RISK ASSESSMENT IN PORTS

Contingency Plan for the port of Huelva

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This presentation deals specifically with the Complementary Studies for the Contingency Plan of the port of Huelva (Spain) carried out at the *CEDEX* Maritime Engineering Department between 2004 and 2006. These works encompass the complementary studies established in the Royal Decree 253/2004 coming from the Spanish government in order to accomplish the commitment made to the International Convention OPRC 90, which sets the Oil Pollution Emergency Plans as the main tool to combat oil pollution at sea. The Complementary Studies hereafter described cope with the environmental features of the port and its surroundings and also with the nature and fate of the potential oil spills in its terminals. As a result, they are a major support to the Operational and Response Projects of the Contingency Plan for the port of Huelva.

1. ANTECEDENTS

Exxon Valdez

Exxon Valdez grounded on Bligh Reef in Prince William Sound, Alaska, on 24 March 1989. About 37,000 tonnes of Alaska North Slope crude escaped into the Sound and spread widely.

There was some limited dispersant spraying and an experimental in-situ burn trial during the early stages of the spill, but at-sea response concentrated on containment and recovery. Despite the utilisation of a massive number of vessels, booms and skimmers, less than 10% of the original spill volume was recovered from the sea surface. The oil subsequently affected a variety of shores, mainly rock and cobble, to varying degrees over an estimated 1,800 km in Prince William Sound and along Alaska's south coast as far west as Kodiak Island.

Shoreline cleanup techniques included high pressure, hot water washing, which was carried out on a scale never attempted previously or subsequently. There were also some relatively large scale bioremediation trials that gave mixed results. About 1,000 sea otters are known to have died, and over 35,000 dead birds were retrieved. Finally, there were particular efforts to protect fisheries, for example with booming of salmon hatcheries.

OPRC 90

In July 1989, four months after the Exxon Valdez accident, a conference of leading industrial nations in Paris called upon IMO to develop further measures to prevent pollution from ships. This call was endorsed by the IMO Assembly in November of the same year and work began on a convention aimed at providing a global framework for international co-operation in combating major incidents or threats of marine pollution.

In summary, **the Parties to the Convention are required to establish measures for dealing with pollution incidents, either nationally or in co-operation with other countries**. To overcome this objective, the Article 3 of the Convention establishes the Oil Pollution Emergency Plans. Here is an extract of the Article 3:

> "3.1) …ships are required to carry a shipboard oil pollution emergency plan…
> 3.3) …authorities or operators in charge of… sea ports and oil handling facilities… are required to have oil pollution emergency plans or similar arrangements which

> must be co-ordinated with national systems for responding promptly and effectively to oil pollution incidents”

In addition, Article 6 sets that “Each Party shall establish a National system for responding promptly and effectively to oil pollution incidents…, including… a national contingency plan for preparedness and response…” (Art. 6.1b). Besides, the convention calls for the establishment of stockpiles of oil spill combating equipment, the holding of oil spill combating exercises and the development of detailed plans for dealing with pollution incidents (Art. 6.2).

Spanish National Contingency Plan

In order to accomplish the Convention (adopted in Spain in 1993) the Ministry for Development released the Order of February 23rd 2001 that approved a very detailed *Oil Pollution National Contingency Plan* as well as it established the “Internal Contingency Plans” as the Emergency Plans to be had by the entities mentioned in the art.3 of the Convention (ships, operators, etc).

The contents of these plans where fairly set although it did not require any deadline.

Prestige

During the afternoon of Wednesday 13 November 2002, the tanker PRESTIGE, carried with a cargo of 77,000 tonnes of heavy fuel oil, suffered hull damage in heavy seas a few miles west from Cape Finisterre on the NW of Spain. Although attempts were made by salvers to minimise the stresses on the vessel, she broke in two early on 19 November some 170 miles west of Vigo, and the two sections sank some hours later in water 3,500 m deep.

In all, it was estimated that some 63,000 tonnes were lost from the PRESTIGE.

Owing to the highly persistent nature of Prestige’s cargo, the released oil drifted for extended periods with winds and currents, travelling great distances. Oil first came ashore in Galicia, and continued travelling over the following weeks, going into the Bay of Biscay and affecting the north coast of Spain and the Atlantic coast of France, as far north as Brittany.

A major offshore cleanup operation was carried out using vessels from Spain and nine other European countries. The response, which was probably the largest international effort of its kind ever mounted, was hampered by severe weather and by the inability of those vessels that lacked cargo heating capability to discharge recovered oil. Over a thousand fishing vessels also participated in the cleanup in sheltered coastal waters and during favourable weather. As some of the oil moved into French waters, control of a reduced at-sea recovery operation passed to the French authorities.

Though the OPRC Convention worked properly, there still were some points to enhance. For instance, the Spanish public opinion got in anger due to the authorities doubts during the decision-making process.

Royal Decree 253/2004 of February 13th 2004

Although the above mentioned Local or Internal Plans would not have been activated after the pollution from the tanker, the Spanish authorities hurried as the global did after the Exxon Valdez.

This Royal Decree arrived 15 months after the Prestige's catastrophe to extend the scope and minimum contents of the Internal or Local Contingency Plans that every ship, operator, etc. must have. These plans are known in Spanish as *PICCMA*, and they are described below.

2. CONTENTS OF A *PICCMA*

As it was said before, the general scope and the main contents of these Plans were fairly set on the Order of February 23rd 2001 and hereafter are summarized. However, there were some novelties, like the deadline of 6 months after it came into force and the complementary studies to give support to the plan itself.

Concerning the **scope**, the *PICCMA* is broadly compulsory for every company, terminal or port authority involved with oil loading or unloading, handling and bunkering.

With reference to the **contents**, it must have at least an **Operational Project** that establishes the main organizational aspects, and a **Response System Project** that describes the equipment, preparedness and training necessary to overcome the objectives set by the *OPRC* Convention (see above).

Annexed to these main parts, and with the aim of giving support to the Response System project, the decree listed a set of **Complementary Studies** coping with the ecological, meteorological and oceanographic variables in the area potentially affected by an oil spill, along with the fate of oils already spilled. In words of the Decree, these studies have a double objective: on the one hand, to identify and determine the risk of incidents; on the other hand, to analyse the fate and effects of oil spills under different environmental conditions. The Complementary Studies should at least include the following aspects:

I. General Description of the Environmental Conditions in the Zone of Influence of a Terminal:
   - I.1. Geographic location and morphologic description of the coast;
   - I.2. An important number of exhaustive studies regarding climate (both atmospheric: winds, temperatures, and oceanographic: waves, water, currents, etc);
   - I.3. Fisheries and aquiculture;
   - I.4. Sensitive and protected areas;
   - I.5. Touristic areas;
   - I.6. Hydrology.

II. Study for the Fate and Effects of the Potential Oil Spills:
   - II.1. Identification and description of the incidents with a major risk of producing an oil spill, including the location of the spots where this risk is greater;
   - II.2. Calculation of the trajectories of an oil spill at every terminal and location of the coastal areas potentially affected;
   - II.3. Description of the spill weathering, taking into account the physical and chemical properties of the product, and under different environmental conditions;
   - II.4. Location and description of the natural barriers or booms that could act as an obstacle to the oil slicks;
   - II.5. Location of the places where contaminants could be driven in order to recover them and accesses to those places.

Although not a piece of the response or preparedness systems, the studies of Section I are fundamental since they will be used as the data source to include in the determination of risk, fate and effects of the oil spills. Regarding the Section II, it is essential since some of its studies constitute a real part of the Contingency Plan.

3. THE PORT OF HUELVA INTERNAL CONTINGENCY PLAN

The Port of Huelva is located in the South Atlantic coast of the Iberian Peninsula, at the centre of the Gulf of Cádiz. Its most important feature is that it takes advantage of the coastal dynamics at the Gulf, which formed a 10 km length channel at the river mouth of the system Tinto – Odiel that shelters all the port facilities with the exception of an external monobuoy.

Close to the port are the Doñana Natural Park at the East and the Portuguese border at the West. Those surroundings have a great natural value, particularly due to the number of quality beaches that go from the Cape San Vicente in Portugal to the city of Cádiz. Only 45 minutes from Huelva and joined by the highway is the known city of Sevilla and the region of the Portuguese Algarve.

Figure 1. Vicinity of the port of Huelva (left) and gulf of Cádiz (right)

Concerning the port facilities, the most important are La Rabida refinery (owned by CEPSA) and some chemical and mineral industries that move both liquid and solids bulk cargos.

In order to accomplish the *PICMMA* requirements, several of those companies decided to join as a whole, given the proximity between them. This group was coordinated by the port of Huelva and it would share the combating equipment and coordination teams and management.

CEDEX Commission

The Port Authority of Huelva commissioned *CEDEX* the main parts of the Complementary Studies: the General and Environmental Description (Section I) was entirely commissioned, while for the Section II, it comprised only the parts (II.1) to (II.3). However, for the other two parts some succinct guidance was inserted as the conclusions of the official reports delivered to the client.

Regarding the preliminary studies (Section I “Environmental Variables”), it was necessary an extensive work that included documents revision, field data surveys and numerical modelling (with *MIKE 21 HD*) for the calculation of the current fields due to the presence of tides and river discharges.

To carry out the first subsection of the Section II (“Identification of spills”) some international studies on spill events statistics were gathered so that spill rates and volumes could be assigned to the potential incidents. After, the type and location of the most probable incidents were determined through the Poisson distribution. Finally, the study set the criteria for selecting the spill incidents that would be modelled.

The “Study of Trajectories” (II.2) was accomplished starting from the information and the data coming from the Section I, and making use of the numerical model *MIKE 21 PA/SA*. Its main result was the “Atlas of trajectories”, a tool consisting of 890 maps that could be used in case of a real oil spill. Besides, and using simple assumptions, the probability of being affected by a spill was calculated for each surrounding area of interest.

Concerning the oil weathering (III.3) the “Study of weathering” comprised the use of a numerical model (*ADIOS 2*) to simulate the fate of two crude oils and two oil products in three different weather conditions each, giving a total of 12 scenarios. Such a difference with the number of trajectories comes from the lower number of products and their similarity on the one hand and from the independence of the fate on the wind and wave direction on the other hand.

The results of these two latter parts constitute an essential source of information when designing the spill countermeasures as well as the strategy of fight. Hence, although the last two parts (II.4 and II.5) were not commissioned to CEDEX and thus carried out, some guidance was given within the official reports delivered to the client.

4. ENVIRONMENTAL STUDIES

As previously said, the Environmental Studies do not represent an essential part of the PICCMA, though they are fundamental since they constitute the source of data needed to accomplish the studies of the Section II.

The environmental description was performed in two parallel approaches. Firstly, the parts I.1 and I.3 to I.6 consisted of exhaustively gathering information already prepared by various geographical, biological or social sources. Given its influence on the fate of an oil spill, the part I.2 was treated in a separate deeper way, including field surveys and numerical modelling.

General description

This work concluded with the report “*General description on the environmental conditions*”, released in October 2004. Along with an exhaustive description of each considered variable, the report contains a wide set of maps covering the following information:

- Geography
- Sensitive, protected or special areas
- Fisheries and aquiculture
- Touristic areas
- Hydrology

The Figure 2 shows two of these maps, regarding some special areas (Sites of Community Interest) and the industrial areas of the port.

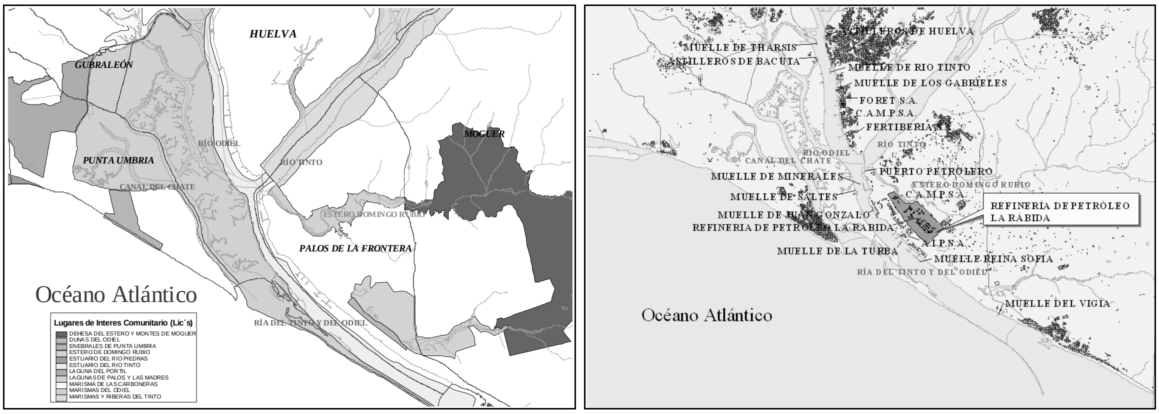

Figure 2. Sites of Community Interest (left) and Industrial areas (right)

Climate

The results from these studies were grouped in the report "*Study of the meteorological and oceanographic conditions*", released in July 2005. Below are described the main tasks carried out.

Winds

Winds were studied in two scopes: on the one hand, the **local winds**, because they have a major influence on the drift of the oil slicks, and on the other hand the **regional winds**, that influence the circulation patterns on the Gulf of Cádiz, which have to be added to the tidal currents in the harbour outer area).

Information regarding both local and regional winds was gathered from two different data bases:

- Visual observations from ships on route
- Fixed weather stations managed by local or autonomic environmental bodies.

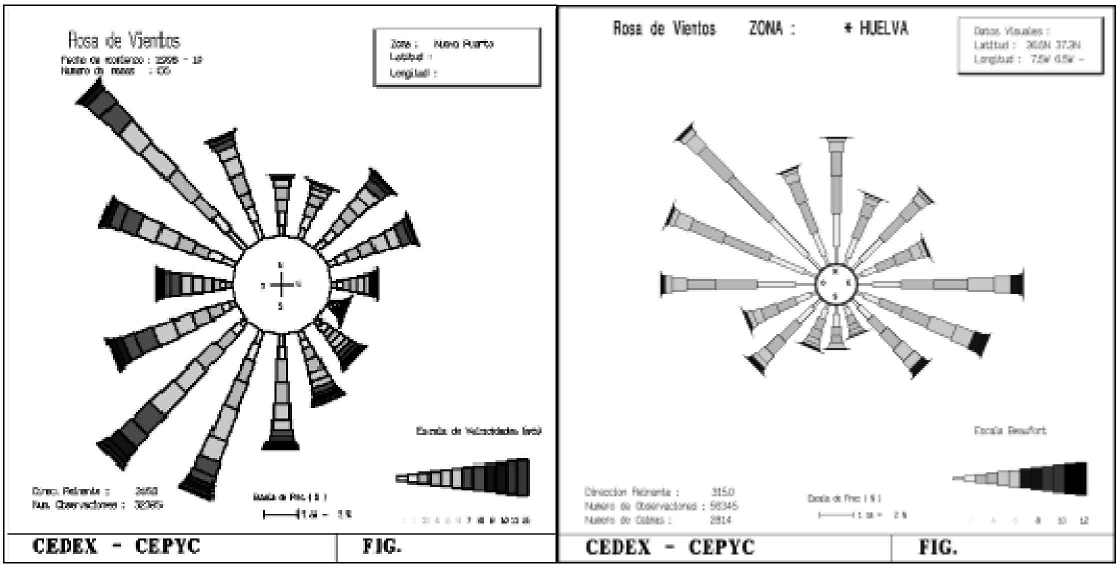

Figure 3. Local winds (left) and winds at the Gulf (right)

Waves, Tides and Currents

Waves only affect the dispersion in the first phases of weathering, thus it was not considered as important as the other two factors in the fate of the spill. However, since it can generate several difficulties when combating an oil spill, it had to be taken into account when designing the Response Project.

In this location, particularly at the inner zone, **tides** were considered of great importance on the fate of the spill. On the one hand, they generate tidal currents, which can go until 2 m/s during some phases of the spring tides. On the other hand, by increasing the water levels they help the spill to reach high land and waters. Given the relevance of the hydrologic system in the area close to the port of Huelva (marshes are predominant), this can produce an important degree of contamination if the pollution is drifted towards that system and the water levels are high.

The **currents** are, along with the winds, the main factor involved with the spill trajectory. They can be generated by tides, circulation patterns (global circulation plus regional winds) and river discharges. Given its importance, the numerical modelling of the hydrodynamics of the port of Huelva was considered necessary in order to use it for the Study of Trajectories.

Numerical modelling of currents

Several scenarios were simulated using the numerical model *MIKE 21 HD* (from the Danish Hydraulic Institute, DHI) and supporting on the field survey measurements.

Given the special features of the area (the channel with the main land terminals and an open harbour with a deployment area, a monobuoy terminal and pipeline) two domains were simulated almost independently.

The **inner domain** comprised the former port of Huelva (located at the mouth of the river Odiel), the last 4 km of the river Tinto and the Huelva channel. Regarding the scenarios simulated, 3 different tides were considered (spring, medium and low) at the inner domain, with only one river discharge.

The Figures 4 and 5 show the results of the currents field for one particular scenario of the inner domain.

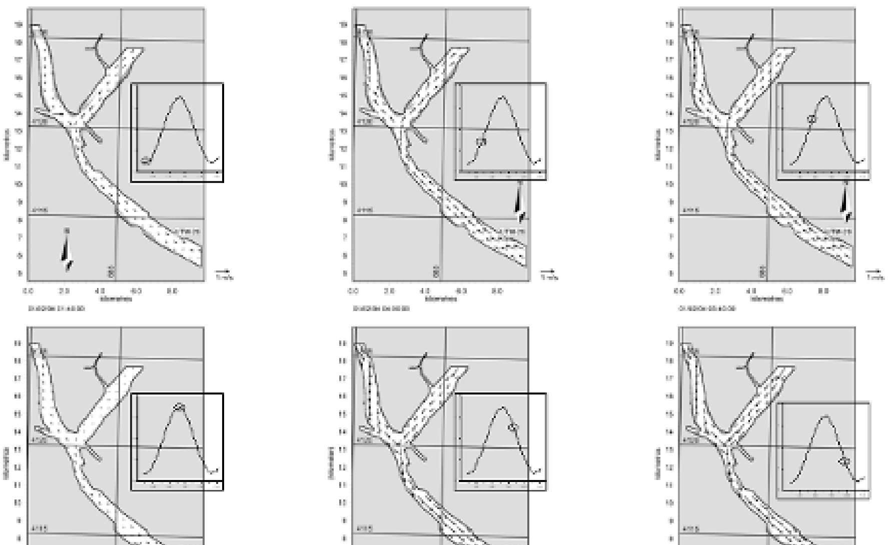

Figure 4. Currents at the inner domain in 6 different phases of the tide.

As it can be seen, the currents were highly influenced by the tidal phase, as it was expected, though there were some phase shifts near the confluence between the rivers Tinto, Odiel and the channel of Huelva, which had to be studied in depth given their special features. The Figure 6 shows a more detailed current near this confluence.

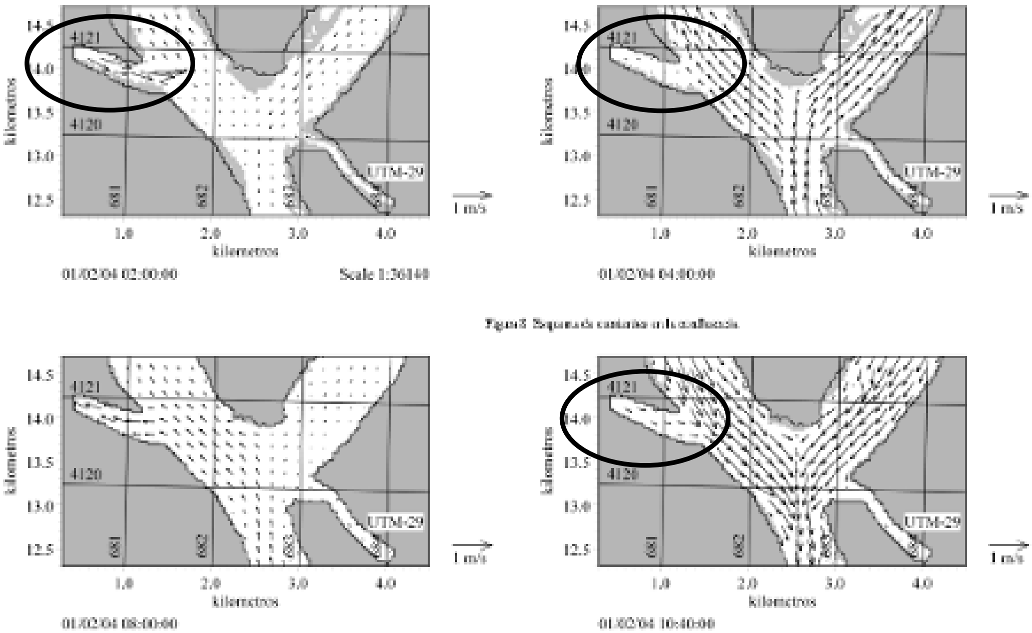

Figure 5. Shifted currents at the *Caño del Burro* (encircled).

The **outer domain** comprised the mouth of the Huelva channel and the outer harbour, which contained the monobuoy and the deployment area.

Regarding the scenarios, not only the tides were considered, but also the circulation patterns at the Gulf, with two scenarios for each possible direction and one for the calms, giving a total of 5 scenarios for the outer domain.

The Figures 6 and 7 show the results of the currents field for one particular scenario of the outer domain.

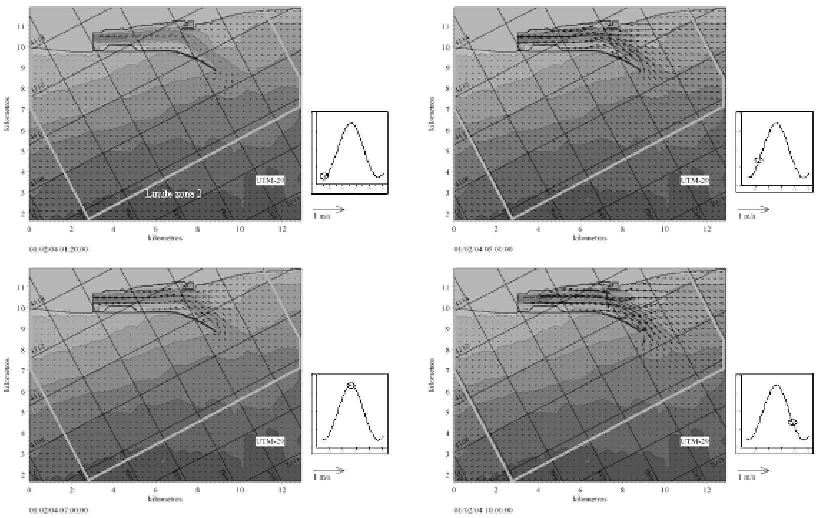

Figure 6. Currents at the outer domain in 4 different phases of the tide.

As for the inner domain, a study in depth had to be accomplished for the port entrance. As expected, it acted like a pump that pumped or suctioned the waters, thus avoiding the potential oil spills to reach the coast (without considering the winds effects).

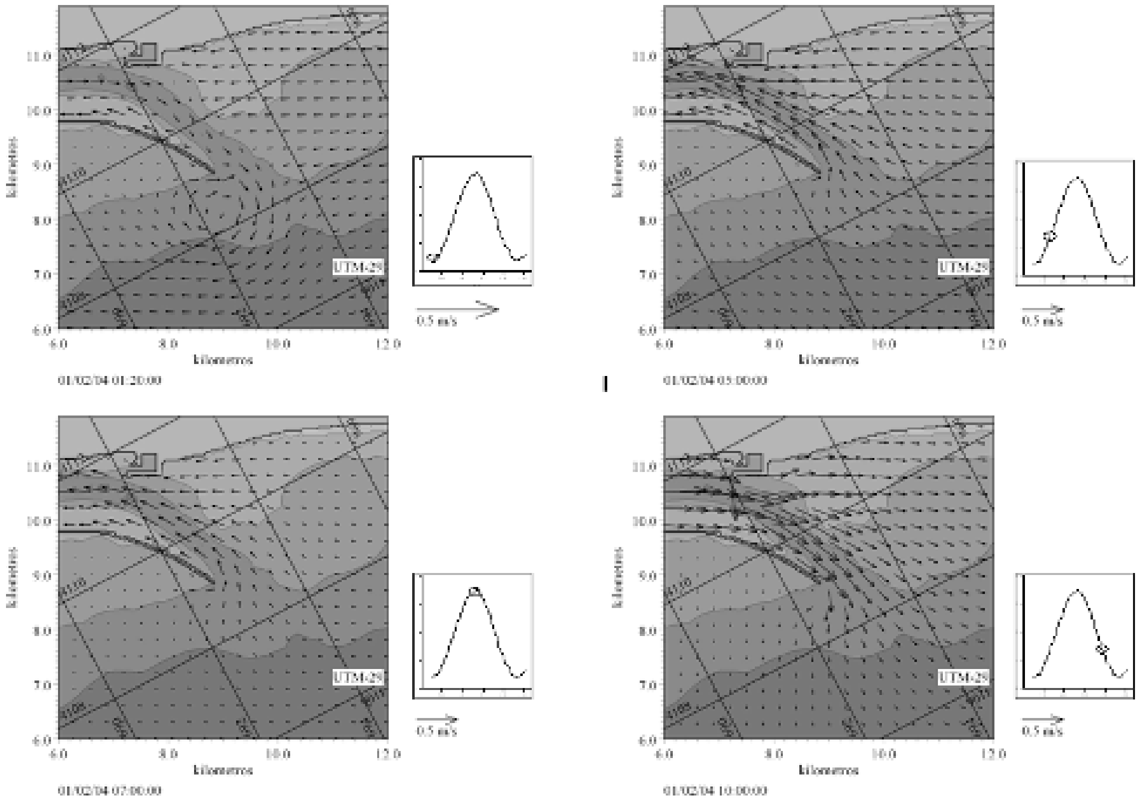

Figure 7. Details of the currents at the port entrance in 4 phases of the tide

5. FATE AND EFFECTS OF THE POTENTIAL OIL SPILLS

Spill features

This part is related with the identification and location of the potential incidents to be considered in the following studies of trajectories and weathering. Also, it aims to the estimation of the probability of occurrence of such incidents, and whenever possible, to the estimation of the volume spilled.

Spill Identification

This part was accomplished after the collection of the information reported by the companies involved with the PICCMA (Port Authority, CEPSA, DECAL Spain, Fertiberia, etc.) with at least information regarding the terminals used, the oil movements and, if possible, the spill events, in order to identify the potential oil spills at the port.

As a brief result, the following list summarizes those potential incidents and their locations:

- The loading and unloading of petrol tankers at the monobuoy and the docks of Torre Arenillas, DECAL and Reina Sofía
- The bunkering at the dock of Levante
- The break of the submarine pipeline
- A moving ship (different locations)
- A ship anchored at a berth at the docks already listed

Estimation of probabilities of occurrence (I). Documents of reference

Taking into account that the information about the incidents produced at a specific site or port results insufficient to estimate the probabilities of incident and the volumes spilled, it was considered necessary to collect as many wide-scoped statistics as possible. Some of then are listed below:

- Anderson, C.M., LaBelle, R.P. (2000). *Update of Comparative Occurrence Rates for Offshore Oil Spills*. Spill Science & Technology Bulletin, Vol. 6, No 5/6, pp. 303-321
- The International Tanker Owners Pollution Federation Ltd (ITOPF), 2004. *Oil Tanker Spill Statistics: 2003*
- Maxim, L.D., Niebo, R.W. (2001). *Oil Spill Analysis for North Slope Oil Production and Transportation Operations*. Appendix B of *Environmental Impact Assessment (EIS) for Renewal of the Federal Agreement and Grant of Right-of-Way for the Trans-Alaska Pilepine System (TAPS)*
- Gibson, P. (2002). *Oil Spill in U.S. Navigable Waters.* American Petroleum Institute

Estimation of probabilities of occurrence (II). Methodology

The following list describe the procedure used to estimate the **probability of occurrence of exactly *n* incidents of a particular type** (load, unload…) **and category (size) in a characteristic period *T***.

The characteristic period was assumed of 10 years. The methodology consisted of:

1. Determine an **occurrence rate** for every incident of a particular type and category (for instance, the number of incidents involved with loading activities resulting in a spill of more than 1000 barrels).
2. Determine the value of a **reference variable** for each particular type and the characteristic period (for example, the barrels moved)
3. Multiply the mentioned values to obtain the **mean number of incidents produced in the characteristic period**. This value is μ.
4. By assuming a Poisson distribution to that variable, the **probability of occurrence of exactly *n* incidents of a particular type** (load, unload…) **and category (size) in a characteristic period *T*** would be:

$$\Pr(n) = e^{-\mu} \frac{\mu^n}{n!}$$

The probability of no occurrence of any spill would be:

$$\Pr(n = 0) = e^{-\mu}$$

The probability of occurrence of any spill would be its complementary value:

$$\Pr(n > 0) = 1 - \Pr(n = 0) = 1 - e^{-\mu} \approx \mu \text{ for } \mu > 0.01$$

Estimation of probabilities of occurrence (III). Results

Considering the data coming from the documents of reference previously mentioned and the volumes of oil products moved by the different companies at the port of Huelva, it was possible to calculate the probability of occurrence of any incident (n > 0) and size (whatever volume spilled) depending on the location. The Table 1 shows that probabilities for incidents with petrol tankers:

Table 1. Probability of occurrence of any incident (*n* >0) for any size

	Monobuoy	Torre Arenillas	Reina Sofía	DECAL
Probability	0.99999999999	0.9770	0.5788	0.8368

This table points out that it is almost definite that any spill will occur. Hence it does not provide sufficient information. The Table 2 shows the probability of occurrence of exactly *n* incidents, depending on the location, for every type and size of the spill, also for incidents involved with tankers.

Table 2. Probability of occurrence of exactly *n* incidents for any size and type spill

MONOBOYA	n	10	15	20	30	40
	Prob	0,00122	0,02148	0,07309	0,02688	0,00035
PETROLEROS	n	1	2	3	4	5
	Prob	0,08670	0,16357	0,20573	0,19407	0,14645
REINA SOFÍA	n	1	2	3	4	5
	Prob	0,36418	0,15743	0,04537	0,00981	0,00170
DECAL ESPAÑA	n	1	2	3	4	5
	Prob	0,29581	0,26816	0,16206	0,07345	0,02663

Volumes of spill to modelize

Considering the precedent results, the main parts involved in the Contingency Plan (port authority, CEDEX and the port companies), met and agreed the following volumes and rates for all the types of spill identified:

- Load / unload.............. nominal flow rate in 10 min (Q_{max}; t = 10 min)
- Bunkering .... nominal flow rate in 10 min (Q_{max}; t = 10 min)
- Moving ships:
  - Petrol tanker .... 1/6 cargo + ½ tanks in t = 1 hour
  - Other vessels .... ½ Tanks in t = 1 hour
- Moored ships.. = moving ships

Study of trajectories

Model features

This study was accomplished starting from the information and the data coming from the Section I (see item 4), and making use of the numerical model *MIKE 21 PA/SA*. The model calculates the movement of an oil particle at the water surface as the addition of its spreading and diffusion and the slick drift due to the winds and currents (see Fig. 8).

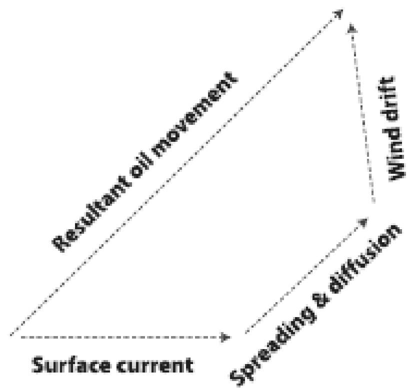

Figure 8. Oil slick resultant movement

Regarding the drift, the model considers that particles at the sea surface move approximately at a speed that is the sum of the currents velocities plus the 3 % of the wind speed:

$U_{drif} = c_c \times u_c + c_w \times u_w$

being the subscripts '*c*' for the currents and '*w*' for the winds. The coefficients values where c_w = 0.03 (= 3 %) and c_c = 1 respectively.

For this study, u_c were taken from the current field calculated with the numerical model *MIKE 21 HD*, and u_w were the local wind velocities taken from the data sources referred to at the item 4.

Modelled scenarios

In order to obtain an effective tool in combating oil spills, the study of trajectories consisted of deterministically simulate a large number of scenarios that combined incident type, current field and local winds.

Regarding the first (**incidents**), 14 different spills were simulated from 12 different spill locations. The types of spills were: load/unload bunkering, docked ship, moving ship and spill from pipeline. The 12 locations are shown in the Figure 9.

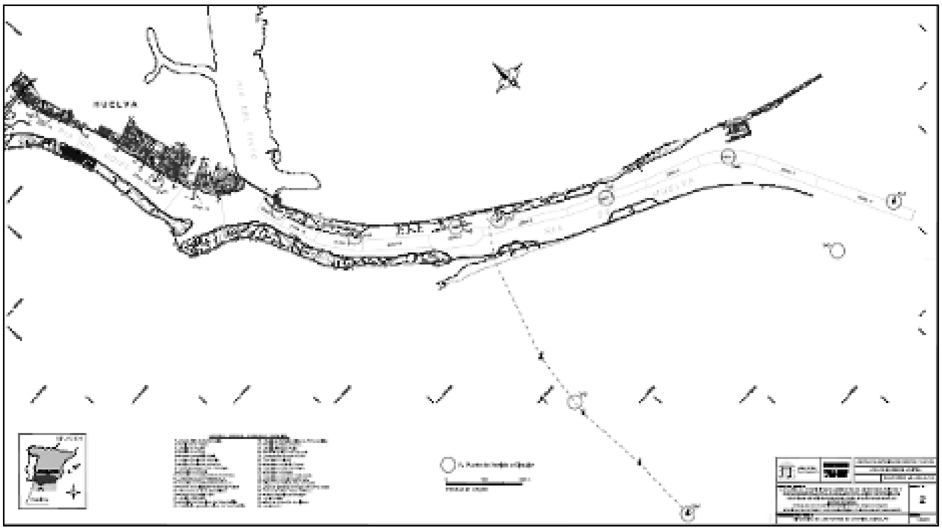

Figure 9. Spill locations

Referring to **hydrodynamics**, six scenarios were simulated for the inner domain, as the result of the combination between the three simulated tides (see item 4) and two phases or tide instants, i.e. the flow and ebb. Given its reduced influence, these latter were not used for the outer domain, thus giving a total of five scenarios, as simulated for the current fields.

Lastly, concerning the **local winds**, 4 or 8 scenarios were selected depending on the spill location. In general terms, the inner domain had 9 wind scenarios (4 directions times 2 wind velocities + 1 calm) while for the outer, 17 winds scenarios were selected (8 directions x 2 velocities + 1 calm).

Results (I) Atlas of trajectories

As said before, the main result of this study was the "**Atlas of trajectories**", a catalogue consisting of 890 maps (350 for the outer domain and 450 for the inner) that could be used in case of a real oil spill. Given the great number of scenarios modelled, it can be understood that a very useful kind of representation was needed, in order to minimize the number of resultant figures.

The variable "time to exposure" provided by the software Mike 21 was found to be very effective in achieving such usefulness, given that only one map could represent many factors about the spill trajectory. **Time to exposure** (units of time) indicates, for each grid element given by its coordinates (x, y), the instant when that grid element is affected for the first time by the spill, i.e. the first time at which an oil particle passes through it. Once the value is set for a given element, it does not change.

Some properties of this kind of representation are:

- Gives the time when an area starts to be affected
- Gives an idea of the velocity of the spill
- As far as a spill can last for a long time it represents the trajectory with one graph
- However it does not give the position of the slick at any time
- Furthermore, it gives some guidance on the trajectory, but not the trajectory itself, that would require too many figures

The next two figures show the result of one particular scenario on the inner and outer domain, respectively.

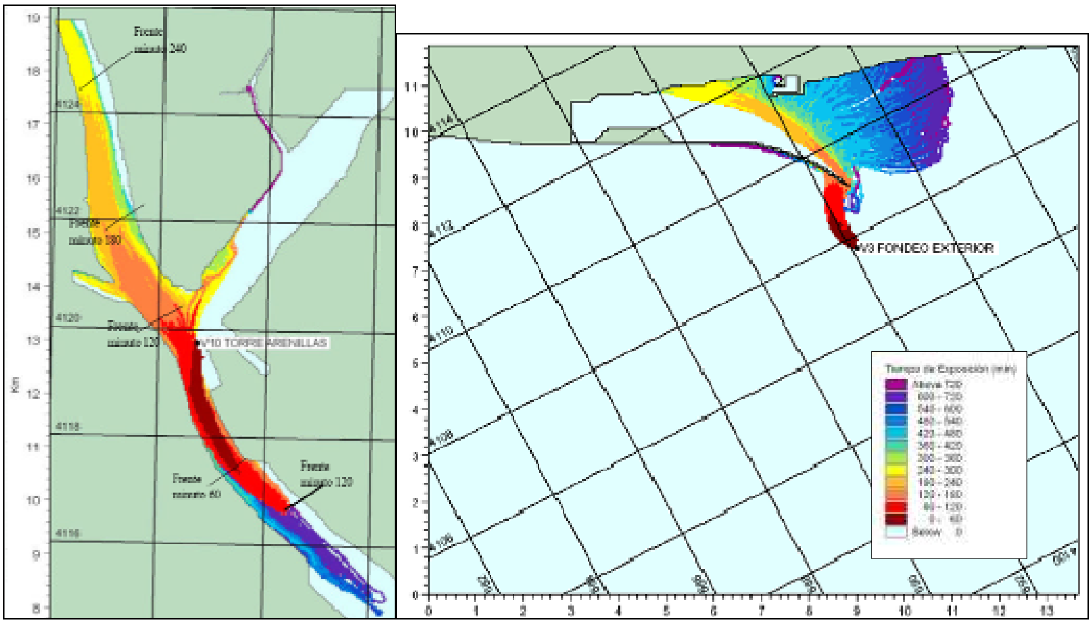

Figure 10. Time to exposure for the inner domain (left) and the outer (right)

Results (II) Probability of affection

Along with the "Atlas of Trajectories", the study contained a probabilistic analysis based on simple assumptions, as the independence between the variables considered, in order to obtain a first approximation on the most likely affected areas.

The analysis started with the zoning of the two studied domains, that is, the identification of homogeneous zones to which the results could be referred to. That analysis made use of the environmental studies (see item 4 above) and, depending mainly on the nature of each zone (natural or anthropogenic) gave in 7 different areas for each domain.

In essence, the study reported the probability for a specific zone of being the first affected by a specific spill. The results were plotted in graphs as well as tabulated. The Figure 11 and the Table 3 show some of them for the outer domain.

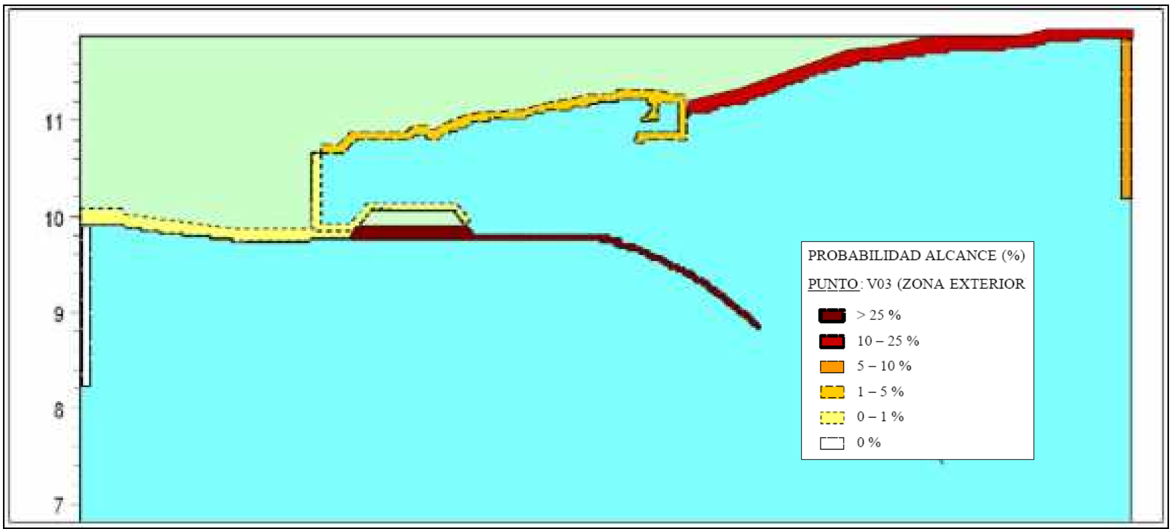

Figure 11. Probability of affection. Spill *V03* (deployment area).

Table 3. Probability of affection. Outer domain.

Coastal zone		V01	V02	V03	V04	V05	V06	Mean
1	Punta Umbría	0.33	4.61	0	0	0	0	0.82
2	Playa apoyada	4.22	17.36	0.03	0	0	0	3.60
3	Dique	9.82	11.75	31.09	3.59	30.70	21.21	18.03
4	Muelles	0.23	0	0.24	3.13	35.01	55.20	15.64
5	Casa del Vigía	0	0	4.12	27.03	34.31	23.60	14.84
6	Playa de Mazagón	0	0	15.32	20.19	0	0	5.92
7	Torre del Loro	0	0	10.73	0	0	0	1.79

Study of weathering

Although the weathering can also be evaluated with Mike 21 SA, this option was not enabled given the number of scenarios and also the possibility of using a more adequate model. Concerning the study of the oil weathering, it was thought that it was better to use the model *ADIOS 2* to simulate the fate a total of 12 scenarios.

Its results constituted an essential source of information when designing the combating equipment as well as the combating strategy.

Model features

The numerical model *ADIOS 2* (*Automated Data Inquiry for Oil Spills*) was developed by the HAZMAT (Chemicals and Hazardous Materials) department of the NOAA (National

Oceanic and Atmospheric Administration) of the USA government. The software incorporates a database containing more than a thousand crude oils and refined products, and provides quick estimates of the expected characteristics and behaviour of oil spilled into the marine environment.

In summary, this is a short term fate model (prediction up to 5 days) that takes into account the main weathering processes, such as the spreading, dispersion, evaporation and emulsification. Its use was considered appropriate since it was designed to make use of as little information as possible, and to use information regarding environmental conditions that can easily be estimated or obtained in the field, such as wind speed(s), wave heights, etc. Besides it also uses little information regarding the incident, such as the type and amount of oil or product spilled, and the rate and duration of the spill.

Modelled scenarios

In order to reduce the total number of scenarios, it were taken into account the similarity between the potentially spilled oils, the independence of the weathering on the wind and waves direction, and at finally the low sensitivity to the water properties.

All this gave a total of 12 scenarios were the result of the combination of the following input data:

- 4 Oil types:
  - 2 crude oils:
    - 1 of the Group 1 (Saharan Blend)
    - 1 of the Group 3 (Maya)
  - 2 products:
    - Fuel-oil
    - Gas-oil
- 3 Weather conditions (wind and waves):
  - Waves assumed dependent on the winds
  - 3 possibilities:
    - Calms
    - Small winds/waves
    - Strong winds/waves
- 1 Water properties: one case (constant temperature of 15 ºC and salinity of 36 gr/l)

The spill size and flow rate were fixed bearing in mind the Study of Spill identification (see above). As a result, only one amount and rate were used for each oil type, thus helping to reduce the number of scenarios.

Results

ADIOS 2 uses mathematical equations and information from the database to predict changes over time in the density, viscosity, and water content of a crude oil or product, the rates at which it evaporates from the sea surface and disperses into the water, and the rate at which an oil-in-water emulsion may form.

The next 3 figures show the results for the scenario nº 8:

- Oil type: Saharan Blend
- Weather conditions: Medium (wind speed of 6 m/s and wave height of 1 m)
- Spilled volume and rate: 717 Tn released in 1 hour.

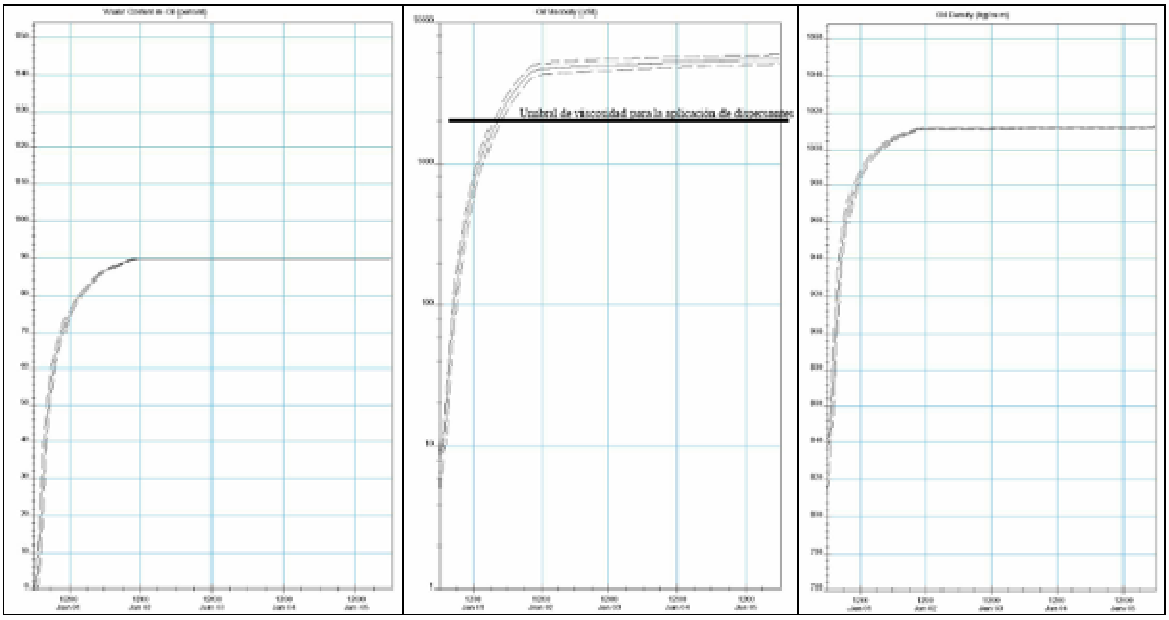

Figure 12. Water content in oil (%) (left), viscosity (centre) and density (right)

Oil Name = SAHARAN BLEND
API = 45.5 Pour Point = -29 deg C
Wind Speed = constant at 6 m/sWave Height = 1 meters
Water temperature = 15 deg C
Time of Initial Release = January 01, 0000 hours
Total amount of Oil Released = 717 metric tons

Hours Into Spill	Released metric ton		Evaporated percent		Dispersed percent		Remaining percent
1	717	-	17	-	0	-	83
2	717		24		0		76
4	717	-	30	-	1	-	69
6	717		34		2		64
8	717	-	36	-	3	-	61
10	717		38		4		59
12	717	-	39	-	4	-	57
18	717		42		5		54
24	717	-	43	-	5	-	52
30	717		44		5		51
36	717	-	44	-	5	-	51
42	717		45		5		50
48	717	-	45	-	5	-	50
54	717		46		5		49
60	717	-	46	-	5	-	49
66	717		47		5		48
72	717	-	47	-	5	-	48
78	717		47		5		48
84	717	-	47	-	5	-	48
90	717		48		5		47
96	717	-	48	-	5	-	47
102	717		48		5		47
108	717	-	48	-	5	-	47
114	717		48		5		46
120	717	-	49	-	5	-	46

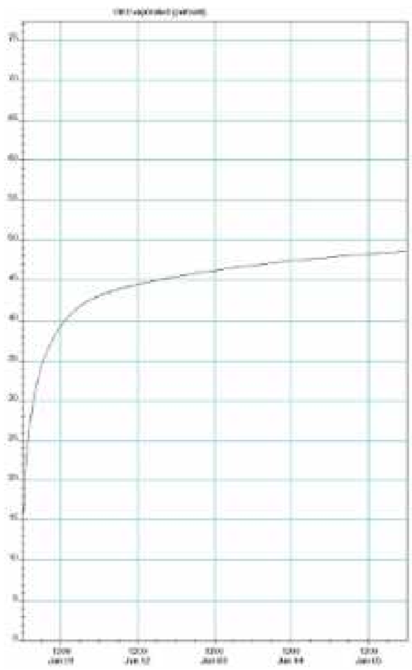

Figure 13. Balance of the total oil remaining

6. PROPOSALS

Proposals regarding the trajectories

Winds are key in the trajectory of the spill, specially in the inner domain, given the narrowness of the channel. Here, the wind can drive the slicks towards the coastline, avoiding their transport out of the port.

Tide coefficients are not as important as initially thought, while the tidal phase, i.e. instant of spill, especially within the inner domain, is much more important than tidal coefficients.

In summary, the most critical areas are located in the outer port. Thus, it is recommended to locate the containment equipment close to the port's entrance.

Proposals regarding the spill weathering

For Light Fuel-Oil (F-O #2) or Gasoil:

- The use of dispersants is not recommended, since it rapidly disperses and evaporates.
- In case of weak winds the most adequate practices are the containment and recovery, as it will be easier given the sea quietness.

Saharan Blend (Cat.1 crude oil):

- As for the light products, in case of weak winds the most adequate practices are the containment and recovery.
- Dispersants may be used with strong winds before 10 hrs off the spill

Maya (Cat.3 crude oil) and Heavy or Medium Fuel Oil: these are the most difficult to combat, since they have heavy compounds that tend to emulsify, avoiding the dispersion, evaporation or containment. However, containment and recovery are the only combating options.

7. REFERENCES

Anderson, C.M., LaBelle, R.P. (2000). *Update of Comparative Occurrence Rates for Offshore Oil Spills*. Spill Science & Technology Bulletin, Vol. 6, No 5/6, pp. 303-321

Gibson, P. (2002). *Oil Spill in U.S. Navigable Waters.* American Petroleum Institute

Maxim, L.D., Niebo, R.W. (2001). *Oil Spill Analysis for North Slope Oil Production and Transportation Operations*. Appendix B of *Environmental Impact Assessment (EIS) for Renewal of the Federal Agreement and Grant of Right-of-Way for the Trans-Alaska Pilepine System (TAPS)*

The International Tanker Owners Pollution Federation Ltd (ITOPF), 2004. *Oil Tanker Spill Statistics: 2003*

CEDEX (2004)

CEDEX (2005)

CEDEX (2006)