

Application of Trajectory Model, Remote Sensing and Geographic Information System (GIS) for Oil Spill Contingency Planning in Straits of Malacca

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ABSTRACT Operational remote sensing and Geographic Information System (GIS) are important tools for oil spill research and development activities. To facilitate these requirements, GIS-based oil spill contingency plan was developed for Strait Of Malacca (SOM) composed, ESI map which created and served as quick references for oil and chemical spill responders. Remotely sensed data are used for detecting the oil spill to support the contingency plan at a specific location and trajectory model are applied to predict spill movement. Finally, the plan preceded to assess resource requirement and response priorities to manage oil spill in SOM.

KEY WORDS Remote Sensing, Geographic Information System, Oil spill

1. Introduction

Shipping casualties often resulted in serious accidental spills as experienced in the Straits of Malacca (SOM) in the past decade. Major spills in the SOM were either due to collision of tankers such as that of Diego Sillang (1978-5500 tons) and recently VI.CC(1997-120,000 tons); groundings, such as that of Showamaru (1975-4000 tons) or due to fire and bad weather, such as Tolasea (1975-60 tons) and M.V. Asian in 1997 (Fig. 1). Most of the shipping casualties occurred in Singapore and a few near the one fathom bank in the SOM in the West Coast of Peninsular Malaysia. Considering the record of oil spill from 1975 till 1997 (Fig. 1), it is evident that major environmental issues in SOM is water pollution and oil spill. Operational remote sensing and (GIS) are important tools for oil spill research and development activities. Tan (1983) developed an oil spill preparedness plan, based on wind and sea surface currents in the East Coast of Malaysia including Sabah and Sarawak coastal water. Cheong H. et al. (1992) developed the numerical modeling of tidal motion in the southern waters of Singapore and south of the Malacca Strait. Also Pohlmann T. (1987) has carried out a three-dimensional circulation model for the South China Sea and the Strait of Malacca. Such efforts are published by Regional Program for the Prevention and Management of Marine Pollution in the East Asian Seas (GEF/UNDP/IMO), for example: Malacca Straits, Documentation Project (1995) Malacca Straits, Environmental Profile (1997) and Malacca Straits, Initial Risk Assessment (1997).

2. Methodology

2.1. Environmental Impact Assessment

A main objective of environmental impact in this study, after protecting human life, is to reduce the

environmental consequences of both spills and cleanup efforts. To do this, it's necessary to identify vulnerable coastal locations before a spill happens, so that protection priorities can be established and cleanup strategies identified. To meet this requirement, Environmental Sensitivity Index (ESI) map has been produced for the study area (Fig. 2). These maps serve as quick references for oil and chemical spill responders and coastal zone managers. ESI maps contain three kinds of information: 1) Shorelines are color-coded to indicate their sensitivity to oiling. 2) Sensitive biological resources, such as seabird colonies and marine mammal hauling grounds, are depicted by special symbols on the maps. 3) ESI maps also show important human-use resources, such as water intakes, marinas, and swimming beaches. Table 1 represents the ESI shoreline sensitivity rankings, applied to three different aquatic settings. In this table, "ESI No." is the number of each shoreline ranking. Descriptions of the types of shorelines that typify each ranking in estuarine, lacustrine, and riverine environments are shown in the remaining three columns of the table.

2.2. Oil Spill Detection

Remote sensing are applied to identify oil spill as a main part of contingency planning in the strait of Malacca. The project consists of four steps: 1) filtering of the images to reduce speckle noise. Gamma function in PCI's EASI/PACE image processing system is performs spatial filtering on each individual pixel in an image using the grey-level values in a square window surrounding each pixel. To remove isolated pixel (pixel of very high or very low value) in homogeneous area all pixels are filtered. In order to filter pixels located near the edges of the image, edge-pixel values are replicated to give sufficient data. 2) dark slicks

detection involving the location on the images of all dark patches which might possibly be oil slick; 3) feature extraction in which a set of backscatter textural and geometric features are extracted for each dark slicks; and 4) dark slick classification in which oil slicks are distinguished from other phenomena that dampen out short waves creating dark slicks are classified into possible oil slicks and look-alikes based on the extracted features (Fig. 3,4). For each dark spot, a set of features is computed. The features constitute general, standard descriptors often applied for regions in general image analysis, and additional features particularly suited for oil slick detection. The features are: Slick complexity, local area contrast ratio, border gradient, smoothness contrast locally, distance to a bright object, slick width, slick area, first planar moment, power-to-mean (PMR) ratio of the slick, number of neighbouring objects, number of objects in the scene, and homogeneity of the surroundings. Fig. (3) represents the algorithm for identification of oil spill in the Strait of Malacca.

2.3. Predicting Spill Movement

Short-range trajectory modeling studies are the most important; therefore it should be done on real time to give day- to -day support oil spill contingency plan at a specific spill. In this project, oil spill trajectory simulations are assumed. Hypothetical spill trajectories will be simulated for each of the potential launch areas across the entrance SOM. These simulations assumed more than hundred spills occurring in each of the four seasons of the year from each launch area. Combining both the current and wind effects, the relationship of the movement of the center of mass of the slick to these factors can be expressed as:

$$d \bar{x}/dt = U_c + 0.035 U_w \quad (1)$$

Regardless the physical properties of oil and water, the size of the spill and its spreading tendency, the resultant vector may be estimated as:

$$\bar{V} = (0.035 U_w) \bar{K}_w + (0.56 U_c) \bar{K}_c \quad (2)$$

Where \bar{V} is spill drift velocity; U_w , wind speed at 10m above the surface; U_c , current speed near the surface; \bar{K}_w , unit vector in the direction of wind drift (inclined at 25° *cum sole* to the wind direction); and \bar{K}_c , unit vector in the direction of current Pgkurup (1983).

In order to model the current velocity by radar data in the study area Martin, equation (3) was applied.

$$U_x = - \frac{\Delta x}{\Delta f} \frac{dx}{v^2} \frac{v^2}{\lambda R} \quad (3)$$

Where Δx is the displacement vector dx is the pixel spacing in azimuth direction and Δf is the difference between the look center frequencies of two successive images and λ is the wavelength and R is the distance between antenna and the target and

v is satellite velocity.

Figure (5) shows the simulated current velocity from Radarsat image. The drift currents are towards the north direction. Figure (6) shows a good correlation between simulated tidal current from Radarsat image and ground data. The maximum current speed detected in the study area is about 1.4 m/sec

2.4. Assessment of Resource Requirement

Planning and decision-making in oil spill response requires an understanding of oil weathering processes and subsequent changes in an oils characteristics and the effect of these changes on response technologies over time. These changes have an important influence on the usefulness and effectiveness of response methods and technologies. Three major categories of response (clean-up) methods are available: (1) mechanical recovery, (2) chemical treatment, and (3) in-situ burning. Methods and technologies in each of these categories are limited by environmental conditions both operationally and as a result of the changes in oil characteristics over time. Integration of a technology database, using changes in specific oil characteristics as a time reference has further improved decision-making capabilities. In addition to dispersants, effective use of in-situ-burning and some mechanical technologies is limited in time and governed by changes in oil properties. The most efficient, environmentally preferred, and cost effective spill response is dependent on chemistry of the spilled product, quantity, location, response time, environmental conditions, and effectiveness of available response technologies (given the first five factors). Utilization of multiple response technologies requires a rapid and scientifically based decision-making tool and an integrated system of response capabilities. In this project, we identify, delineate, and estimate selected response technologies used in SOM oil spill clean up, related to given environmental conditions, changes in oil characteristics and operational considerations in the Straits of Malacca (Fig.7). Table (2) provides typical Personnel/Equipment requirements from Naval Spill Response experience.

3. Conclusion

Modeling, analysis and various functions of digital image processing were applied to develop an oil spill contingency plan for the Strait of Malacca. In this study remote sensing and GIS tools play a valuable part in protecting the sensitive environmental and socio-economic resources and acting as an effective repository for local and regional knowledge of those resources in the strait

of Malacca.

References

Anon (eds.), 1991. Environmental Law Reporter, Environmental Law Institute Washington, D. C., Oil Pollution Deskbook.

Anon (eds.), 1995. Malacca Straits Documentation Project Tropical Coasts; 2 (1).

Anon., 1997. Malacca strait: Environmental Profile, Regional Program for the Prevention And management of Marine Pollution in the East Asian Seas (GEF/UNDP/IMO). Printed in Manila, Philippines.

Cheong H. -F, Shankar, N. J., Chan C. -T., 1992. Numerical modeling of tidal motion in the southern waters of Singapore; Department of Civil Engineering, National University of Singapore, 10 Kent Ridge Crescent, 0511 Singapore,.

Ging Tuang Tan (Sarawak Shell Berhad Sabah Shell petroleum company Lutong, Sarawak - Malaysia), 1983. Oil spill preparedness in a tropical offshore area. Oil spill conference San Antonio, Texas. February 28 -March 3,

Martain K., 1997. Detection and Focused Imaging of Moving Objects Evaluating a sequence of Single Look SAR images. 3rd international Airborne Remote Sensing Conference and Exhibition, Copenhagen, Denmark, Vol. I, pp.393-400.

Peter Calow and Valery E. Forbes,. 1997. Malacca strait: Initial Risk Assessment, Regional Program for the Prevention and Management of Marine Pollution in the East Asian Seas (GEF/UNDP/IMO). Printed in Manila, Philippines.

Pgkurup., 1983. Oil slick drift trajectory for hypothetical spills in the Arabian Sea; Indian Jornal of Marine Scinces, 12, 1-10.

Pohlmann T. A., 1987 three dimensional circulation model of the South China Sea; Institut für meereskunde der universität Hamburg Heimhuder Straße 71, 2000 Hamburg 13, FRG,.

Table (1) Shoreline Habitat Sensitivity Ranking System

ESI NO.	ESTUARINE	LACUSTRINE	RIVERINE
1A	Exposed rocky shores	Exposed rocky shores	Exposed rocky banks
1B	Exposed, solid man-made structures	Exposed, solid man-made structures	Exposed, solid man-made structures
2A	Exposed wave-cut platforms in bedrock, mud, or clay	Shelving bedrock shores	Rocky shoals; bedrock ledges
2B	Exposed scarps and steep slopes in clay	N/A	N/A
3A	Fine- to medium-grained sand beaches	Eroding scarps in unconsolidated sediments	Exposed, eroding banks in unconsolidated sediments
3B	Scarps and steep slopes in sand	N/A	N/A
4	Coarse-grained sand beaches	Sand beaches	Sandy bars and gently sloping banks
5	Mixed sand and gravel beaches	Mixed sand and gravel beaches	Mixed sand and gravel bars and gently sloping banks
6A	Gravel beaches	Gravel beaches	Gravel bars and gently sloping banks
6B	Riprap	Riprap	Riprap
7	Exposed tidal flats	Exposed tidal flats	N/A
8A	Sheltered rocky shores and sheltered scarps in bedrock, mud, or clay	Sheltered scarps in bedrock, mud, or clay	N/A
8B	Sheltered, solid man-made structures	Sheltered, solid man-made structures	Sheltered, solid man-made structures
8C	Sheltered riprap	Sheltered riprap	Sheltered riprap
8D	Vegetated, steeply-sloping riverine bluffs	N/A	Vegetated, steeply-sloping bluffs
9A	Sheltered tidal flats	Sheltered sand/mud flats	N/A
9B	Vegetated low riverine banks	Sheltered vegetated low banks	Vegetated low banks
10A	Salt- and brackish-water marshes	N/A	N/A
10B	Freshwater marshes	Freshwater marshes	Freshwater marshes
10C	Swamps	Swamps	Swamps
10D	Scrub-shrub wetlands	Scrub-shrub wetlands	Scrub-shrub wetlands

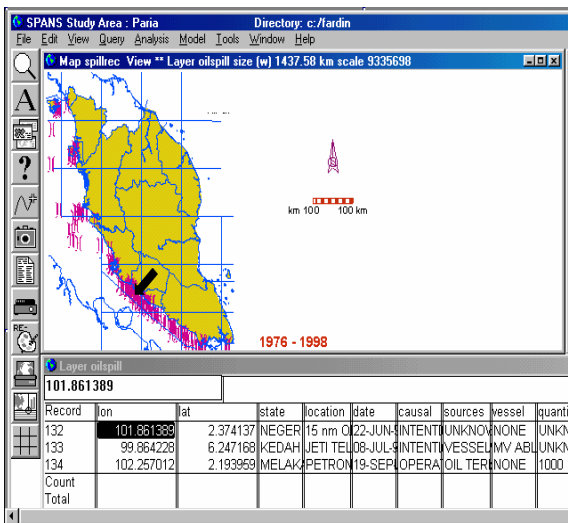


Fig. (1) Oil spill Incidents record in the Strait of Malacca in the SPANS7

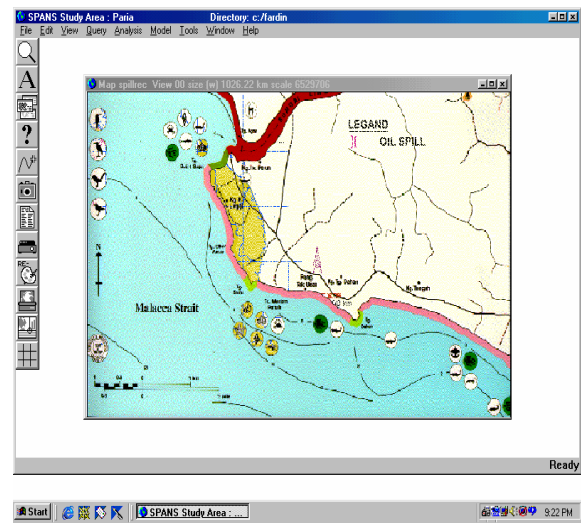


Fig. (2) Example of ESI Map from SOM in the SPANS7 file

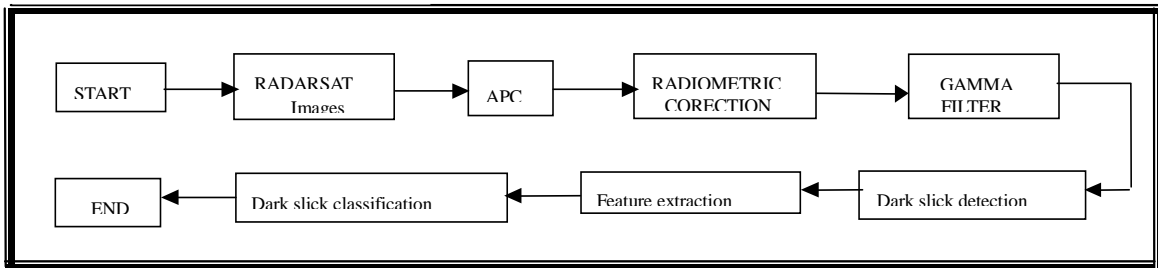


Fig.(3) The algorithm for identification of oil spill in the Strait of Malacca

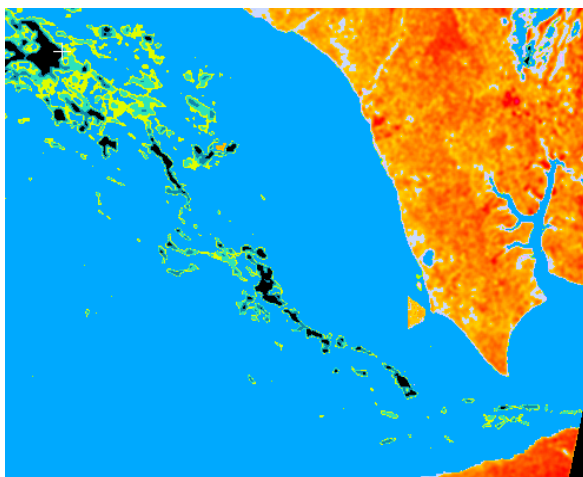


Fig. (4) Automatic detection of oil spills in C band Radarsat image in the straits of Malacca

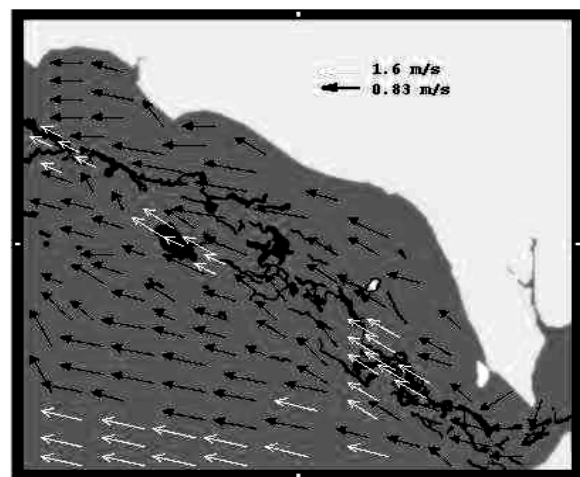


Fig. (5) Simulated Tidal Current Vectors from Radarsat Image with Oil Spills

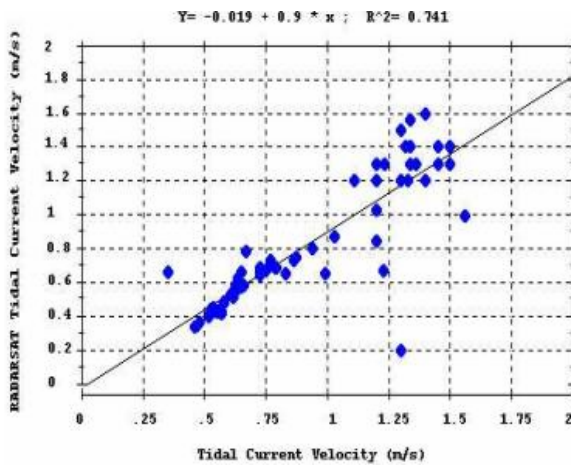


Fig. (6) Correlation Between Simulated Tidal Current from Radarsat Image and Ground Data

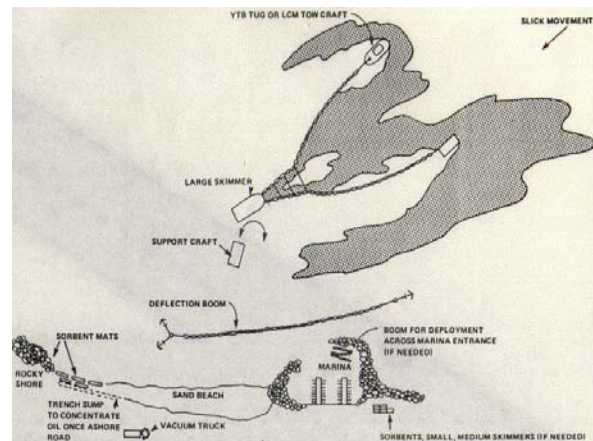


Fig. (7) Utilization of multiple response technologies in SOM oil spill clean up

Table (2) Typical Personnel/Equipment Requirements for oil spill response

SPILL LOCATION	SPILL VOLUME	RESPONSE SYSTEM	TYPICAL EQUIPMENT REQUIREMENT	TYPICAL-PERSONAL REQUIREMENTS
At pier side	< 100 gallons	1	1 utility boat, small skimmer, boom	4
		2	1 utility boat, medium skimmer, boom	4
		3	1 utility boat, large skimmer, boom	5
	> 100 gallons < 1000 gallons	1	1 utility boat, small skimmer, boom	4
		2	1 utility boat, medium skimmer, boom	4
		3	1 utility boat, large skimmer, boom	5
Away from pier	< 100 gallons	1	2 utility boats, small skimmer, boom, floating platform	7-8
		2	2 utility boats, medium skimmer, boom, LCM	8-10
		3	2 utility boats, large skimmer, boom	6-7
	> 100 gallons < 1000 gallons	1	2 utility boats, small skimmer, boom, floating platform	7
		2	2 utility boats, medium skimmer, boom, LCM	8-10
		3	2 utility boats, large skimmer, boom	7
Any location	> 1000 gallons	3	2 utility boats, large skimmer, boom	> 20
On land	All sizes		Hazardous substance OSOT	Variable