the actions and measures that are taken to strengthen preparedness and enhance the response to oil spill. It covers but not limited to preparing national oil spill contingency plan and industry oil pollution contingency plans, establishing national response management system, coordination of oil spill response resources, drawing vulnerability and sensitivity maps, issuing national legislations and regulations and signing international conventions (IMO, 1995).

In many countries, the government sector and private sector share the oil spill management, for example the Danish Defense Command is the responsible authority for pollution control in Danish water, but it can arrange to involve the private parties and use their own assets and equipment during oil pollution combat situation (Christensen and Carpenter, 2016). In Canada, the oil spill management was developed based on public-private sectors partnership, regulations in Canada require the private parties to maintain the minimum level of capabilities to respond to oil spill incidents (Kanjilal, 2015).

In the Kingdom of Bahrain, the private coastal and offshore facilities are required to prepare oil spill contingency plans, and to maintain the minimum equipment and resources to respond to minor oil spill incidents occur in their facilities, the president of SCE is authorized to use the assets available in the private facilities during responding to oil major oil spill incidents (SCE, 2013). However, countries face some difficulties and challenges in involvement of the private sector into the oil spill management such as defining the responsibilities of the private

sector during incidents, the availability of sufficient personnel and response resources in the private sector (Knol and Arbo, 2014).

To increase the preparedness and to ensure a timely and effective response an integrated system of contingency planning must be established and maintained regularly. The main purpose of contingency plans is to coordinate all aspects related to the oil spill response (Fingas, 2010). Kingdom of Bahrain has adopted the national oil spill contingency plan that aims to protect the marine environment by providing a safe, timely, effective and coordinated response to oil spills incidents. Several governmental organizations are involved in this plan such as Bahrain Coast Guard, Ports and Maritime Navigation Affairs, Ministry of Information, Civil Defense, Public Security and Bahrain Petroleum Company (BAPCO), the plan identifies the roles and responsibilities of each concerned authority (Zainal et al., 2008). The National Plan is integrated with the ROPME Oil Spill Contingency Plan that aims to ensure an integrated and coordinated response to oil pollution incidents at the regional level (MEMAC, 2010). According to Bahrain National Contingency Plan for Combating Pollution by Oil and Other Harmful Substances, each coastal facility either in the governmental sector or the private sector, is required to prepare its local oil spill contingency plan to respond to Tier 1 oil spill incidents, these plans must be integrated with Bahrain National Plan. Many ports and coastal facilities in Kingdom of Bahrain such as Khalifa Bin Salman Port, BAPCO and ASRY have their own oil spill contingency plans which have been reviewed and approved by the Supreme Council for Environment.

Sensitivity maps and oil spill modeling are important elements in oil spill contingency plans. The aim of drawing sensitivity maps is to identify the potentially threaten sensitive areas and setting the protection

priorities. The planners may develop the potential oil spill scenarios and apply oil spill models to these scenarios to expect the trajectory and fate of the oil and the natural resources which could be effected by the oil (Zafirakou et al., 2015, IPIECA, 2015).

Determining exposure level to oil spill aids in determining the vulnerability and producing the sensitivity maps, different pollution metrics are used in determining the exposure level to oil spill such as oil beaching time, the average volume of oiling expected to reach beach coastlines and the probability of oiling per beach segment. The metrics can be determined by applying oil spill models to different oil spill scenarios (Al Shami et al., 2017). Several oil spill models have been developed in the last four decades (Simecek-Beatty and J. Lehr, 2007), many of them were applied during oil spill incidents in different areas. Some of these model are used in researches and studies to simulate the trajectory of oil slicks. OILMAP model was used to simulate oil spill in different countries such as Egypt (Donia, 2010), Turkey (Kabdasli et al., 2010) and China (Wang and Ye, 2011).

EUROSLPILL is another model which used in many studies in Europe to expect the fate of oil and the trajectory of spills (Walker et al., 2005, Leech et al., 2005).

The General NOAA Operational Modeling Environment (GNOME) model is the most popular model which was used in many studies and different areas in the world (Başar, 2010, Remyalekshmi and Hegde, 2013). It had been developed by NOAA to simulate the trajectory and the fate of oil spills. When the model fed with the required data such as weather conditions, the type and quantity oil, etc. it calculates the best guess of the spill's trajectory (Agustin et al., 2015). It was applied by

many researchers in different area such as Istanbul (Başar, 2010) and India (Remyalekshmi and Hegde, 2013). Experiments showed that GNOME gives better expectation than other models like OILMAP and EUROSPILL models (Lopes et. al, 2006).

Within the Arabian Gulf, GNOME was applied by (Farzingohar et al., 2011) to simulate different scenarios of oil spill from ships in Rajaei Port located on the eastern coast of the Arabian Gulf near the Hormuz Strait. That study showed that GNOME is a useful tool to identify the areas at potential risk and the factors that effecting the fate of oil such as time, oil type, wind and current. GNOME was also applied by Zhao et al. (2015) to track oil slicks detected by satellites in April 2014 near Al-Khafji and in May 2014 near Al-Fujairah. The simulation results from GNOME were compared with the images received from MODIS and VIIRS satellites for the first 48 hours. According to this study, GNOME correctly predicted the direction of the slicks and the prediction was consistent with satellites images, but there was small variation in term of the slicks velocity, this is perhaps due ignoring the weathering factor by the authors. MEMAC worked with NOAA to develop a trajectory model for the Arabian Gulf region. MEMAC recommends the states in the Arabian Gulf to use NOAA model (GNOME) in simulation the trajectory of oil spills and in the incident investigation (MEMAC, 2010). During the oil spill incident occurred in 2003, the Kingdom of Bahrain used GNOME model to simulate the trajectory and fate of oil (PCPMEW, 2003). Another element of oil spill management is the coordination of oil spill response resources. Industry which represents the private sector may provide and maintain the necessary oil spill response equipment and resources to respond to small scale oil spill incident. However, in large scale incidents, the response organizations and possibly governments

must ensure the availability of oil spill response equipment and resources by adopting adequate arrangements and pre-established mechanisms (IMO, 1995).

According to the National Contingency Plan for Combating Pollution by Oil and Other Harmful Substances, all industries that may cause or suffer oil pollution must provide the necessary equipment and resources to respond effectively to Tier 1 oil spill incidents within or around their facilities, the equipment must be maintained regularly and made ready to use during emergency.

Kingdom of Bahrain owns a national stockpile of oil spill response equipment described in Table 3 that is stored in the Central Stores in Sitra. The equipment is regularly maintained and made ready to use in Tier1 and Tier2 oil spill incidents. The National Oil Spill Contingency Plan gives the authority for the president of the Supreme Council for Environment to request assistance, equipment or oil spill response resources from any authority or industry. Therefore, during emergency all equipment and response resources in Kingdom of Bahrain will be made available under the request of the president of SCE (SCE, 2013).

Establishing a national oil spill response management system is essential element that aids in integration of the response resources, operational processes and personnel available in the government and industry. Flexible and robust response system helps in providing the most effective response (IMO, 1995). Kingdom of Bahrain utilizes Incident Command System (ICS) as a management system to respond to oil spill incidents, this system is used to coordinate the response operations from different ministries and organizations such as the SCE, Coast Guard, Civil Defense, Ports and Maritime Navigation Affairs and Ministry of

Works, Municipalities and Urban Planning (SCE, 2013). Figure 1 describes the organizational structure of Incident Command System.

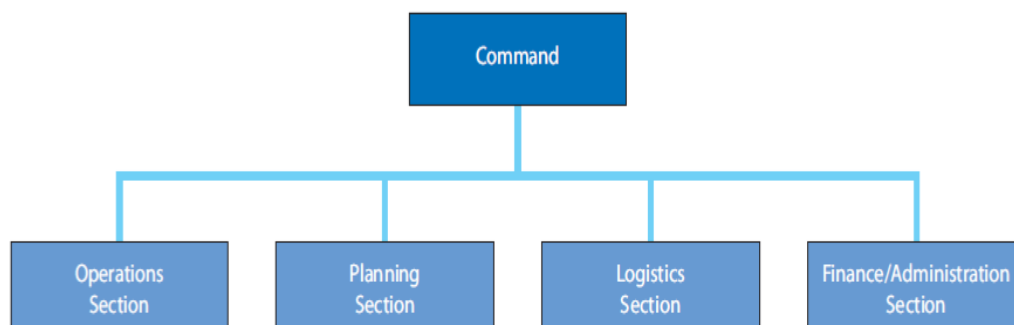


Figure (1)
Organizational Structure of Incident Command System (SCE, 2013).

Table (3)
Oil Spill Response Equipment Available in Central Stores (SCE, 2013)

#	Equipment	Total Quantity (Pcs)
1	Desmi Power Pack	4
2	Desmi Skimmer	3
3	Desmi Skimmer Floating Unit	3
4	Desmi Hydrualic Hose Reels	4
5	Generator AIRMAN Batery Opreated	4
6	German Power Pack	4
7	German Skimmer	2
8	Oil Booms 20 Meter Long	
	Type A1	101
	Type C1	20
9	Oil Booms 15 Meter Long	
	Type A	130
	Type B	31
	Type C	25
	Type D	2
10	Shovels-long 227 pcs+ small 180 pcs	407
11	Rakes - Garden used Big and Small	91
12	Cleaning Mop	65
13	Oil Catchers - supper attach (50x50x4cm)	120
14	Oil Catchers - neo arrack acc(50x50)	61

15	Oil Catchers - mitsui (65x65x0.4cm)	63
16	Anchors - Large - 200 Kg	2
17	Anchors - Medium - 100 Kg	2
18	Anchors - Small	16
19	Joemith Hyogo Anchors	3
20	Rope - 200 meter	1
21	Spare discharge hose (rolled)	1
22	Floaters - Small	44
23	Floaters - Large	8
24	Floaters - Big size	15
25	E.P.C - 18 meters	24
26	Hydraulic Black Rubber hose	1
27	Oil Boom Big Size 5 meters	1

Issuing national legislations and signing international conventions is a part of oil spill management. Kingdom of Bahrain has issued laws to prevent pollution from oil, as an earlier effort, Law No.3 on Public Health was issued in 1975, according to article No. 63 of this law (amended by Legislative decree no.16 of 1993) it is prohibited to discharge oil or any other substance containing oil from a ship or any land-based sources into Bahraini territorial water (Official Gazzete, 1975). Kingdom of Bahrain has also issued Legislative Decree No.21 of 1996 with respect to the environment which requests the Public Commission for the Protection of Marine Resources, Environment and Wildlife (the old name of the Supreme Council for Environment) to coordinate and cooperate with the relevant authorities to develop preventive measures for minimizing marine pollution by oil and other harmful substances. The council in cooperation with the competent parties shall develop and train employees to prepare plans for combating these types of pollution (Official Gazzete, 1996).

In addition to issuing the national legislations, Kingdom of Bahrain has signed many regional and national conventions as a part of oil spill management and to enhance the preparedness and response to oil spill incidents. In April 1978 Kingdom of Bahrain signed the Protocol Concerning Regional Cooperation in Combating Pollution by oil HNS in Cases of Emergency as a part of the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution. The protocol aims to ensure effective and cooperative preventive and response measures by the contracting states to marine pollution resulting from spillage of oil and hazardous and noxious substances (Official Gazzete, 1978). Kingdom of Bahrain had also joined the International Convention on Civil Liability for Oil Pollution Damage (CLC) through the legislative decree No.13 of 1995 which issued in August 1995 (Official Gazzete, 1995). This convention aims to ensure that the persons who suffer damage by oil pollution caused by oil ships will get adequate compensation. As per the regulations of this convention the International Oil Pollution Compensation Fund was liable to pay 1.4 million U.S dollars to the Kingdom of Bahrain as a compensation for the damages caused by the oil spill incidents that occurred in 2003.

To enhance the preparedness to response to oil spill incidents, Kingdom of Bahrain joined the International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC) through the Law No.4 of 2010 which issued in February 2010 (Official Gazzete, 2010) The convention aims to minimize the consequences of the marine pollution incidents by oil, through encouraging the states to build their national capacity to respond for oil pollution. Parties to the convention are obligated to develop the proper measures for dealing with marine pollution by oil through preparing a national contingency plan, providing

the necessary equipment, conduct exercise programs and establishing a coordination mechanism, ships must carry oil spill emergency plans and they have to report any oil incidents to coastal authorities (IMO, 1991). To prevent oil pollution from ships, Kingdom of Bahrain signed in August 2005 the first annex of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) (Official Gazzete, 2005). The convention aims to preserve marine environment by preventing pollution caused by ships from accidental or operational causes. The first annex of the convention sets regulations for the prevention of pollution by oil (Dotinga and Kwiatkowska, 2001).

The above literature review can be summarized as follows; the review was divided into two themes, the first theme presented a historical background on oil spill incidents, while the second theme focused on oil spill incidents management. The historical background highlighted some oil spill incidents occurred in different places in the world such as Exxon Valdez oil spill in Alaska, Prestige oil spill in Spain and Deep Horizon oil spill in the Gulf of Mexico. It also presented the massive oil spill incidents that took place in the Arabian Gulf, like Hasba oil spill in 1980, Nowruz oil spill in 1983 and the oil spill incidents occurred during the Gulf War in 1991. The oil spill incidents occurred in 1980, 1991, 1993 and 2003 in the Kingdom of Bahrain were also presented. The environmental, social and economic impacts of oil spills were summarized in this section.

The main elements of oil spill incidents management were outlined in the second theme. The role of the private sector in the oil spill management and the challenges of its involvement in the oil spill management were highlighted. More emphasis was given to oil spill contingency planning and its tools; oil spill modeling and sensitivity

mapping. An overview about the National Oil Spill Contingency Plan and the Industries Oil Pollution Plans was given in this section. The National oil spill response management system is another part of oil spill management; it was covered in the literature review with a brief description to the response management system that is utilized in the Kingdom of Bahrain. Other elements such as coordination of oil spill response resources and issuing national legislations and regulations and signing international conventions was also summarized in the literature review focusing on the conventions signed and the national legislations issued in the Kingdom of Bahrain. Table 4 summarizes the literature review of this study.

Table (4)
Summary of the Literature Review

Subjects	Author (s)	Findings	Comments
Environmental, Social and Economic Impact of Oil Spill	Simon-Friedt et al., 2016 Beyer et al., 2016 Dietrich et al., 2014 ITOPF, 2011 Al Malek and Mohamed, 2005	Oil spill incidents cause destructive damage on marine environment, they also cause adverse impact on economy and society. Tourist coastal facilities and many industries like fishing industry are severely impacted during oil spill incidents. Deep Horizon oil spill is a recent example which shows the massive impact of oil spills on economy, environment and society.	Most of the literature and researches focused on environmental impact of oil spill incidents. Less studies were conducted on the social and economic impacts of oil spill incidents.
Oil Spill Incidents Occurred in the Arabian Gulf	Michel, 2011 Elhakeem et al., 2007 MEMAC, 2003 Proctor et al., 1994 Amirah, 1983 Lehr and Belen, 1983	More than one hundred and forty oil spill incidents occurred in the Arabian Gulf region, the largest incident occurred during the Gulf War in 1991. Nowruz oil spill is another massive incident occurred in the Gulf Region in 1983. Marine environment had severely impacted by these incidents.	Despite the sensitivity of the coastal marine environment of the Arabian Gulf, and the massive oil spill incidents that occurred in the region, few studies were conducted in the region compared to the number of studies conducted in other regions. The incidents were not documented probably and related data and information is missing.
Oil Spill Incidents Occurred in the Kingdom of Bahrain	Naser, 2011 Zainal et al., 2008	Oil pollution is one of the stressors on the coastal and marine	Although Kingdom of Bahrain suffered from many oil spill incidents, the subject

		environment in Bahrain. Oil tankers, under water pipeline, offshore oil wells and oil terminals are sources of oil spill in Bahrain. Many oil spill incident occurred in Bahrain due to industrial activities, transportation and military actions.	was not studied intensively. No studies were conducted to review the oil spill management and the response system Bahrain. No researches about the oil spill incident which occurred in 2003 in Bahrain were found.
Oil Spill Contingency Plans	Fingas, 2010 MEMAC, 2010 Zainal et al., 2008	The main purpose of oil spill contingency plans is to coordinate all aspects related to the oil spill response. Bahrain has adopted the national oil spill contingency plan that aims to protect the marine environment by providing a safe, timely, effective and coordinated response to oil spills incidents	National oil spill contingency plan, and oil spill plans for many coastal facilities were prepared in Kingdom of Bahrain. However, no studies were conducted to review the efficiency of these plans and whether these plan are activated during the incidents occurred in Bahrain.
Coordination of Response Resources	SCE, 2013 Christensen, 2016 IMO, 1995 Kanjilal, 2015	Coordination of response resources is important in the management of oil spill. Industry is requested to provide resources to response to small scale incidents, while government must ensure the availability of the response resources during the large scale incident.	Although this point is highlighted in Bahrain National Contingency Plan, researches are needed to explore the availability of the response resources and the level of the coordination of response resources in Bahrain.
Oil Spill Modeling	Agustin et al., 2015	Several oil spill models have been	Although GNOME model was validated

	Remyalekshmi and Hegde, 2013 Yang et al., (2013) Başar, 2010	developed such as GNOME, ADIOS, EUROSPIII and OILMAP. GNOME model is the most popular model which was applied in many regions and validated in by many researches.	by different studies in the Arabian Gulf Region and other regions, it was not validated in Bahrain territorial water.
Vulnerability and Sensitivity Mapping	Zafirakou et al., 2015 IPIECA, 2015	Vulnerability and sensitivity mapping is an important tool in oil spill management, it is used to identify the coastal and marine sensitive areas at risk. Planners use sensitivity maps to set the protection priority. Oil spill modeling helps in producing the sensitivity maps.	The sensitivity maps for oil spill are not available in Bahrain. Therefore, preparing the sensitivity maps is highly important to set the protection priorities for the coastal facilities and the protected areas along Bahrain's coastline.
Exposure to Oil Spill Incidents	Al Shami et al., 2017	To determine the level of exposure to oil spill, three metrics were used, the first metric is oil beaching time, the second one is the average volume of oiling expected to reach beaches and the probability of oiling per beach segment.	Determining the exposure level of the coastal facilities to oil spill will be an important achievement, this will aid in setting the protection, preparing contingency plans, allocation and mobilization of the response resources which eventually enhance the oil spill response in the Kingdom of Bahrain.

Chapter Three

Methods and Procedures

The purpose of this chapter is to explain the research methods, tools and procedure used to achieve the objectives of this study. This chapter was divided into two sections, the first section includes the procedure used to examine the oil spill management in the Kingdom of Bahrain and the second section explains the method and tools used to determine the exposure level of the coastal facilities to oil Spills. Figure 2 describes briefly the procedure and the methods utilized to achieve the objectives of this study.

3.1 Oil Spill Management in Bahrain

To achieve the first objective of this study, the oil spill management in the Kingdom of Bahrain was examined from different aspects, such as issuing of national legislations, signing the regional and international conventions, preparing contingency plans and coordination of response resources. To do this the following documents were reviewed:

- The issued national laws and regulations related to oil spill.
- The related regional and international conventions that were signed by Kingdom of Bahrain.
- The National Contingency plan for Combating Pollution by Oil and Other Harmful Substances.
- The oil spill contingency plans of the coastal facilities in which oil spill incidents occurred in the last 10 years.
- The reports of the oil spill incidents occurred in the last 10 years.
- The list and the maps of the coastal facilities including the governmental, industrial and tourist facilities.

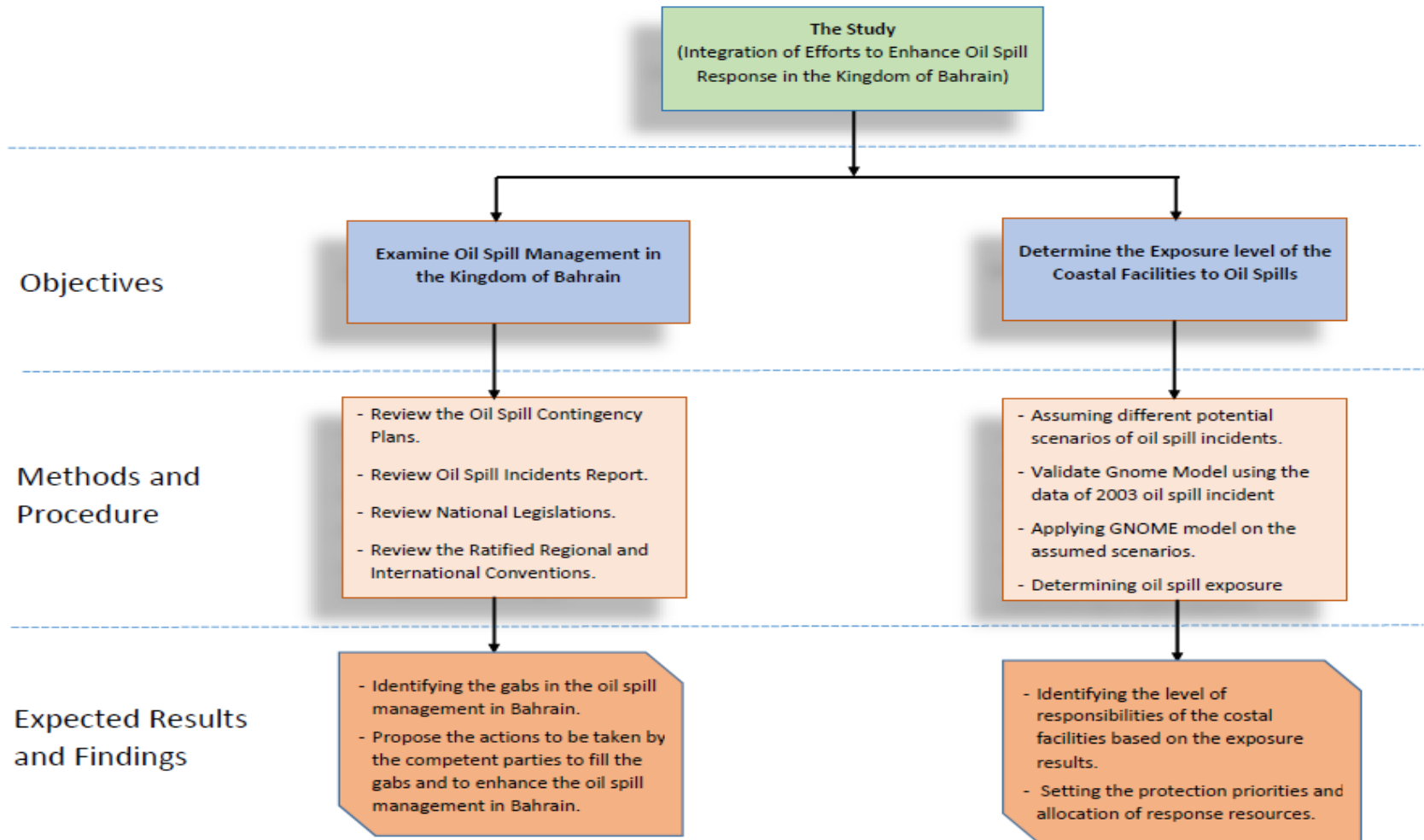


Figure 2
Methods and Procedure Utilized to Achieve the Study Objective

The National Contingency plan for Combating Pollution by Oil and Other Harmful Substances, the local oil spill contingency plans of the coastal facilities and the reports of the oil spill incidents that occurred in the last 10 years were obtained from the Supreme Council for Environment. The list and the maps of the costal facilities were obtained from the Ministry of Works, Municipalities and Urban Planning. The related national laws and regulations were downloaded from the official website of the Legislation and Legal Opinion Commission. The list of the related regional and international conventions ratified by the Kingdom of Bahrain were downloaded from the official websites of MEMAC and IMO respectively. The national laws and resolutions mentioned in Table 5 were reviewed to assess whether these laws properly cover the management of oil spill or further legislations are required in the kingdom of Bahrain. This was achieved by investigating if the current legislations consider the matters related to oil spill such as the responsibility of provision the response resources, claim and compensation, sanctions and penalties. The current legislations related to oil spill were also reviewed to assess whether they fulfill the requirements and obligations of the ratified conventions related to oil spill or further legislations are required to comply with these requirements. The lists of the regional and international conventions related to oil spill will be compared with the list of the ratified conventions shown in Table 6. This can help in investigating whether all the conventions related to oil spill management were ratified by the Kingdom or there are some conventions to be singed to enhance the oil spill management in Bahrain.

Table (5)
The Issued Laws and Regulations Related to Oil Spill in Bahrain

No.	Laws/Regulations	Issuing Date	Related Articles
1	Law No.3/1975 on Public Health	1 st February 1975	63, 64 and 70
2	Legislative Decree No.21/1996 with Respect to Environment	13 June 1996	4 and 29
3	Law No. 61/2006 issuing the Law of the General Institution for Marine Ports.	4 th September 2006	4
4	Ministerial Resolution No.6/2010 on Implementation of Law No.61/2006.	13 th December 2010	4, 12, 15, 18 and 19

Table (6)
The Conventions Related to Oil Spill that Signed by Bahrain

No.	Conventions	Signing Date
1	Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution	16 October 1978
2	Protocol Concerning Regional Co-operation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency	16 October 1978
3	United Nations Convention on the Law of the Sea	28 March 1985
4	International Convention on Civil Liability for Oil Pollution Damage 1969 (1969 CLC), Brussels, 1969, 1976, and 1984	09 August 1995
5	International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage 1971 (1971 Fund Convention)	09 August 1995
6	International Convention for the Prevention of Pollution from Ships, 1973, as Modified by the Protocol of 1978 (MARPOL 73/78),	17 August 2005
7	International Convention on Oil Pollution Preparedness, Response, and Co-operation (OPRC), London, 1990	04 February 2010

The Guideline of the International Petroleum Industry Environmental Conservation Association (IPIECA) for preparing oil spill contingency plans was considered as a reference in preparing many manuals and guidelines for oil spill response planning, such as the manual prepared by the Regional Association of Oil and Gas Companies - Latin

America and the Caribbean (ARPEL) (Taylor et al., 2014), the Proposed International Guide for Oil Spill Response Planning and Readiness Assessment which was prepared by (Taylor et al., 2008) and the Guidelines for Offshore Oil Spill Response Plans which was prepared by the American Petroleum Institute (API).

The National Contingency Plan for Combating Pollution by Oil and Other Harmful Substances in the Kingdom of Bahrain requires the coastal facilities to draw up their contingency plans and respond to oil spill incidents by following IPIECA Guideline. The plan also requires each authority and industry to clean up its minor spill and protect their sensitive installation by purchasing, operating and maintaining its own protection and cleanup equipment.

To evaluate the compliance of the coastal facilities to these requirements, the reports of the oil spill incidents occurred in the last 10 years and the correspondent oil spill contingency plans of the coastal facilities in which those incidents occurred were reviewed. The review focused on the availability of the plans, equipment and response teams, and whether the operators of the facilities had activated the plans during the incidents. To facilitate the examination of the coastal facilities compliance with the above mentioned requirements, a set of 13 questions indicating the attributes of the compliance was developed as described in Table 7. These questions were evaluated by referring to the incidents reports. The qualitative answers of the review questions were quantified by using the index used by Atkinson et al. (2000), Söderman (2005), Khera and Kumar (2010) and Naser (2015). The index reflects the overall compliance of the targeted facilities with the above mentioned requirements and was calculated as follow:

$$CI = \frac{A + 0.5 B}{Q - NA} \quad (1)$$

CI: Compliance Index

A: Number of questions that fully comply with the requirements

B: Number of questions that partially comply with the requirements.

Q: Total number of the review questions.

NA: Not Applicable Questions

The maximum value of the Compliance Index is 1 where all the requirements were met. Zero is the minimum value of the index where none of the requirements were met. To simplify the comparison of the facilities compliance, the index scores were grouped into four ranges, between 0.0 and 0.25 (poor), 0.26 and 0.50 (borderline), 0.51 and 0.75(satisfactory), and 0.76 and 1.00 (good).

The index is a useful tool for quantifying and comparing the compliance of the targeted coastal facilities with requirements of the National Oil Spill Contingency Plan. However, comparing overall scores can hide the weakness or strength of the evaluation criteria. In addition, the evaluation is based on the researcher's evaluation of the reviewed oil incident reports.

Table (7)
Questions Indicating the Attributes of the National Plan Requirements

Criteria	Attributes / Questions	
Availability and Activation of the oil Spill Plan.	1	Does the coastal facility have an oil spill contingency plan?
	2	Did the coastal facility activate the plan during oil spill incidents?
Notifications and reporting	3	Did the coastal facility notify SCE on time about the incident?
	4	Did the coastal facility notify the neighbor sensitive facilities about the incident?
	5	Did the coastal facility send the final report of the incident to SCE?
Response resources	6	Does the coastal facility have a response team to oil spill incidents?
	7	Did the response team execute its roles and responsibilities during the incident?
	8	Does the coastal facility have equipment to respond to oil spill incidents?
	9	Have the equipment been used during the oil spill incidents?
Response management	10	Does the plan describe the organization's oil spill incident management system?
	11	Did the facility activated the management system during the incident?
Waste management	12	Does the plan contain a section or a guidance for waste management?
	13	Did the facility follow the guidance to manage the waste during the incident?

3.2 Exposure of the Coastal Facilities to oil Spill

There are many coastal facilities distributed along Bahrain's coastline. Some of them are owned by the government while others are operated by the private sector. Quantifying the potential exposure of these facilities to oil spill incidents aids in sharing the responsibilities, setting the protection priorities and allocating the equipment and resources required in oil spill management.

General NOAA Operational Modeling Environment (GNOME) model was used in quantifying the exposure of the coastal facilities to oil spills. To validate GNOME model and to ensure its accuracy, the data of the oil spill incident occurred in the Kingdom of Bahrain in 2003 was fed into the model. The modeling results were compared with the real trajectory and fate of oil. The metrological data of March 2003 was obtained from the Metrological Directorate in the Ministry of Transportation, while the other information and data related to the type and quantity of the spilled oil, the spill location, the real path and fate of the spilled oil were obtained from SCE and MEMAC. After validating GNOME model it was used in quantifying the exposure of the coastal facilities to oil spills. The model was applied to 40 oil spill scenarios occurred under different weather conditions and from different sources such as ships, pipelines and exploration wells. To make the scenario more realistic, the metrological data of the year 2016 was used, the actual locations of the exploration well and the real data related to the maritime navigation such as the location ships anchorage and the navigational channel and the size of ships were considered during the simulations of the scenarios. The duration of the 40 scenarios was set as three days which is the maximum run duration in GNOME Model. The GNOME model was downloaded from the NOAA official site, the data related to the maritime navigation

and the metrological data for the year 2016 was obtained from the Ministry of Transportation and Telecommunications.

To facilitate quantifying the exposure of the coastal facilities to oil spill incidents, Bahrain's shoreline was divided into five segments as shown in Figure 3 based on the dominant type of the coastal facilities and the operator sector of these facilities as described in Tables 8, 9, 10, 11 and 12.

Table 8
The Coastal Facilities within Segment A

#	Facility	Type of Facility	Operator Sector
1	Al-Jazaer Beach and Resort	Tourist / Recreational	Private
2	Bahrain Sailing Club	Recreational	Private
3	Zalaq Beach	Tourist / Recreational	Public
4	Zalaq Fishermen Port	Industrial	Public
5	Sofitel Hotel	Tourist	Private
6	Royal Palaces	Residential	Public
7	Al-Malkiya Beach	Tourist / Recreational	Public
8	Al-Hamala Beach	Tourist / Recreational	Public
9	Al-Jasra Beach	Tourist / Recreational	Public
10	Al-Budaiya Beach	Tourist / Recreational	Public
11	Al-Budaiya Fishermen Port	Industrial	Public

Table 9
The Coastal Facilities within Segment B

#	Facility	Type of Facility	Operator Sector
1	Al-Shemalia City	Residential/ Recreational	Public
2	Nurana Project	Tourist / Recreational	Private
3	Abu Subh Beach	Tourist / Recreational	Public
4	Public Beaches (Karana, Barbar, Jidd Alhaj, Alqlaa, Barbar Seef)	Tourist / Recreational	Public
5	Ritz Carlton Hotel	Tourist / Recreational	Private
6	Reef Island	Tourist	Private
7	Bahrain Bay	Tourist	Private
8	Diyar Al-Muharaq	Tourist / Residential	Private
9	Delmonia Islands	Tourist / Residential	Private
10	Amwaj Islands	Tourist / Residential	Private
11	Al-Hidd Housing Project	Tourist / Recreational	Public

Table 10
The Coastal Facilities within Segment C

#	Facility	Type of Facility	Operator Sector
1	Khalifa Bin Salman Port	Industrial	Private
2	Bahrain International Investment Park	Industrial	Private
3	SULB Company	Industrial	Private
4	Arab Shipbuilding and Repair Yard (ASRY)	Industrial	Private
5	ASRY Beach	Recreational	Public
6	Kingdom Group	Industrial	Private
7	Awal Ready Mix Concrete Company	Industrial	Private
8	Open Sea Marine Services Company	Industrial	Private
9	UCO Marine Contracting	Industrial	Private
10	Al-Saman for Sand and Block	Industrial	Private
11	Nass Asphalt	Industrial	Private
12	UltraTech Cement Bahrain company	Industrial	Private
13	Al-Hidd Power Plant	Industrial	Private
14	Base of the National Guard	Security	Public
15	Al-Sulaiti Trading and Marine Services	Industrial	Private
16	Bahrain Mineral Company	Industrial	Private
17	Bahrain Enterprises	Industrial	Private
18	Awal Trading and Contracting Company	Industrial	Private
19	Sitra Water and Power Plant	Industrial	Public
20	Bahrain Petroleum Company (BAPCO) Wharf	Industrial	Public
21	Sitra Housing Project	Residential	Public
22	Aluminum Bahrain Company (ALBA)	Industrial	Public
23	Gulf petrochemical Industries Company	Industrial	Private
24	Sitra Fishermen Port	Industrial	Public
25	Bahrain Yacht Club	Recreational	Private
26	Coast Guard Base	Security	Public
27	Al-Bander Resort	Recreational	Private
28	Royal Palace	Residential	Public
29	BAPCO Water Intakes	Industrial	Public
30	Ras Abu Jarjoor Water Plant	Industrial	Public

Table 11
The Coastal Facilities within Segment D

#	Facility	Type	Operator
1	Al-Dur Water and Power Plants	Industrial	Private
2	Public Beaches	Tourist / Recreational	Public
3	Ras Hayan Fish Farm	Industrial	Public
4	Durrat Al-Bahrain	Tourist / Residential	Private

Table12
The Coastal Facilities within Segment E

#	Facility	Type	Operator
1	Public Beaches	Tourist / Recreational	Public
2	Hewar Resort Hotel	Tourist / Recreational	Private

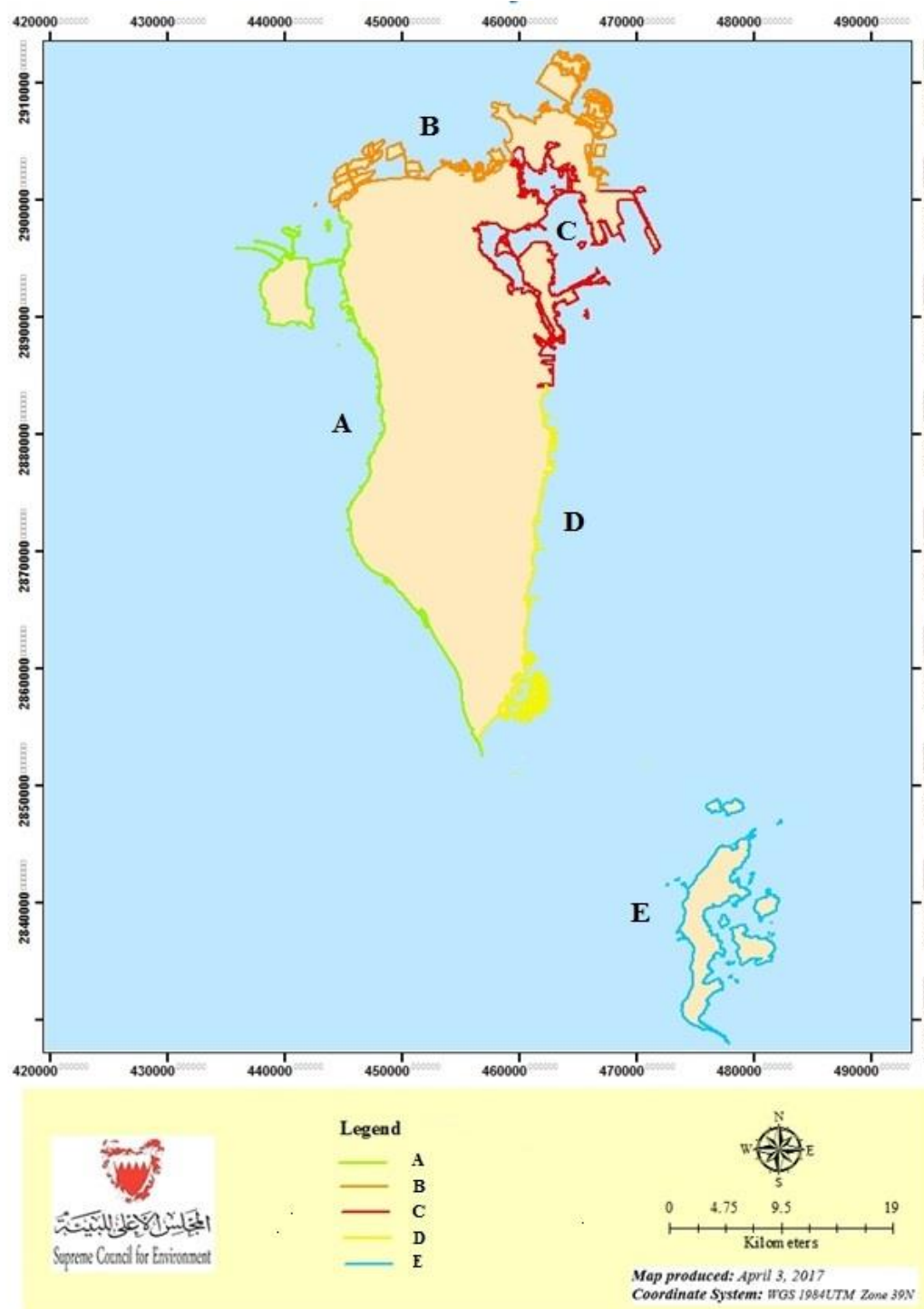


Figure (3)
Dividing Bahrain's Shorelines into Five Segments

The modeling approach which used by Al Shami et al. (2017) was used in this study to quantify the exposure of the coastal facilities to oil spill incidents. Three hazard metrics were used to quantify the exposure, the first metric is related to the probability of shoreline to be hit by oil, it is estimated by counting the number of times at which oil hit the segment during the 40 simulations. Therefore, each of the segments will be assigned with a score ranged between 0 and 40, 0 means that the segments experienced no oiling during the 40 runs, and 40 means that the segments experienced oiling across all 40 runs. The second metric is applied to determine the average concentration of oil reaching the shorelines. It is evaluated by calculating the mean concentration of oil (tons/kilometer) reached the shoreline segment. This can be estimated by dividing the quantity of oil reached the segment over the length of the shoreline segment. The concentration will be averaged over the 40 spill simulations. The third metric is used to calculate the time needed to reach the shorelines. It is quantified by calculating the minimum time in hours required for oil to hit the segments shoreline in a given scenario. Every segment will be assigned scores between 0 and 72. The score 0 means that segment shorelines were hit by oil immediately, 72 means that three days are required for oil to hit a segment in a given scenario, and > 72 means that the segment was not hit during the run of the scenarios.

The recent map of the Kingdom of Bahrain was obtained from Information and eGovernment Authority through the GIS server in SCE. A geodatabase was developed by creating five feature datasets, one dataset was specified for each coastline segment; feature classes was created under the main groups, one feature class was specified for each coastal facility as shown in figure 4. The geographical data of the coastal facilities was inserted into the feature classes which was arranged under

the feature datasets based on the location of the coastal facilities. Five layers with different colors were created using ArcGIS for the five segments to produce the map. To facilitate the visualization of the exposure level of each segment, the values of the exposure metrics were divided into ranges and fed to the ArcGIS software, a specific color will be assign for each range, this aids in producing the final maps with the level of exposure to oil spill along Bahrain’s coastline.

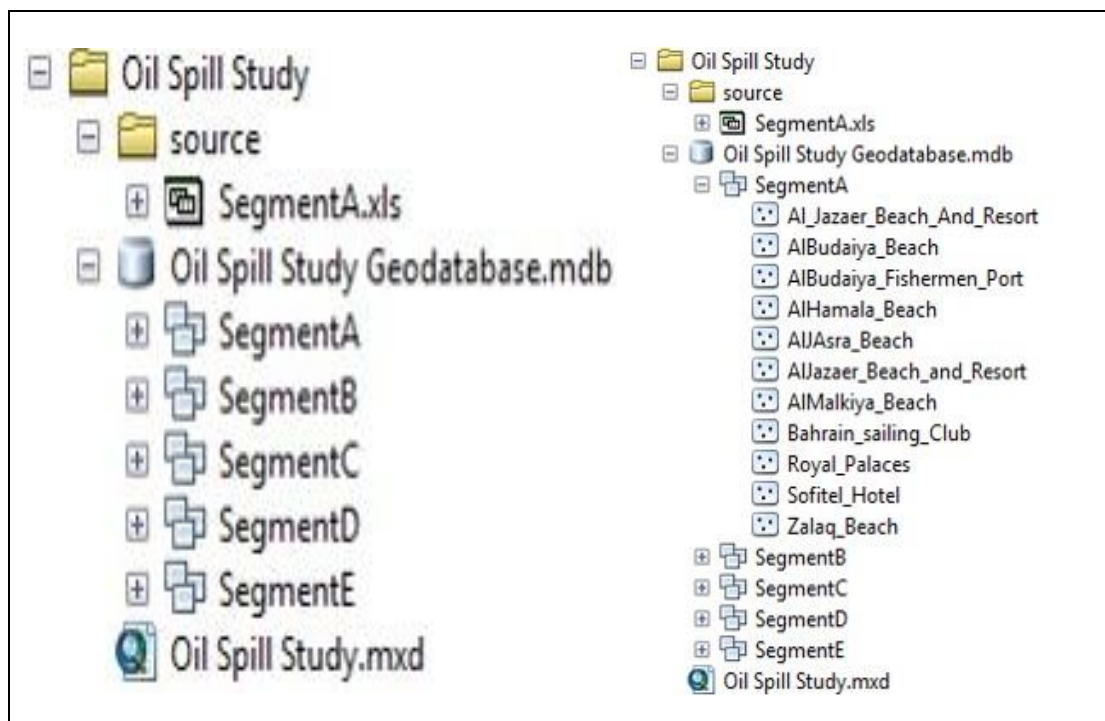


Figure (4)
Screenshot of the Geodatabase Created by Using ArcGIS

Chapter Four

Results, Discussion, and Recommendations

This chapter includes the following parts: results, discussion, conclusion and recommendations. The results of the study were presented in the form of tables and figures. The results were discussed in order to answer the research questions, and the recommendations which address the study's problem and the recommendations for future research were raised at the end of this chapter.

4.1 Oil Spill Management in Bahrain:

The national legislations, the signed regional and international conventions and the contingency plans in the Kingdom of Bahrain were reviewed and the following results were achieved.

4.1.1 Results of Reviewing the National Legislations and Signed Conventions

Development of national legislations for implementing the regional and international conventions is important to ensure that the national laws and regulations are consistent with the requirements of the conventions (Mukherjee and Brownrigg, 2013). Implementation of the IMO conventions is also important to ensure the effectiveness of the global environmental regime. A successful implementation of the IMO conventions requires a practical steps such as adopting national laws, regulations and policies to meet the obligations of the conventions. In addition to imposition of sanctions and penalties for non-compliance to the obligations and requirements. In the developed countries, one of the main challenges of the conventions implementation is incorporation of these convention into the national legislation (Karim, 2015). Kingdom of Bahrain had signed regional and international conventions, and issued national legislations which are related to oil spill management (Al-Janahi, 2008). The list of the regional and international conventions related to oil spill management which have been signed by the Kingdom of Bahrain are

mentioned in Appendix 1. Kingdom of Bahrain signed all regional and international conventions except the International Convention on Civil Liability for Bunker Oil Pollution Damage (IMO, 2017, MEMAC, 2017). These conventions were reviewed to explore the articles and the requirements related to oil spill management. In order to examine the consistency and the compliance of the national legislations with the requirements of the signed conventions, the articles of the national laws and orders which mentioned were reviewed (Appendix 2, 3 & 4).

4.1.2 Discussion of Reviewing the National Legislations and Signed Conventions

Signing the International Convention on Civil Liability for Bunker Oil Pollution Damage is important, because it deals with oil pollution from the bunker of all ships other than oil tankers. The cleanup process of fuel oil is more costly and difficult. For example, in Australia the government's response cost for oil spill from non-tanker was US\$625,000 while the response costs for oil tanker spills was US\$115,000. The Pallas incident in Germany is another example which shows that little amount of fuel oil from cargo ship can cause massive damage to environment (Zhu, 2007). The International Convention on Civil Liability for Oil Pollution Damage is applied only for the ships which are constructed or adapted for the carriage of oil in bulk as cargo, it is not applied for other ships which carry oil as bunker only. To fill this gap, the International Convention on Civil Liability for Bunker Oil Pollution Damage was adopted entered into force in 2008 (Damar, 2011). Therefore, signing the Bunker Convention is important to ensure the availability of a mechanism for providing compensation for damage caused by bunker oil pollution in the Kingdom of Bahrain.

According to Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution (Kuwait Convention), the Kingdom of Bahrain is requested to take the appropriate measures to prevent, abate and combat pollution of the marine environment from ships and other sources. Bahrain shall also ensure the availability of adequate equipment and qualified personnel to deal with marine pollution. These requirements were found in the national legislations through Law No.3 of 1975 on Public Health. According to articles 63 and 64 of this law, discharge of oil from ships or other sources and dumping of grease and sludge into Bahrain's territorial water is prohibited. The law has defined the responsibilities and the sanctions against the violators through article No.69.

As per the Protocol Concerning Regional Co-operation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency, the Kingdom of Bahrain shall take the effective measures to protect the coastal and marine environment from oil pollution. Bahrain shall also prepare and maintain contingency plans and ensure the availability of equipment and manpower for combating marine pollution by oil. Bahrain has included these requirements in the Legislative Decree No. 21 of 1996 with Respect to Environment through article No.4, which requests the environmental body in Bahrain to coordinate and cooperate with the relevant authorities to take the effective measures to protect marine environment from oil pollution and to train the manpower to lay out plans for combating oil pollution. However, it is very general article and does not contain the details required for preparedness and combating oil pollution. The required details were highlighted later through the discussion of the International Convention on Oil Pollution Preparedness, Response, and Co-operation (OPRC). According to Article No.7 of the

Protocol Concerning Regional Co-operation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency, the Kingdom of Bahrain shall require masters of ships to report the existence of any marine emergency to the appropriate national authority. This article was included in the Ministerial Order No.6/2010 on Implementation of Law No.61/2006 through Article No. 12 which requires port operators, owners, captains and agents of ships to report oil pollution incidents immediately to the Ports and Maritime Affairs in the Ministry of Transportations and Telecommunications.

The United Nations Convention on the Law of Sea is considered as the first comprehensive regime for the protection and preservation of the marine environment (Oral, 2013). Many countries have incorporated the articles of this convention in their national legislations. For example, Denmark have incorporated parts of this Convention into the Danish Marine Environment Protection Act 2013 (Christensen and Carpenter, 2016). According to Article No. 42 of the United Nations Convention on the Law of Sea, Kingdom of Bahrain shall adopt laws and regulations relating the prevention, reduction and control of pollution, by giving effect to applicable international regulations regarding the discharge of oil, oily wastes and other noxious substances. The national law and regulations contain some articles which aim to prevent, reduce and control of pollution by oil. Articles No.194 and No. 211 of the convention require the states to adopt laws and regulations and to take all measures that are necessary to prevent, reduce and control pollution of the marine environment from any source such as vessels, installations used in exploration and devices operating in the marine environment. The national legislations mentioned in Appendix 2 do not cover the pollution related to oil exploration operations. Bahrain needs to adopt regulations

that define the requirements to prevent and control pollution from such activity. This will contribute to the enhancement of oil spill management by enforcing the preventative measures, preparing the contingency plans, maintaining the required equipment and resources to response to oil spill incidents resulted from exploration projects and activities. As per Article No.199 the states shall jointly develop and promote contingency plans for responding to pollution incidents in the marine environment. Kingdom of Bahrain complied with this requirement through the Article No. 4 of the Legislative Decree No. 21 of 1996 with Respect to Environment. Bahrain had developed a national contingency plan for combating pollution by oil and other harmful substances (Zainal et al., 2008). Bahrain is one of the parties of the regional oil spill contingency plan which was adopted by MEMAC to coordinate the response to oil spill incidents at the regional level (MEMAC, 2010).

The obligations and requirements of the International Convention on Civil Liability for Oil Pollution Damage and the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage are related to the legal side and shall be met by ships owners (Karim, 2015). However, as per these conventions, when preventive measures have been taken to prevent or minimize pollution damage from an oil incident in a contracting state, it shall ensure that its Courts possess the necessary jurisdiction to entertain such actions for compensation. According to Article No.70 of the Law No,3 of 1975 on Public Health, the competent authority shall order the polluter to combat the pollution and rehabilitate the impacted area in a defined period. If the polluter failed combating and rehabilitation, the competent authority shall combat and rehabilitate the impacted area, and

shall issue an order to fine the polluter all the costs and expenses of the cleaning and rehabilitation processes.

MARPOL 73/78 is considered as the most important convention for prevention pollution from ships (Mensah, 2007). Article 4, Regulation 37 and Regulation 38 of MARPOL 73/78 convention have not been incorporated in the national legislations. There is no law or ministerial order in Bahrain that obligates oil tankers to carry onboard oil pollution emergency plan. Although Article No.63 of the Law No.3/1975 on Public Health prohibits discharge of oil from ships to the marine environment. To comply with the Regulation 11 of MARPOL 73/78 the maritime administration in Bahrain (Ports and Maritime Affairs) needs a legal instrument to inspect ships in order to ensure the availability of procedures relating to the prevention of pollution by oil. According to MARPOL 73/78 convention, all loading terminals and repair ports shall be provided with adequate reception facilities to receive oily waste from ships. Although some oil terminals in Bahrain like Bapco Wharf and Khalifa Bin Salman Port have reception (IMO, 2017), laws and orders in Bahrain include no article to obligate the loading terminals and repair ports to comply with this requirement. Sanctions and penalties are not established under the national legislation in Bahrain in order to take the necessary legal actions against the violations of MARPOL 73/78 obligations.

The International Convention on Oil Pollution Preparedness, Response, and Co-operation (OPRC), is an important convention that aims to increase the preparedness at the national level and cooperation with other countries to respond to oil spill incidents (Bellefontaine et al., 2016). According to this convention the competent authority in Bahrain shall ensure that all ships visiting Bahrain, sea ports and oil handling

facilities have oil pollution emergency plans. However, there is no law or order obliges ships, sea ports and oil handling facilities to comply with this requirement. There is no legal instrument defines the penalties and sanction of non-compliance with this requirement. Article 4 of this convention require ships, sea ports, oil handling facilities and pilots of civil air crafts to report any event involving a discharge or probable discharge of oil or the presence of oil to the competent national authority. This requirement was covered in the national legislations through Article No.12 of the Ministerial Order No.6/2010 on Implementation of Law No.61/2006. According to Article No.6 of OPRC convention, Kingdom of Bahrain shall establish a national system for responding promptly and effectively to oil pollution incidents. Bahrain shall also establish a minimum level of pre-positioned oil spill combating equipment, a program of exercises for oil pollution response, communication capabilities and a mechanism or arrangement to co-ordinate the response to oil pollution incidents. Kingdom of Bahrain had met these requirements by developing the National Contingency Plan for Combating Pollution by Oil and Other Harmful Substances.

From the above discussion, the following obligations and requirements need to be incorporated in national legislations in the Kingdom of Bahrain:

- Articles related to sanctions and provision of waste reception facilities under MARPOL 73/78.
- Obligations related to preparation of oil spill contingency plans for ports, oil terminals and oil tankers.
- Obligations related to the adoption of appropriate procedures for the determination of civil liability and compensation for damage resulting from pollution of the marine environment.

Incorporating the above requirements into the national legislations contributes to the enhancement of oil spill response in the Kingdom of Bahrain by preventing oil spill or minimizing its impact on the marine environment. Finally, to enhance the compliance to the above conventions and protocol, it is recommended to update the current national legislations to incorporate all conventions requirements related to oil spill management.

4.1.3 Results of Examining the Compliance of the Coastal Facilities with the Requirements of the National Contingency Plan

The reports of the twenty three oil spill incidents listed in Table 2, and the correspondent oil spill contingency plans were reviewed. By applying the compliance index in Equation 1, it was found that the overall compliance of the coastal facilities with the national requirements of oil spill management was good during eight incidents, satisfactory in two incidents, borderline in five incidents and poor in eight incidents. The results are shown in Figure 5.

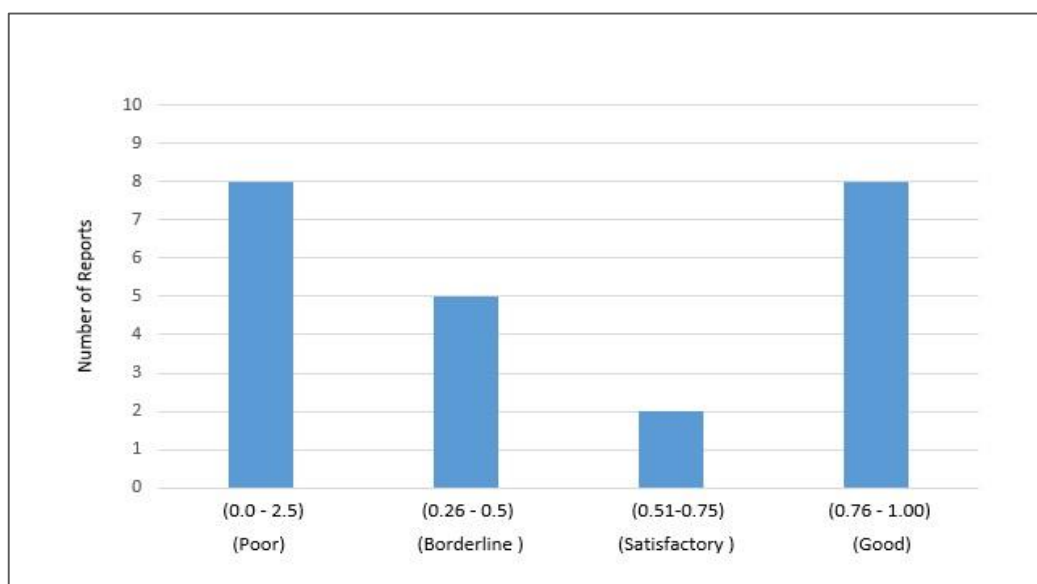


Figure (5)
Compliance Index of the Coastal Facilities with the National Requirements

The overall compliance of the coastal facilities with the national requirements were evaluated using IPIECA guidelines based on the following topics; availability and activation of oil spill contingency plan, notification and reporting, response resources, response management and waste management.

Table (13)
Evaluation Results for the Availability and Activation of oil Spill
Contingency Plan

Questions	Result			
	0	0.5	1	N/A
1. Does the coastal facility have an oil spill contingency plan?	8	0	15	0
2. Did the coastal facility activate the plan during oil spill incidents?	5	0	10	8

Oil spill contingency plans are useful in developing tactics and strategies which minimize the adverse impacts of oil spill incidents on marine and coastal environment (Taylor, 2005). The reports of the oil spill incidents occurred in the last ten years were reviewed. It was found that fifteen incidents had occurred in facilities that have oil spill contingency plans. The other eight incidents had occurred in facilities which have no oil spill contingency plans in place. As shown in Table 13, the contingency plans were activated in ten incidents only. That means, during five incidents there were oil spill contingency plans in the facilities, but they were not activated. The results in Table 13 indicate that not all the coastal facilities in the Kingdom of Bahrain have oil spill contingency plan, some of them have contingency plans but do not have the necessary capabilities and resources to activate their plans. Therefore, it is necessary not only to ensure that all coastal facilities in Bahrain have their oil spill contingency plans, but also to ensure that they are able to activate their plans during the oil spill incidents by having the necessary resources such as response team and equipment.

Table (14)
Evaluation Results for Notification and Reporting

Questions	Result			
	0	0.5	1	N/A
3. Did the coastal facility notify SCE on time about the incident?	8	2	13	0
4. Did the coastal facility notify the neighbor sensitive facilities about the incident?	21	2	0	0
5. Did the coastal facility send the final report of the incident to SCE?	16	0	7	0

If a spill occurred in the port limits, the coastal facilities are required to report the spill to the Supreme Council for Environment (SCE, 2013). As mentioned in the IPIECA guidelines, the facilities are also required to report spill incidents to their neighbor sensitive facilities such as desalination plants in order to take their precaution measures, and to send the final report of the incident to the competent authority which is SCE. By reviewing the reports of the twenty three incidents, it was found that during thirteen incidents the coastal facilities had promptly notified SCE about the spill. However, in eight incidents SCE have not received notification from the facilities in which the incidents occurred. The notification was received from other sources such as citizens, environmental activists and journalists. During two incidents, SCE indirectly received the notifications from the facilities in which the spill incidents occurred. In that incidents the facilities notified Ports and Maritime Affairs and BAPCO, who in turn notified SCE. As shown in Table 14 during twenty one incidents, the coastal facilities had not notified their neighbor sensitive facilities, SCE had taken this responsibility. During two incidents the coastal facilities in which the incidents occurred had notified some of their neighbor sensitive facilities but not all of them were notified. Although submitting the final report of

the incident is important for SCE to know the causes of the spill, the measures were taken and the damages occurred, out of twenty three incidents SCE had received the final report of six incidents only.

Table (15)
Evaluation Results for Response Resources

Questions	Result			
	0	0.5	1	N/A
6. Does the coastal facility have a response team to oil spill incidents?	8	0	15	0
7. Did the response team execute its roles and responsibilities during the incident?	2	6	7	8
8. Does the coastal facility have equipment to respond to oil spill incidents?	13	1	9	0
9. Was the equipment used during the oil spill incident?	0	0	10	13

To ensure an effective and successful implementation of oil spill contingency plans, coastal facilities shall have well-trained response teams. The team's members should be fully aware of their roles and responsibilities as assigned in the plan (Fingas, 2011). In addition to response teams, coastal facilities shall have enough and adequate equipment to respond to oil spill incidents in their facilities limits (Knol and Arbo, 2014). By reviewing the reports of the incidents mentioned in Table 2, it was found that the facilities in which the incidents occurred have their own response teams in fifteen incidents. According to the reviewed reports, during the remaining incidents either the oil slicks were cleaned up by the SCE's response team, or left for natural dispersion and evaporation. Table 15 shows that during seven incidents the response teams of the coastal facilities executed their roles and responsibilities, while in two incidents the response teams didn't execute their roles and responsibilities either because of lack of equipment in the facilities or the team members do not have the necessary experience to response to the

incidents. The response teams partially executed their roles in six incidents and failed in executing some responsibilities such as notification of the concerned parties, containment of the oil patches or deployment of the necessary equipment. With regard to the availability of combating equipment in the coastal facilities, Table 15 shows lack of equipment in the facilities during fourteen incidents, while sufficient equipment were available in the facilities during nine incidents. There was insufficient equipment in one facility. The reviewed reports show that all the facilities which own equipment had used that equipment to combat oil spill occurred in their facilities limits.

Table (16)
Evaluation Results for Response Management

Questions	Result			
	0	0.5	1	N/A
10.Does the plan describe the organization’s oil spill incident management system?	0	0	15	8
11.Did the facility activated the management system during the incident?	5	0	10	8

Incident management system is important in managing oil spill incidents. This system shall describe the roles and responsibilities, the response organization and planning processes and procedures. The system can expand or shrink in size depending on the tier level. The contingency plans of the coastal facilities shall clearly explain and describe the oil spill incident management system (IPIECA, 2015). By reviewing the oil spill contingency of the coastal facilities in which oil spill incidents occurred, it was found that the incident management system was described in contingency plans of fifteen incidents. By reviewing the reports of the oil spill incidents and as shown in Table 16, the coastal facilities activated their incident management system during eight

incidents. While during five incidents the incidents management system was described in the plan but was not activated because of the lack of the necessary capabilities in the facilities to activate the system.

Table (17)
Evaluation Results for Waste Management

Questions	Result			
	0	0.5	1	N/A
12.Does the plan contain a section or a guidance for waste management?	1	0	14	8
13.Did the facility follow the guidance to manage the waste during the incident?	5	0	9	9

Pre-plan for waste management is essential to ensure a proper compliance with regularity requirements of waste handling, temporary storage, transportation and disposal of waste generated during oil spill combating operations (Carro et al., 2008). Lack of waste management may lead to disruption of combating operations. Waste management guidance should be included within the oil spill contingency plan, or a waste management plan can be separately prepared for this purpose. As described in Table 17, during fourteen incidents the correspondent facilities had a waste management plan or a section in the oil spill plan for waste management. However, the facilities followed the waste management guidance in nine incidents only. During five incidents there were waste management plans but were not followed or activated by the facilities either because of the lack of response team, or the response team was not activated, in those incidents the SCE's response team dealt with the waste according to the national regulatory and requirements.

4.1.4 Discussion of Examining the Compliance of the Coastal Facilities with the Requirements of the National Contingency Plan

To achieve the first objective of this study, the overall compliance of the coastal facilities with the national requirements related to oil spill management was examined using the compliance index mentioned in Equation 1. The results of the compliance index which were presented in Figure 5 showed that during eight incidents, the overall compliance of the coastal facilities was good, while it was poor in other eight incidents, borderline in five incidents and satisfactory in two incidents. That means, the overall compliance was good during 35% of the reviewed incidents. Therefore, further efforts are required to increase the preparedness and enhance the response to oil spill incidents in Kingdom of Bahrain. This can be achieved by ensuring the compliance of the coastal facilities with national requirements of the oil spill management related to preparing and activation of oil spill contingency plans, the availability and activation of response teams, maintaining and utilizing the resources to respond to oil spill incidents, .. etc.

The compliance indexes covered the following topics; availability and activation of oil spill contingency plan, notification and reporting, response resources, response management and waste management. As mentioned in the results section during some incidents there were oil spill contingency plans in place. However not all coastal facilities have activated the plan. Therefore, it is important not to only ensure that the coastal facilities have their own oil spill contingency plans but to ensure that they have the required capabilities and resources to effectively activate these plans during oil spill incidents.

Initial notification and final reporting to the competent parties is highly important. It allows those parties such as SEC, PMA and the

neighbor sensitive facilities to take their precautions and preventative measures. Submitting the final report of the incident is important because it documents the source of the spill, the measure taken and the damage occurred. This helps in the claim and compensation processes and gaining the lessons for future (IPIECA, 2015). Table 14 shows during eight incidents the SCE was not notified by the coastal facilities in which the incidents occurred. During twenty one incidents the coastal facilities did not notify their neighbor sensitive facilities and during sixteen incidents the coastal facilities did not send the final incident reports to SCE. Therefore, more effort is required in this part of oil spill management to emphasize the importance of notification and reporting. Enhancing the initial notification aids in taking the necessary preventative measures and minimize the potential damage of oil spill incident on the marine and coastal environment. This can be done by developing a national notification system which requires the governmental and private coastal facilities in which an incident occurred to promptly notify the competent parties SCE, PMA and the sensitive neighbor facilities.

The availability of the response resources such as response teams and clean-up equipment is important to ensure effective response to oil spill incidents (Knol and Arbo, 2014). As described in Table 15, during eight oil spill incidents, there was no response team in the coastal facilities, while there was no clean-up equipment during thirteen incidents. According to the reports of those incidents SCE took the response responsibility by activating its response team and deploying its response equipment. Table 15 also shows that in two incidents there was a response team in the coastal facilities but it was not activated either because the team members are not aware with their roles and responsibilities or there is no capabilities in the coastal facilities to

activate that team. To manage response to oil spill incidents, a management system must be available and well described in the oil spill contingency plans of the facilities. As shown in Table 16, management system was described in oil spill contingency plan in fifteen incidents. However, during five incidents the management system was available but was not activated. Therefore, it is highly important to ensure the availability of the oil spill management system, and check whether the necessary resources are available and the members of the response teams are well-trained to activate the oil spill management system. Waste management plan is an important element to manage the large quantity of waste generated from clean-up operations during oil spill incidents. Lack of such plan during oil spill incidents makes the disposal process of the mixed waste expensive and timely consuming (Carro et al., 2008). During the reviewed oil spill incidents, there was waste management plan to manage the oily waste in fourteen incidents. During nine incidents there was no waste management plan, in those incidents SCE coordinate with the coastal facilities in which the incidents occurred to manage the generated waste according to the related national laws and regulations.

4.2 Quantifying the Exposure Level of the Coastal Facilities to Oil Spills

4.2.1 Results of Quantifying the Exposure Level of the Coastal Facilities to Oil Spills

Before using GNOME model to determine the exposure level of the coastal facilities to the oil spill, the model was validated by applying it to the oil spill incident occurred in 2003 in the Kingdom of Bahrain. The data of the incident in Table 18, and the correspondent metrological data was fed to GNOME model. The model was run for three days which is the maximum running duration for the model.

Table (18)
Data of 2003 Incident which Fed to GNOME Model

Date of Incident	15 March 2003	Time of Incident	10:00 am
Type of Oil	Crude Oil	Quantity of Oil	5000 Bbl.
Location	26°32'38.00"N 50°31'36.20"E	Source	Unknown

Table 19 shows the results obtained after running GNOME model.

Table (19)
Modeling Result of the Incident Occurred in 2003

Point No.	Date	Time	Location		Quantity (Bbl)	
			Latitude	Longitude	Evaporated	Floating
1	15-Mar-03	10:00	26°32'38.00"N	50°31'36.20"E	0	5000
2	15-Mar-03	16:00	26°27'13.00"N	50°33'30.00"E	365	4635
3	15-Mar-03	22:00	26°23'50.00"N	50°35'00.00"E	640	4360
4	16-Mar-03	4:00	26°21'50.00"N	50°37'16.00"E	925	4075
5	16-Mar-03	09:10	26°19'41.00"N	50°40'00.00"E	1095	3905
6	16-Mar-03	22:00	26°18'40.00"N	50°39'00.00"E	1380	3610
7	17-Mar-03	10:00	26°22'00.00"N	50°38'00.00"E	1550	3450
8	17-Mar-03	22:00	26°21'30.00"N	50°37'40.00"E	1700	3300
9	18-Mar-03	10:00	26°16'25.00"N	50°41'25.00"E	1850	3150
10	18-Mar-03	22:00	26°15'15.00"N	50°39'15.00"E	1975	3025

Figure 6 shows the trajectory of the oil slick in different days and times during the 2003 oil spill incidents as obtained from GNOME model. According to the modeling results the oil slick was moving toward South East during the first 24 hours then the direction changed with the wind direction to the South west and reached Muharraq coastline 19 March 2003.

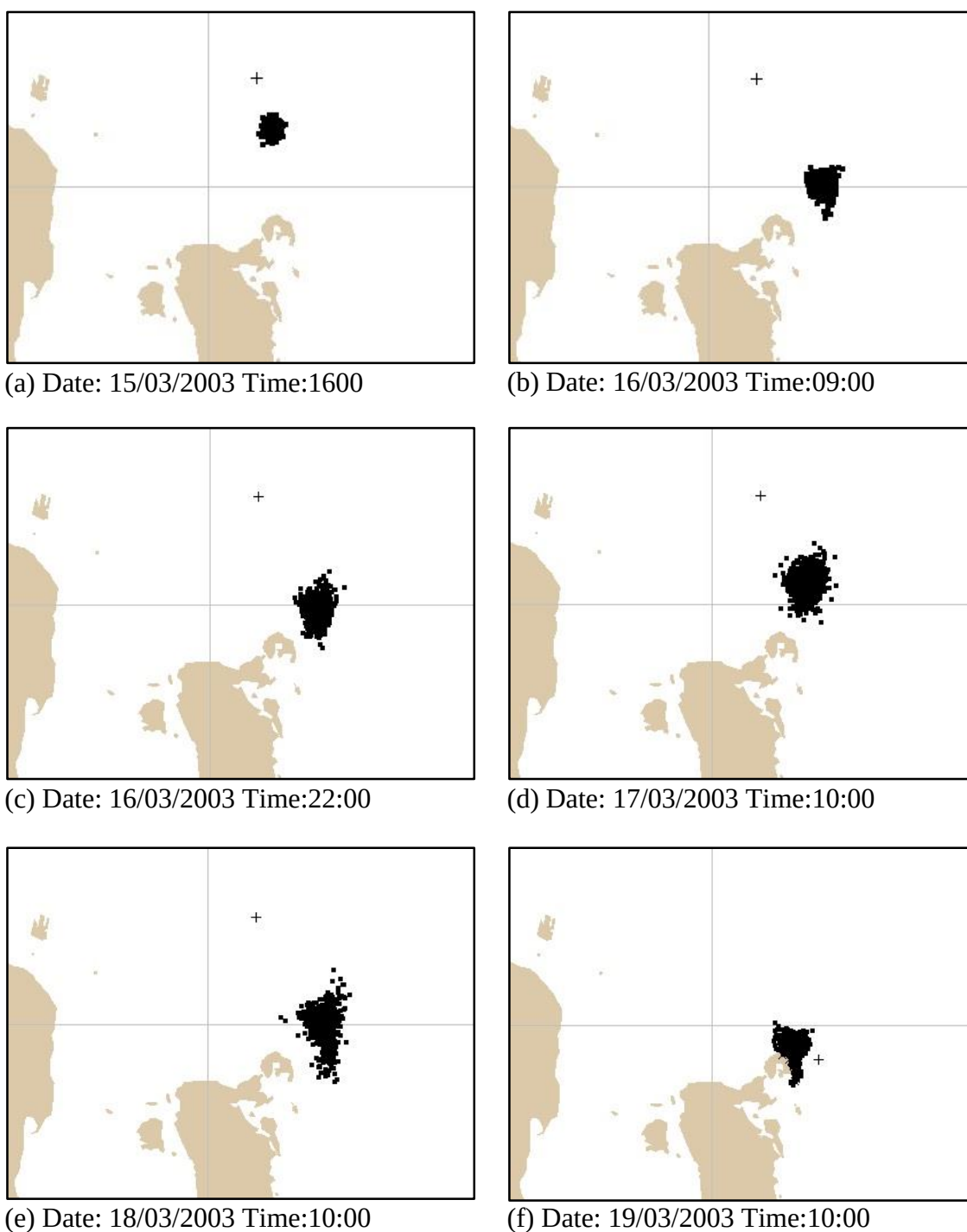


Figure (6)
The Trajectory of the Oil Slick in 2003 Incident

As shown in Figure 7, locations of the points mentioned in Table 29 were drawn in map to described the path of the oil slick during the oil spill incident occurred in 2003.

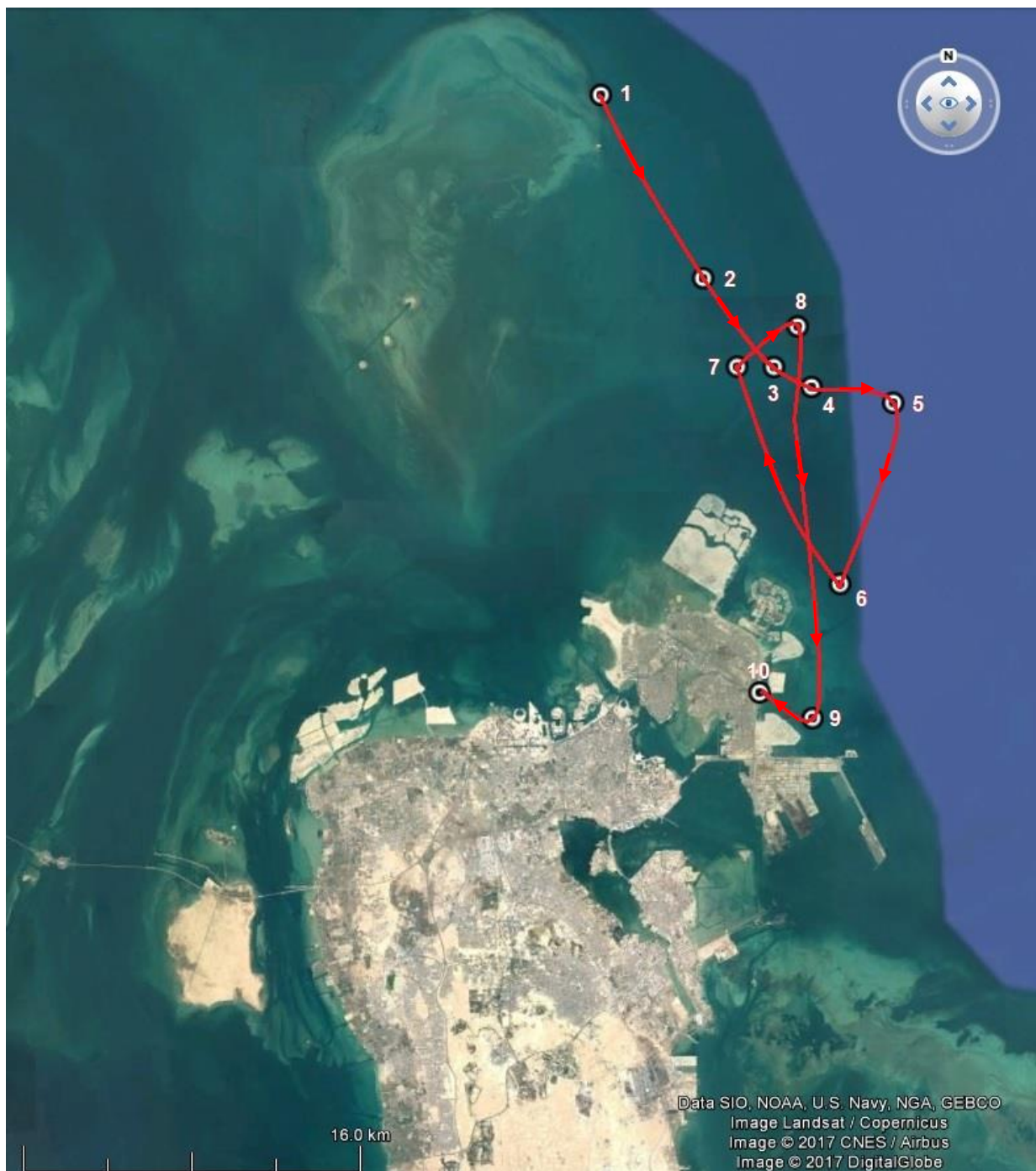


Figure (7)
The Path of the Oil Slick in 2003 Incident

During the oil spill incident that occurred in Bahrain in 2003, a modeling was conducted using GNOME model to simulate the trajectory of the oil slick (PCPMEW, 2003). The modeling results of this study was compared with the real oil spill trajectory as described in Table 20.

Table (20)
Comparison between the Actual and the Simulated Trajectories

Date	Time	Location of Spill	
		Simulation (This Study)	Actual Location Fly Wing/Coast Guard
15.03.2003	10:00	26°30'32.80"N 50°35'66.90"E	26°30'32.80"N 50°35'66.90"E
16.03.2003	09:10	26°21'51.00"N 50°44'23.00"E	26°24'21.50"N 50°45'49.50"E
17.03.2003	10:00	26°23'43.00"N 50°39'50.00"E	Between Fasht Al-Jarem and Fasht Al-Dibel
18.03.2003	10:00	26°14'35.00"N 50°41'11.00"E	26°14'36.00"N 50°39'28.00"E

As shown in Table 20, by running GNOME Model for 23 hours, the oil slick reached a location near to the slick real location recorded by the Fly Wing in the Ministry of Interior. By running the model for 48 hours the oil slick reached a location between Fasht Al-Jarem and Fasht Al-Dibel, which is consistent with the location recorded by the Fly Wing in 2003. According to the Coast Guard survey conducted during the incident, the oil slick reached near Muharraq coastline after three days which is consistent with the modeling results of this study.

After validating GNOME model, exposure level of the coastal facilities to oil spills was quantified by simulating forty different oil spill scenarios using the validated Model. The details of the forty scenarios is

described in Appendix 6. The three metrics which were developed by Ashami, (2017) were applied to the scenarios of this study to quantify the exposure level to oil spills in the five segments defined in the previous chapter. Table 21 shows the modeling results of the oil spill incidents scenarios which hit the western coastlines (Segment A).

Table (21)
The Modeling Results of Oil Spill Scenarios which Hits Segment A

No.	Date	Source	Time to Hit (hr)	Oil Quantity (mt)	Concentration (mt/Km)
1	15-Jan-2016	Exploration Rig	33	164	0.951
2	09-Feb-2016	AB Pipeline	6	403	2.338
3	11-Apr-2016	Exploration Well	33	16	0.093
4	15-Sep-2016	AB Pipeline	17	24.1	0.140
5	22-Oct-2016	Unknown	4	167	0.969
6	14-Nov-2016	Exploration Rig	36	346	2.007

The potential source of oil spills which can affect Segment A are exploration rigs, exploration wells and AB pipeline. There are no ships anchorages or ships traffic near this segment. Therefore, it is not expected to be impacted by oil released from ships. Furthermore, the force of water current and weather conditions drift the oil released from ships in the north of Bahrain to the other segment. During the simulation of the forty oil spills scenarios, Segment A was hit in six scenarios. The minimum time needed for oil to reach the shoreline of the Segment A was four hours only, while the maximum time was 36 hours. Oil took short time to reach this segment because of the availability of potential sources nearby the segment.

According to the modeling the maximum oil quantity reached this segment was 403 metric tons from a leakage in AB Pipeline between Kingdom of Bahrain and Kingdom of Saudi Arabia, while the minimum quantity reached the segment was 16 metric tons released from an exploration well. Figure 8 shows the oil trajectories and the impacted areas during different scenarios which hit Segment A.

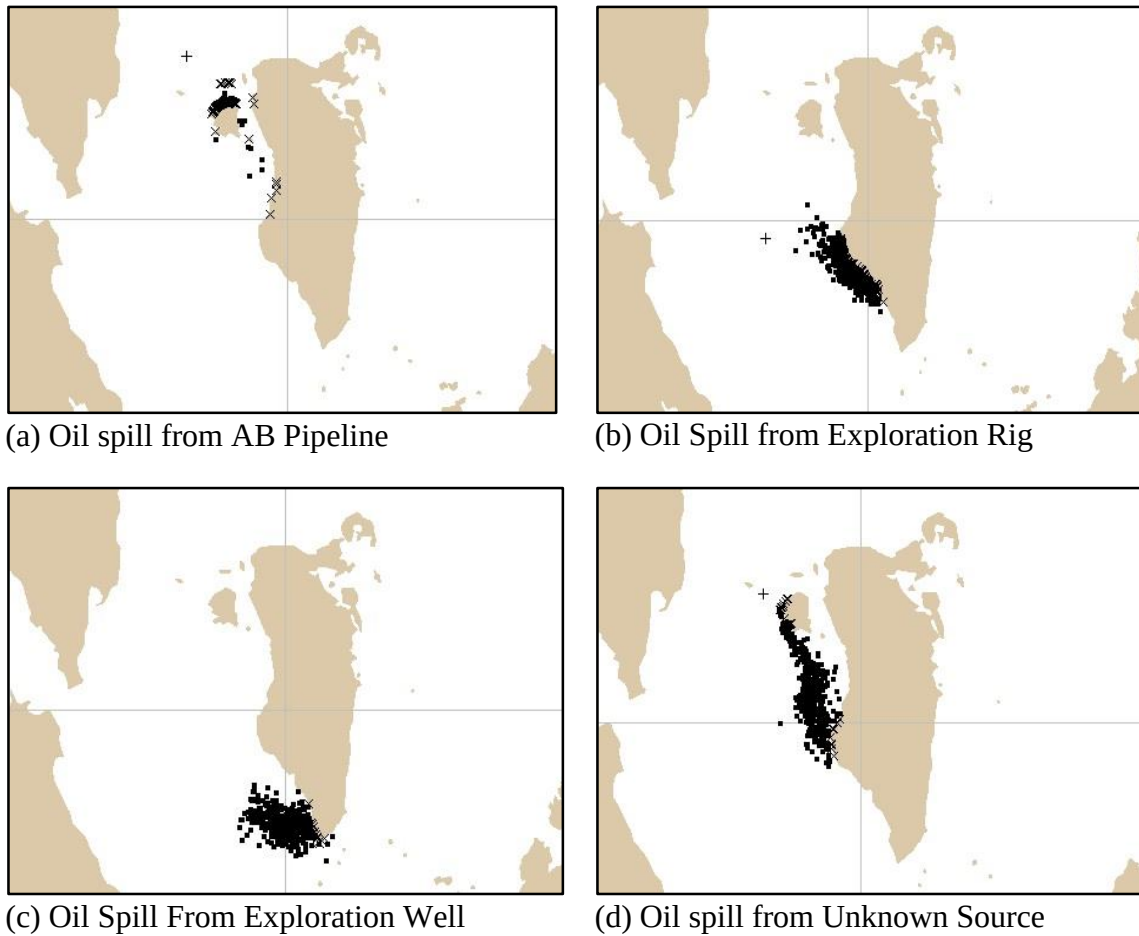


Figure (8)
Some Oil Spill Scenarios which hit Segment A

Table 22 shows the modeling results of the oil spill incidents scenarios which hit the northern coastlines (Segment B). By running GNOME model for the forty scenarios, Segment B was hit eleven times. This means the probability of this segment to oiling is higher than Segment A. However, oil patches required longer time to reach the shoreline of this segment. By running the

scenarios it found that the minimum time needed for oil to reach this segment was 36 hours while the maximum time was 64 hours which is longer than the time needed to reach Segment A. as shown in Table 22, Segment B is vulnerable to receive more quantity of oil than Segment A. The maximum quantity of oil which can reach Segment B is 1428 metric tons, which is three times more of the maximum quantity of oil which hit Segment A. This is because of the variety and nature of the oil spill potential sources around this segment. Segment B is vulnerable to be hit by oil released from ships in the navigation channels, oil fields in neighbor countries, exploration wells and exploration rigs in and out of Bahrain's territorial water.

Table (22)
The Modeling Results of Oil Spill Scenarios which Hits Segment B

No.	Date	Source	Time to Hit (hr)	Oil Quantity (mt)	Concentration (mt/Km)
1	17-Mar-2016	Ship	64	232	0.867
2	18-May-2016	Oil Field	50	1428	5.338
3	18-Jun-2016	Oil Tanker	60	364	1.361
4	25-Jun-2016	Exploration Rig	55	126	0.471
5	17-Jul-2016	Unknown	53	102	0.381
6	23-Jul-2016	Oil Field	30	904	3.379
7	11-Aug-2016	Cargo Ship	55	37	0.138
8	15-Aug-2016	Ship	41	681	2.546
9	18-Aug-2016	Ships	42	313	1.170
10	17-Oct-2016	Exploration Well	42	159	0.594
11	7-Nov-2016	Unknown	36	666	2.490

As shown in Figure 9 and Table 22, Segment B was heavily impacted by large quantities of crude oil, fuel oil and diesel. Figure 9 shows the trajectory and fate of oil slicks and the impacted areas during some scenarios which hit Segment B. From the metrological data received from

the Directorate of Metrology, it was found that the dominant wind in Bahrain is the northern wind, and this helps in drifting the oil patches toward the northern coast of Bahrain. The time needed for oil to reach this segment is longer than in Segment A because of the long distance between the potential spill sources and the coastline of the segment.

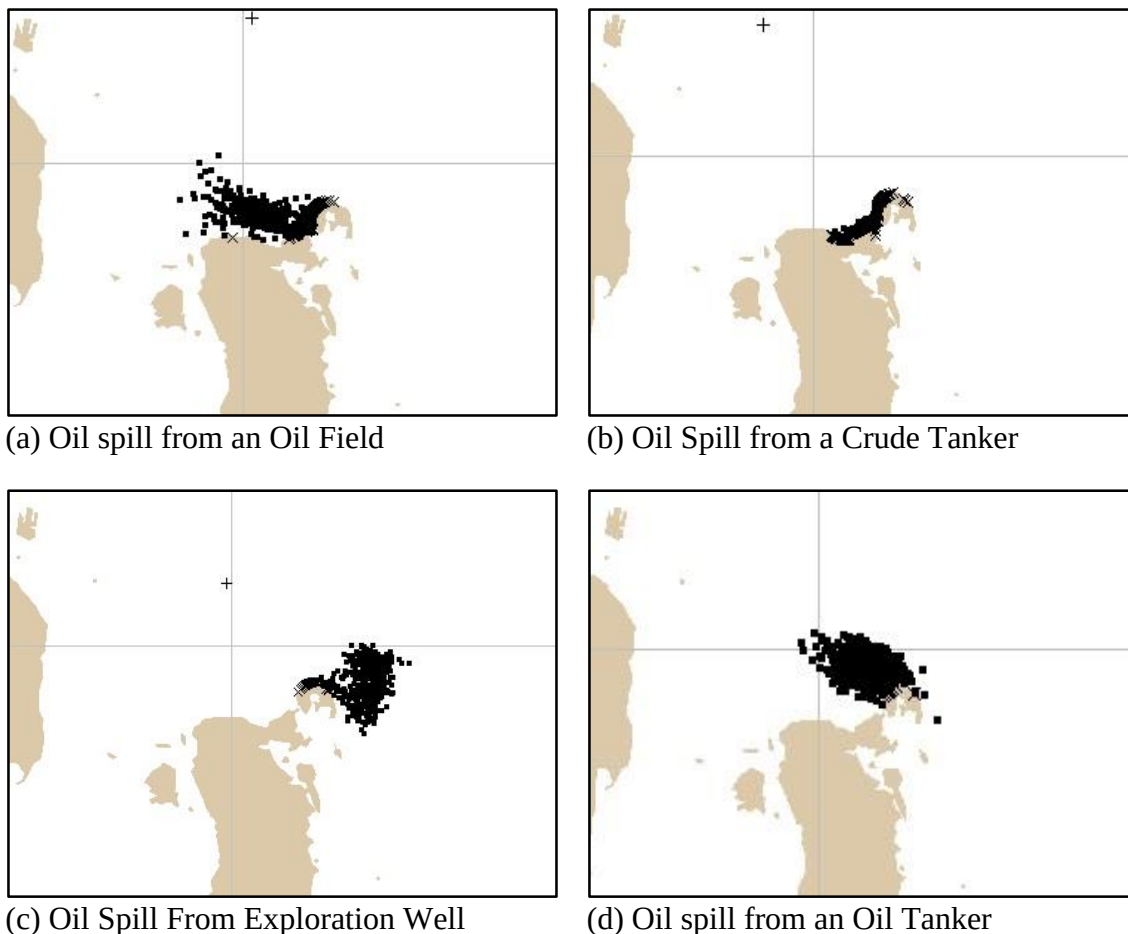


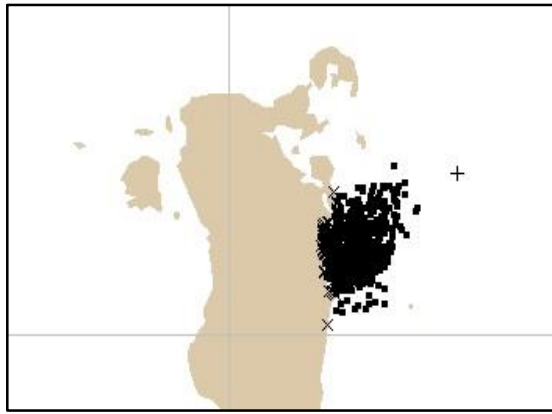
Figure (9)
Some Oil Spill Scenarios which hit Segment B

Table 23, shows the result of the scenarios modeling which hit Segment C. By running the modeling of the forty scenarios, Segment C was hit in 13 scenarios. Which means that the hitting probability of this segment is greater than Segment A and Segment B. This is because of the number of potential spill sources around this segment compared to Segment A and Segment B. There are many ports, oil terminals and

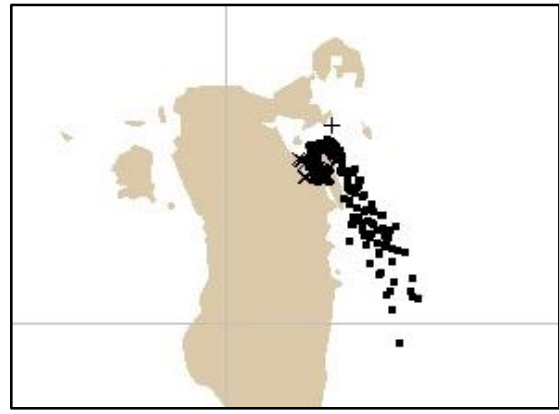
jetties which are considered as potential sources for oil spill because of the ships visiting these coastal facilities. In addition to the underwater pipelines in BAPCO terminal. From the data and information received from Ports and Maritime Affairs, it was noticed that Bahrain Ships Anchorage is located 10 kilometer from the nearest point in Segment C, which add another source of oil spill impacting this segment. In addition the navigational channel is near this segment.

Table (23)
The Modeling Results of Oil Spill Scenarios which Hits Segment C

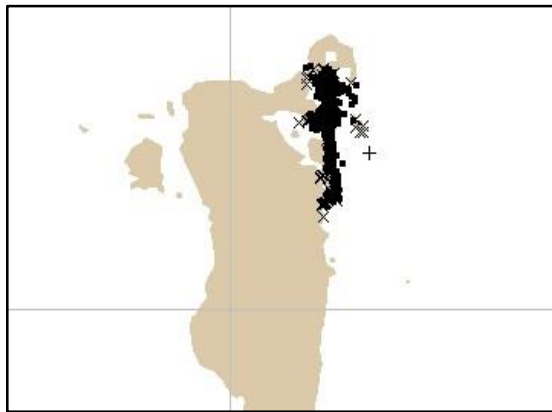
No.	Date	Source	Time to Hit (hr)	Oil Quantity (mt)	Concentration (mt/Km)
1	22-Jan-2016	Ship	35	28.2	0.094
2	25-Feb-2016	Unknown	60	75.0	0.251
3	11-Apr-2016	Ship	5	24	0.080
4	24-Apr-2016	Pipeline	6	4.1	0.014
5	5-May-2016	Exploration Rig	56	110	0.368
6	9-May-2016	Ship	36	70	0.234
7	17-May-2016	Ship	48	134	0.448
8	18-Jul-2016	Ship	22	471	1.574
9	27-Jul-2016	Ship Bunker Tank	8	78	0.261
10	23-Aug-2016	Ship	28	347	1.160
11	14-Sep-2016	Ship Bunker Tank	1	10.3	0.034
12	1-Dec-2016	Ship Bunker Tank	3	15.3	0.051
13	13-Dec-2016	Pipeline	23	26.2	0.088



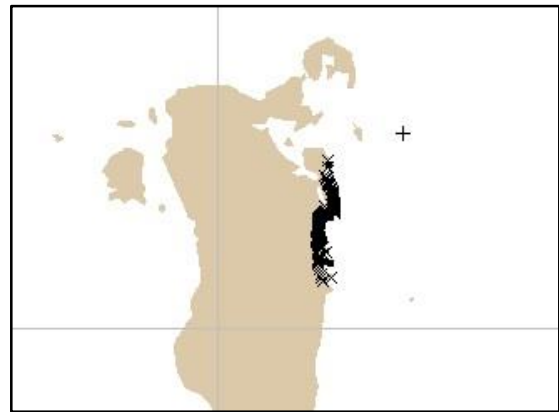
(a) Oil spill from Oil Tanker in Anchorage



(b) Oil Spill from a Ship Bunker Tank



(c) Oil Spill From a Pipeline



(d) Oil spill from a Ship

Figure (10)

Some Oil Spill Scenarios which hit Segment C

As shown in Table 24, out of forty scenarios Segment D was hit in seven scenarios. Therefore, Segment D is less susceptible to oil spill than Segment B and Segment C, but more susceptible to oil spill than Segment A. There are many potential sources of oil spill near this segment such as exploration wells, ships which anchor in the jetties and terminals and ships which anchor in Bahrain anchorage. According to the modeling results, the minimum time required for oil to reach Segment D is 25 hours, while the maximum time is 56 hours. This means that the time required to hit the Segment D is longer than the time required to hit Segment B and Segment C, but it is shorter than the time required to hit Segment A. During the modelling the maximum quantity of oil received by Segment D was 820 metric ton of crude oil released from an exploration well.

Table (24)
The Modeling Results of Oil Spill Scenarios which Hits Segment D

No.	Date	Source	Time to Hit (hr)	Oil Quantity (mt)	Concentration (mt/Km)
1	20-Feb-2016	Exploration Well	48	820	5.398
2	19-Mar-2016	Ship	42	125	0.823
3	26-Apr-2016	Unknown	25	288	1.896
4	23-Jun-2016	Ship Bunker Tank	52	11	0.072
5	8-Sep-2016	Exploration Well	56	144	0.948
6	23-Oct-2016	Ship	50	12	0.079
7	23-Nov-2016	Ship Bunker Tank	52	46	0.303

Figure 11 shows the trajectories of oil slicks and the area impacted by the oil spill incidents which hit Segment D.

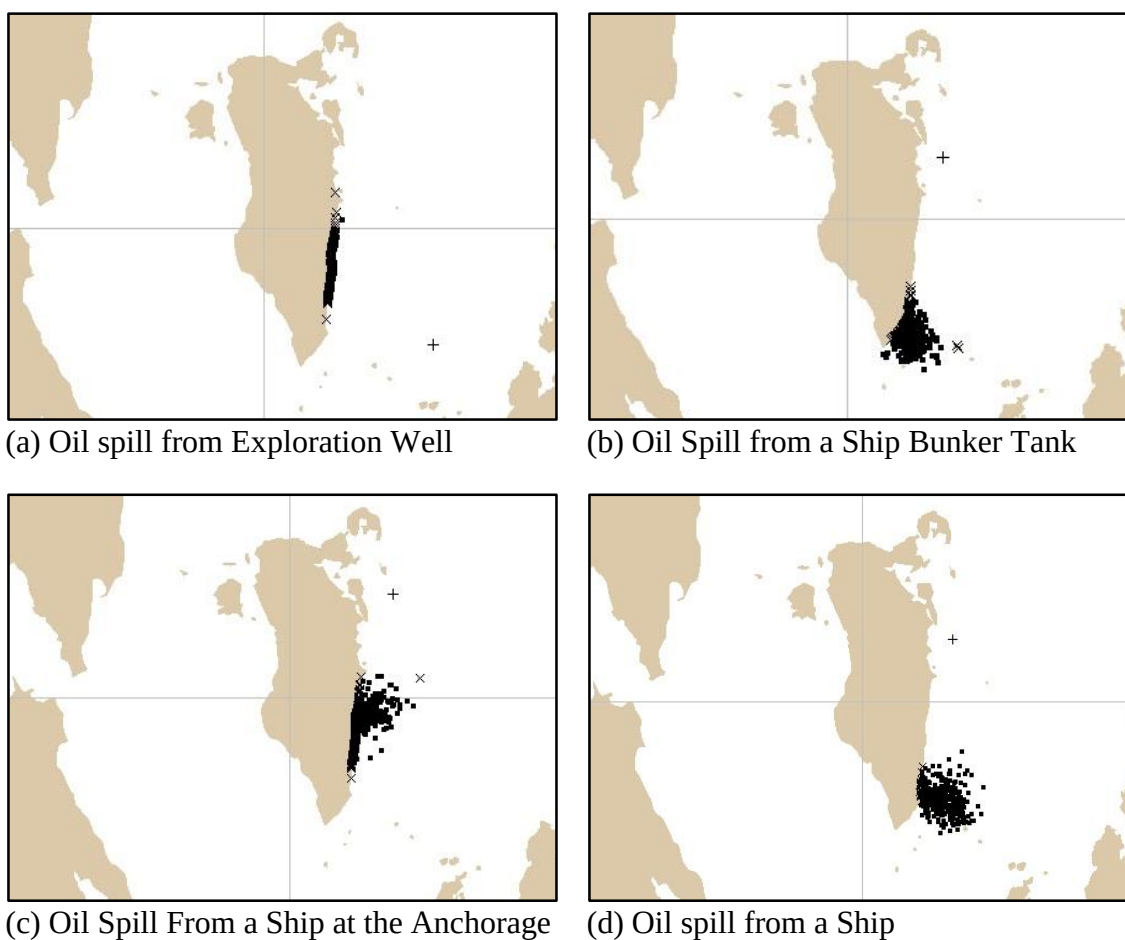


Figure (11)
Some Oil Spill Scenarios which hit Segment D

Segment E is less susceptible to oil spill incidents than Segments A, B, C and D. Out of forty incidents, Segment E was hit in three incidents only. Less number of potential sources of oil spill is available around this segment. Oil exploration projects near this segment are considered as a potential source of oil spill. There is no movement for oil tankers or general cargo ships near this segment. However, ships in the anchorage can be considered as a potential oil spill source which can affect this segment during northern wind with speed not less than 8 knots.

As shown in Table 25, Segment E was hit three times only during the incidents modelling. This make it the less segment susceptible to oil spill incidents. The minimum time required for oil to reach this segment is 11 hours which is longer than the time required for oil to hit Segment A and Segment C and shorter than the time Required to hit Segment B and Segment D. The maximum quantity of oil received by this segment was 175 metric tons. Which is small quantity compared with the oil quantities received by the other segments. This is because of either the long distance between the source and the segment or the maximum possible quantity of oil which can be released form the source. Most of the oil released from ships in Bahrain anchorage will evaporate before reaching Segment E. The maximum quantity which can be released from an exploration rig does not exceed the maximum capacity of the rig bunker tank.

Table (25)
The Modeling Results of Oil Spill Scenarios which Hits Segment E

No.	Date	Source	Time to Hit (hr)	Oil Quantity (mt)	Concentration (mt/Km)
1	6-Mar-2016	Ship	55	150	1.239
2	24-Jul-2016	Exploration Rig	11	175	1.446
3	26-Sep-2016	Exploration Rig	55	75	0.620

Figure 12 shows the trajectories of oil slicks and the area impacted by the oil spill incidents which hit Segment E.

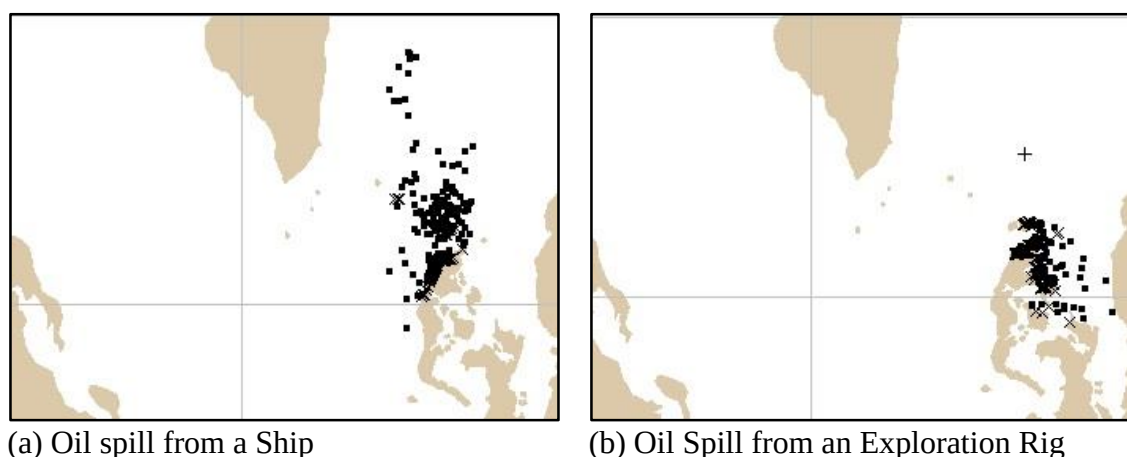


Figure (12)
Some Oil Spill Scenarios which hit Segment E

To facilitate the comparison, the average value of the three exposure metrics was calculated for the five segments. As shown in Table 25, the maximum number of hits was in Segment C while the minimum was in Segment E. The shorter time for oil to reach the segments was in Segment A while the longer time was in Segment B. The highest concentration of oil was received by Segment B while the lowest concentration was in Segment C. The values in Table 26 were presented in Figures 13, 14 and 15.

Table (26)
The Results of the Average Exposure Metrics Obtained from Gnome Model

Segment	Number of Hits	Average Time to Hit (hr)	Average Oil Concentration (mt/Km)
A	6	22	1.083
B	11	48	1.703
C	13	25	0.358
D	7	46	1.360
E	3	40	1.101

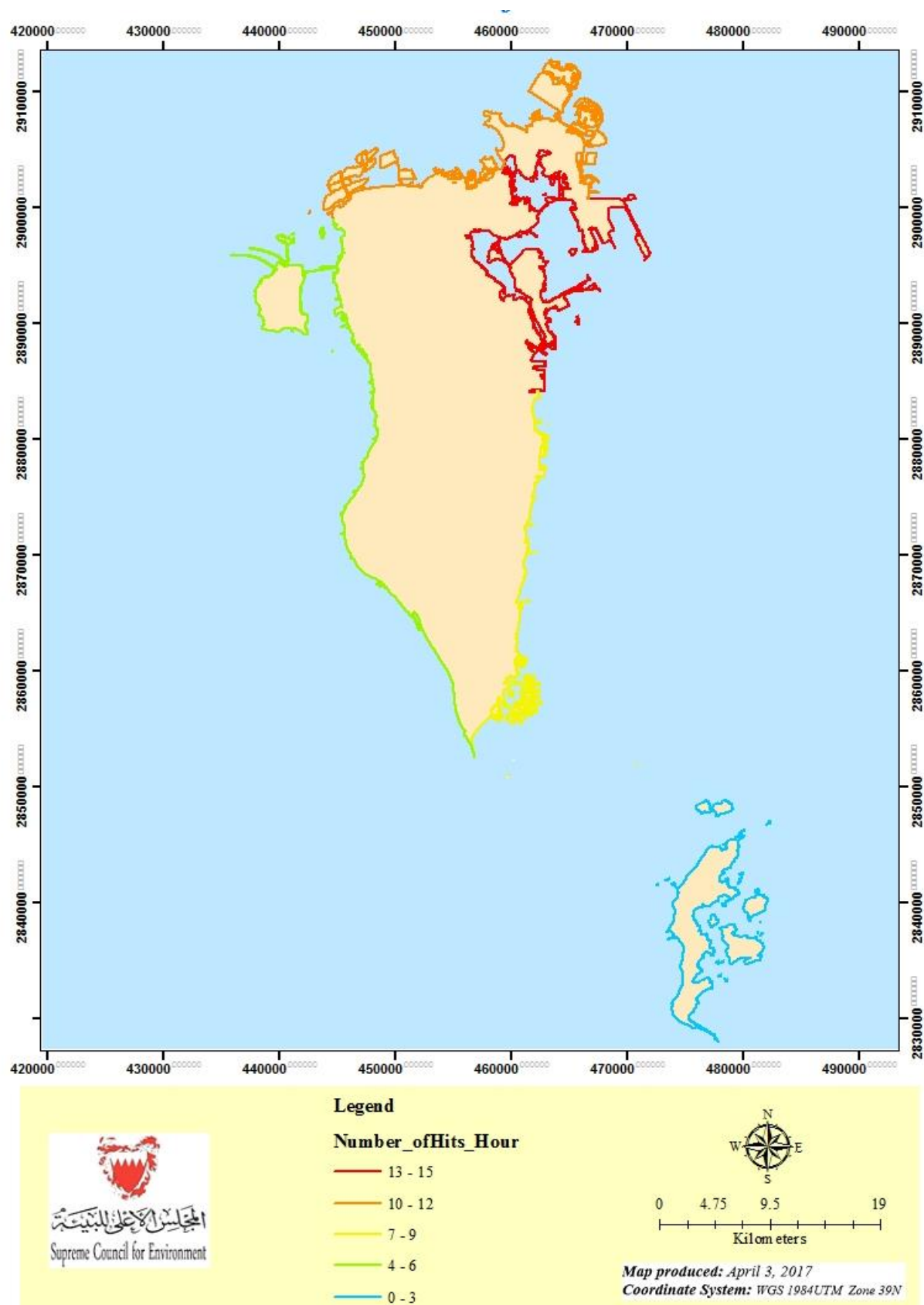


Figure (13)
Number of Hits

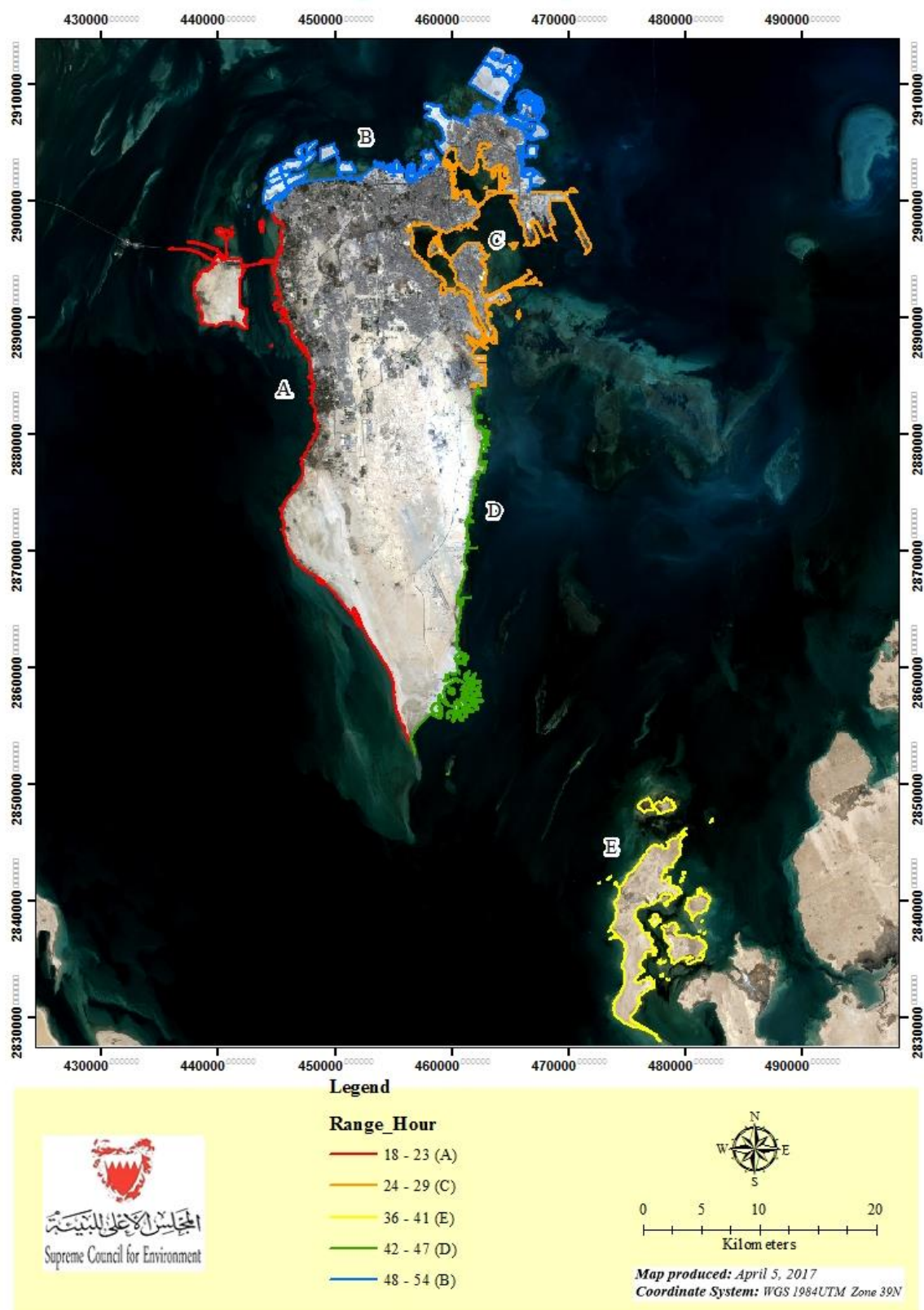


Figure (14)
Average Time to Hit

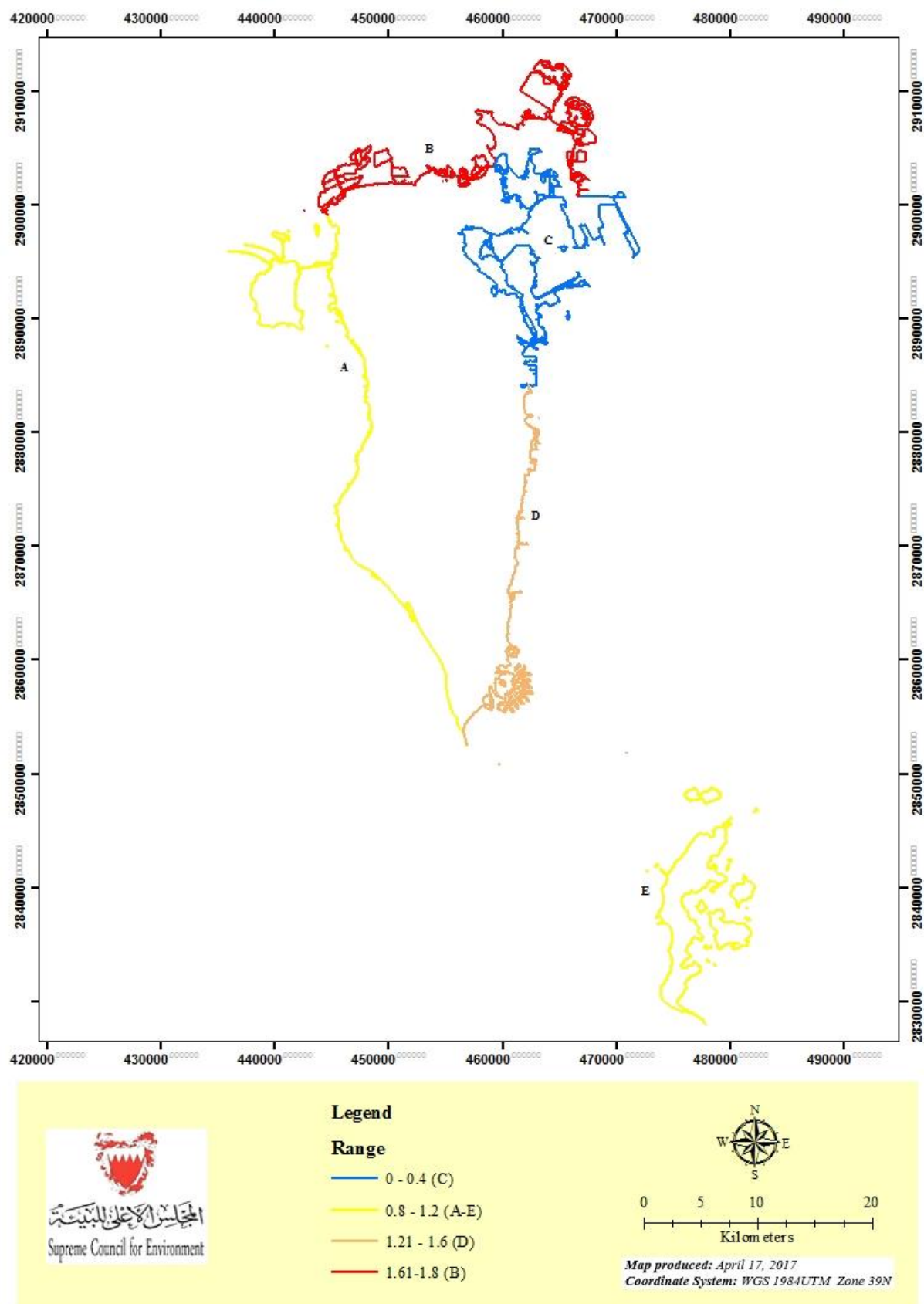


Figure (15)
Average Oil Concentration

To link the modeling results with the compliance of the coastal facilities, the incidents mentioned in Table 2 was classified according to the segments in which the incidents occurred. Figure 13 shows that Segment C is the highest susceptible segment, Segment B is the second highest susceptible segment while Segment E is the lowest susceptible segment to oil spill incidents. As shown in Table 27, the modeling results consist with the historical record of the oil spill incidents occurred between 2006 and 2016. The relation between the modeling results and the compliance of the coastal facilities will be discussed in the following section.

Table (27)
The Compliance of the Coastal Facilities during the Incidents Occurred
between 2006 and 2016

Segment	Number of Incident	Compliance
A	2	Good in 2 incidents
B	6	Good in 2 incidents Poor in 4 incidents
C	14	Good in 3 incidents Satisfactory in 2 incidents Borderline in 5 incidents Poor in 4 incidents
D	1	Good in 1 incident
E	0	-

4.2.2 Discussion of Quantifying the Exposure Level of the Coastal Facilities to Oil Spills

By applying GNOME model to the oil spill incident occurred in Bahrain in 2003, it was found that the modeling results in this study were consistent with the real trajectory of the oil slick. The oil slick almost follow the real path of the slick with slightly difference, by continue running the model for the third day, the oil slick reached Al-Hidd beach on 18 March 2003, which comes in line with information mentioned in the report of the incident. Therefore, feeding GNOME model with the real metrological data of March 2003 enhanced the simulation results conducted in this study. At the end of this part of the study it was concluded that GNOME model can be utilized during oil spill incidents in Bahrain territorial water to simulate the trajectory of the oil slicks, provided that accurate metrological data is fed to the model. These findings agree with the study conducted by Zhao et al. (2015) to validate GNOME model near Kuwait and UAE coastlines, and by Yang et al. (2013) to validate GNOME model during Deep Horizon oil spill incident occurred in the Gulf of Mexico.

After validating GNOME model, the metrics developed by Al Shami et al. (2017) were used in this study to measure the exposure level of the coastal facilities to oil spill incidents. The results of the exposure metrics obtained from the scenarios modeling was used to produce the maps shown in Figures 13, 14 and 15. The produced figures are very important in preparing oil spill contingency plans, determining the protection priorities and allocation of combating equipment and resources during oil spill incidents. Figure 13 shows that Segment C is the highest susceptible segment to oil spill incidents. Therefore, the coastal facilities along this segment are required to increase their preparedness by drawing

up oil spill contingency plans and providing the necessary resources and equipment to prevent and respond to oil spill incidents within their facilities. Table 10 shows that most of the coastal facilities along Segment C are industrial facilities operated by the private sector. As shown in Table 26 during the incidents occurred in Segment C, the compliance of the coastal facilities was good in 3 incidents and satisfactory in 2 incidents only, while it was between borderline and poor in 9 incidents. Therefore, the private sector is required to take more responsibility in strengthen the preparedness of the coastal facilities along this segment and respond oil spill incidents effectively. As described in Figure 13, Segment B is the second highest susceptible segment to oil spill incidents, it was hit 11 times during the scenarios modeling. Therefore, the facilities in this segment shall be given the priority after Segment C in enhancement the preparedness and response to oil spill incidents.

The coastal facilities along Segment B are either tourist, recreational or residential. That means, during oil spill incidents in this segment public beaches, resorts and the properties of the citizens and investors will be impacted. Some of these facilities are operated by the private sector while others are belong the public sector. Therefore, the responsibility to protect these facilities during oil spill incidents are shared between the public sector and private sector.

The compliance of the coastal facilities was poor during the response to 4 oil spill incident occurred in Segment B, it was Good only in 2 incidents. That means that, more effort is required to be exerted by the private sector and public sector to enhance the response to oil spill incident and to strengthen the preparedness in the facilities along Segment B. Segment E as shown in Figure 13 is the lowest susceptible segment to oil spill incident because of less number of potential sources

compared to the other segments like Segment C and Segment B. Only one coastal facilities available in this segment which is Hewar Hotel and resort, other areas along this segment are public beaches. Therefore, minimum resources and capabilities are required to protect this segment. According to the modeling results, the exposure level of Segment A and Segment D is moderate compared to the exposure level of the other segments. They should be given the priority in strengthen the preparedness after Segment C and Segment B. The coastal facilities along Segment A and Segment D are either industrial, recreational or tourist and operated by private and public sectors. Therefore, both sectors share the responsibility of the protection and raising the level of the preparedness in these two segments.

Quick response to oil spill incidents can minimize the impact on the economy and environment. Therefore, the time required for mobilization of equipment and response resources is an important factor in achieving an effective response and minimizing damage (Zhong and You, 2011). Figure 14 classifies the segments according to the average time required for oil to hit the coastlines of the segments. The modeling results show that the oil slicks require shorter time to reach Segment A compared to the other segments. That means, Segment A shall be given the priority in mobilizing equipment and response resources. To ensure rapid mobilization, equipment warehouse shall not be located far from this segment. The average time required for oil slicks to reach Segment C is 25 hours which is longer than the average time to reach Segment A. Therefore, Segment C shall be given the priority in mobilization of equipment and response resources after Segment A. The modeling results show that the oil slicks require longer time to reach Segments B, D and E, so the priority to locate the equipment warehouse near these segments

will be lower than the priority to locate it near Segment A and Segment C. Equipment and response resources shall be mobilized to Segments B, D and E after they mobilized to Segment A and Segment C.

When oil slicks reach shorelines, a lot of effort and resources will be required to clean-up the impacted shorelines. Allocation of response resources shall be based on damage occurred in the shorelines, large quantities of beached oil required a lot of effort, equipment and response resources. Amount of oil present at each location is one of the factors which should be considered during developing shorelines clean-up plans (Owens, 2017).

Figure 15 classifies the segments according to the oil concentration experienced by the segments during the scenarios modeling. Although oil slicks require longer average time to reach Segment B and Segment D, these segments experienced the higher concentration of oil. Therefore, during oil spill incidents it is expected that Segment B and Segment D will experience large quantity of oil. Accordingly, a lot of effort, equipment and response will be required to clean and rehabilitate these segments. During the modeling of the scenarios, Segment C is the highest susceptible segment to oil spill. However, it experience the lowest concentration of oil. Therefore, during oil spill incidents the resources and equipment required to clean-up this segment will be less than what is required to clean the other segments. Segment A and Segment E experienced moderate concentration of oil compared to Segments B, C and D.

4.4 Conclusion and Recommendations

The study first tried to find the answers of the questions related to the available capabilities and current practices in the government and private sector to respond to oil spill incidents. To achieve, the reports of the oil spill incidents occurred in the last ten years and the correspondent oil spill contingency plans have been evaluated. The evaluation revealed that the compliance of the coastal facilities was good in 35% of the evaluated incidents, satisfactory in 9% of the evaluated incidents, while in the remaining incidents was poor and borderline. These results reflect the available capabilities and the current practice in responding to oil spill incidents in both sectors. The study revealed a need in Kingdom of Bahrain to enhance the response of the coastal facilities by raising the compliance of the coastal facilities with the national requirements. This can be achieved by ensuring the availability of the oil spill contingency plans in the coastal facilities in addition to the availability and readiness of the required resources such as equipment and trained response teams to respond effectively to oil spill incidents.

The national legislations and the conventions related to oil spill management have been reviewed in this study. The review showed a need to sign the International Convention on Civil Liability for Bunker Oil Pollution Damage. It also showed a need to update the current national legislations to incorporate the obligations of the regional and international conventions related to the preparation of oil spill contingency plans for ports and oil terminals, provision of ships waste reception facilities and the adoption of appropriate procedures for the determination of civil liability and compensation for damage resulting from pollution of the marine environment. To this point the first objective of the study was achieved.

The second objective of this study was achieved through generating three GIS maps to present the exposure level of the coastal facilities to oil spills. The first map showed that Segment C is the most segment susceptible to oil spill incidents. Most of the coastal facilities in this segments are ports and oil terminals operated by the private sector. In the last ten years 14 oil spill incidents had occurred in this segment, the compliance of the coastal facilities during was good only in three incidents. Therefore, the private sector are required to raise the preparedness level in this segment to enhance the response to oil spill incident. The second generated map showed that the time required for oil to reach Segment A is shorter than the time required to hit the other segments. Therefore, the government sector are required to allocate enough equipment stockpile near this segment to protect the public beaches such as Al-Zalaq beach, Belaj Al-Jazaer Beach, Um Al-Naasan Island and Jedah Island. The third generated map showed that during oil spill incident Segment B is vulnerable to receive more quantity of oil than the other segment. The private sector is required to provide enough quantity necessary to protect the tourist facilities like Reef Islands, Amwaj Islands, Bahrain Bay, and Retz Carlton Hotel from the large quantity oi oil which will be received by this segment during potential oil spill incidents.

At the end of this study it is recommended to:

- Utilize the modeling results and the exposure maps produced in this study to enhance oil spill response in Bahrain particularly in contingency planning, setting protection priorities, allocation and mobilization of equipment and response resources.
- Sign the International Convention on Civil Liability for Bunker Oil Pollution Damage.

- Update the current national legislations to incorporate all of the obligations of the regional and international conventions related to oil spill management.
- Strengthen the communication during oil spills incidents between the competent parties in both sector by developing a national communication system to enhance the notification and reporting processes during oil spill incidents
- Utilize the study results in the future studies related to the vulnerability and producing sensitivity maps of Bahrain coastlines.
- Conduct the same study for the other countries in the region.

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الخلاصة

تعتبر حوادث انسكاب النفط واحدة من الكوارث البيئية على البيئة البحرية. وقد نالت حوادث انسكاب النفط اهتمامًا عالميًا بسبب آثارها السلبية على البيئة البحرية والمجتمع والاقتصاد. وقد أدت حوادث انسكاب النفط التي وقعت في مملكة البحرين إلى إلحاق أضرارًا بالبيئة البحرية والمرافق الساحلية الحيوية. ويرجع ذلك إلى احتمال عدم استجابة الجهات المعنية في القطاعين الحكومي والخاص لهذه الحوادث بصورة فعالة ومنسقة وفي الوقت المناسب. إضافة إلى احتمال انخفاض مستوى الاستعداد والتأهب والاتصال بين الجهات المعنية أثناء تلك الحوادث.

وتهدف هذه الدراسة إلى اختبار وتقييم عملية إدارة حوادث انسكاب النفط في مملكة البحرين وتحديد مستوى تعرض المنشآت الساحلية لهذه الحوادث وتعزيز الاستعداد والاستجابة لهذه الحوادث في مملكة البحرين.

ومن خلال هذه الدراسة تمت مراجعة التشريعات الوطنية والاتفاقيات المتعلقة بإدارة حوادث انسكاب النفط والتقارير الخاصة بالحوادث التي وقعت في مملكة البحرين خلال السنوات العشر الماضية، كما تم استعراض وتقييم خطط الطوارئ المتعلقة بتسرب النفط من خلال استخدام مؤشر الجودة. ولتحديد مستوى التعرض للمرافق الساحلية للانسكابات النفطية، تم التحقق من نموذج (GNOME) وتطبيقه على أربعين سيناريو لحوادث انسكاب نفطي افتراضية.

وقد أظهرت نتائج النمذجة أن احتمالية تعرض المرافق الساحلية في الحد وسترة لحوادث انسكاب النفط أعلى من احتمالية تعرض المنشآت الساحلية في المناطق الأخرى لمثل هذه الحوادث. كما أظهرت النتائج أن المرافق الساحلية في السواحل الشمالية معرضة لتلقي كميات أكبر من النفط مقارنة بالمرافق الساحلية الأخرى. إلا أن الوقت اللازم للوصول للنفط إلى الساحل الشمالي أطول مقارنة بالسواحل الأخرى لمملكة البحرين. وعليه، توصي الدراسة باستخدام نتائج النمذجة المذكورة لتعزيز الاستجابة لحوادث انسكاب النفط، وذلك من خلال الاستعانة بها أثناء التخطيط لحوادث انسكاب النفط، وتحديد أولويات الحماية وتوزيع ونقل موارد الاستجابة الموجودة في القطاعين الحكومي والخاص إلى موقع الحادث. ومن خلال استعراض التشريعات والاتفاقيات الوطنية المتعلقة بإدارة الانسكاب النفطي تبين أن هناك حاجة إلى تحديث التشريعات الوطنية الحالية لإدراج التزامات ومتطلبات الاتفاقيات التي تم استعراضها ضمن التشريعات الوطنية. كما بينت عملية تقييم تقارير حوادث الانسكاب النفطي وخطط الطوارئ أن هناك حاجة لتعزيز قدرات الاستجابة الحالية وعملية الاتصال فيما بين الجهات المعنية أثناء حوادث انسكاب النفط. ولذلك، توصي الدراسة بوضع نظام وطني للاتصال لتعزيز عمليات التبليغ عن حوادث انسكاب النفط.

جامعة البحرين

برنامج البيئة والتنمية المستدامة

كلية العلوم



تكامل الجهود لتعزيز الاستجابة لحوادث الانسكابات النفطية في مملكة البحرين

بحث مقدم استكمالاً لمتطلبات الحصول على درجة الماجستير في البيئة والتنمية المستدامة

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