UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF GIS·BASED OIL SPILL DETECTION AND MONITORING SYSTEM

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Faculty: **Engineering**

Geographical Information System (GIS) and remote sensing technologies were used to develop a GIS-based Oil Spill Detection and Monitoring System in this study. The system can be used to manage, identify, and predict oil movement when there is an incident of oil spill.

Historical oil spill data, accessibility of response team's information and prevention/protection methods were established and placed in GIS for rapid access, retrieval and query. However, the archive remotely sensed data from SPOT Panchromatic, SPOT XS, NOAA AVHRR, and Landsat TM were analysed to identify and derive valuable information such as location, quantity, and distribution of oil spill in the affected area. A simple oil trajectory model was incorporated into GIS context to predict the slick movement's magnitude and direction.

The developed GIS database contained over 15 layers of oil spill and coastal data. These data could be applied for mapping, overlay, classification, and integration analysis. As more data were collected, new layers could be produced, stored, and

updated. The oil slick could be identified from the SPOT Panchromatic and SPOT XS. Three criterias used to identify the oil slick were the location of incidence, size of the spill and the reflectance verification. Oil prediction trajectory showed a good predicted direction of slick movement on panchromatic image. In contrast, the SPOT XS result indicated the oil impinged on the shoreline before the image was captured.

The GIS-based system can be used to establish the appropriate response to locate the dense areas of slicks and for local surveillance, in order to permit clean-up vessels to detect the oil to be cleared rapidly. Also, it allows new opportunities for multiple resource planning, and permits the viewing of a state's natural resources. Therefore, the GIS-based system can consequently improve the decision-making process, and provide a baseline for future assessments.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

PEMBINAAN SISTEM PENGESANAN DAN PENGAWASAN TERHADAP TUMPAHAN MINYAK YANG BERDASARKAN PENGGUNAAN SISTEM MAKLUMAT GEOGRAFI

Oleh

TEE TUAN POY

Mei 2000

Pengerusi: **Profesor Madya Shattri Mansor, Ph.D.**

Fakulti: **Kejuruteraan**

Projek kajian ini membentang tentang penggunaan teknologi penderiaan jauh dan sistem maklumat geografi (GIS) dalam pengesanan dan pengawasan tumpahan minyak. Sistem ini boleh digunakan untuk mengurus, mengesan, dan menjanka pergerakan minyak ketika kecemasan tumpahan minyak berlaku.

Rekod berkaitan tumpahan minyak, penggunaan dan kaedah pencegahan dimasukkan dalam GIS untuk tujuan penggunaan, dapat semula serta pertanyaan. Manakala, data penderiaan jauh seperti SPOT Panchromatic, SPOT XS, NOAA AVHRR dan Landsat TM telah dianalisis untuk mengesan dan mendapatkan maklumat tentang lokasi, kuantiti, dan penyebaran minyak di sekitar tumpahan. Model pergerakan minyak diintegrasikan dalam sistem ini untuk meramalkan arah dan magnitud pergerakan minyak.

Kajian sistem maklumat geografi ini mengandungi lebih 15 lapisan data berkaitan maklumat tumpahan minyak dan data sekitar pantai. Ia boleh digunakan

untuk proses analisis seperti pemetaan, pertindihan, pengelasan serta integrasi. Lapisan baru boleh dibentukkan jika terdapat maklumat baru. Dalam analisis pengesanan minyak dari imej satelit, hanya SPOT Panchromatic dan SPOT XS berjaya dikesankan. Ciri-ciri pengesahan tumpahan minyak dari imej-imej ini adalah berdasar pada tempat kejadian, saiz tumpahan minyak dan penggunaan kaedah pengesahan nombor digit pada imej-imej ini. Ramalan tentang pergerakan trajecktori tumpahan minyak telah dilakukan pada imej SPOT Panchromatic dan SPOT XS, di mana imej SPOT Panchromatic telah menunjukkan keputusan pergerakan minyak yang seperti didapati pada imej. Tetapi keputusan yang berlawanan untuk imej SPOT XS, di mana, pergerakan tumpahan minyaknya telah menghampiri tepi pantai sebelum imej ini diambil.

Sistem maklumat geografi ini boleh digunakan untuk membuat satu tindakan yang sesuai kepada tumpahan minyak tentang lokasi minyak serta pengawasannya. Ia juga boleh memberi peluang baru dalam proses perancangan dan mempercepatkan proses membuat keputusan serta menyediakan dasar dalam penilaian masa hadapan.

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LIST OF ABBREVIATIONS

AM/FM	Automated Mapping and Facilities Management
AVHRR	Advanced Very High Resolution Radiometer
CASI	Compact Airborne Spectrographic Imager
CS	Climate and Stochastic
DN	Digital Number
DOE	Department of Environment
DV	Digital Value
DWG	Drawing File
DXF	Digital Exchange File
EEZ	Economic Exclusive Zone
ER	Emergency Response
ERS	European remote sensing satellite
ESI	Environmental Sensitivity Index
GIS	Geographical Information System
GMT	Greenwich Mean Time
GPS	Global Position Systems
HFO	Heavy Fuel Oil
IR	Infra Red
Landsat TM	Landsat Thematic Mapped
MACRES	Malaysia Centre of Remote Sensing
MMS	Malaysia Meteorological Services Department
MSMM	Maximum Shape-Matching Method
MWR	Microwave Radiometry
NOAA	National Oceanic and Atmospheric Administration

NOSCP	National Oil Spill Contingency Plan
OSC	On-Scene Commander
OSDMS	Oil Spill Detection and Monitoring System
PIMMAG	Petroleum Industry of Malaysia Mutual Aid Group
RMAF	Royal Malaysia Air Force
RSO	Rectified Skew Orthomorphy
SAR	Synthetic Aperture Radar
SLAR	Side-Looking Airborne Radar
SPOT XS	SPOT Multispectral Scanner
UV	Ultraviolet

CHAPTER I

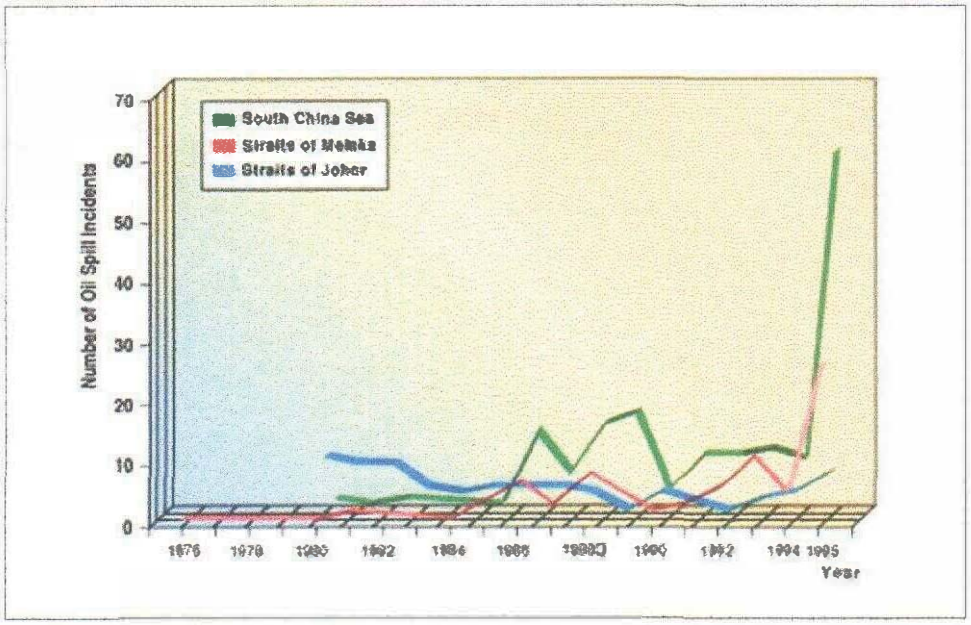
INTRODUCTION

Oil Spills in Peninsular Malaysia

The marine pollution issue in Malaysia is one of the critical environmental problems we face, which is gaining more and more attention from the public. Marine pollution, especially oil spillage from oil production at offshore, tanker accidents, and discharge at ports has increased over the years (Figure 1). It has become a constant threat to the coastal ecosystem of Malaysia. This oil pollution will damage the coastal natural resources, such as coral reefs, mangroves, beaches and many rare wildlife species. In the mean time, the pollution also affects the livelihood of coastal residents whose remunerative income depends on fisheries and aquaculture activities significantly.

Among the agencies or organisations concerned about the oil pollution problems in Malaysia are the Department of Environment (DOE), Marine Department, Fisheries Department, Shipping authorities, private oil companies, and local universities that are interested in research and development activities. These agencies have put in a lot of efforts in the on-going research and the collection of spillage records, effects of marine pollution, oil spill trajectory, and the development of

a response system. For example, the DOE has constituted a National Oil Spill Contingency Plan (first developed in 1976) which included the development of local oil spill strategies to aid in the oil spill response. The efforts have yet to provide a clear picture of this issue, which tag on the tail of the development.



Source: DOE Report (1995)

Figure 1: Malaysia: Annual Trend of Oil Spill Incidents, 1976 - 1995

With the amounting concern over this marine problem, these agencies have been relentlessly gathering large amount of oil pollution data and developing rescue strategies from the spillage incidents. Almost invariably, the data and plans need to be analysed, and a spatial database is needed to contain all the information.

Oil Spill Management Problems

Oil Spill and marine pollution management in Malaysia is under the responsibility of the DOE. The department is responsible to conduct the marine pollution surveillance and monitoring, regulating enforcement as well as containment procedure during an incident. The DOE has constituted an Oil Spill Contingency Plan to contain the spillage problem at Malaysian water and Economic Exclusive Zone (EEZ). But, DOE has faced some problems in current oil spill monitoring and response system such as high operational cost and limitation of using aircraft in monitoring and surveillance at coastal areas. Moreover, the problems also include lacking proper communication system such as networking, telemetry system, and comprehensive database for mapping and retrieving the needed information in oil spill response management.

As we know that information such as the position, extent, and the sources of oil spill is crucial for operational oil spill incident in emergency situations. It is important to identify the sources and risk in a spillage in order to formulate counter response for emergency situations immediately. Existing problems include integrating critical data for emergency management prior to impact, the immediate post-impact response period, the recovery period and the opportunity for mitigation. In addition, oil spill incident covers a large extent of spatial area. Thus, it is essential to have a spatial response management system that can manage the large collection of spatial geographic information and compile the data for analysis. The response

management system should allow faster access for emergency co-ordinators to the best information as soon as possible in the current oil spills management system.

GIS-based System for Oil Spill Detection and Monitoring

Fortunately, for the past two decades, coastal and marine applications have benefited from information derived from commercial satellite imagery, and Geographical Information System (GIS) has been used as a powerful tool in managing oil pollution at coastal areas. The GIS possesses the capability for dealing with complex relationships, storing, updating, analysing, integrating, and displaying geographical information. GIS can provide well-organised and informative retrievable spatial data for the management and the handling of oil spill problems as well as a platform for integrating the remotely sensed data. The GIS also has an emergency oil trajectory model for predicting oil slick movement.

In view of the significant role of the GIS in oil pollution management, this study focuses on work done in utilising GIS and remotely sensed data to identify and manage oil spill incidents in Peninsular Malaysia. The GIS-based oil spill detection and monitoring system has been developed in order to assist rapid and effective decision making in oil spill containment and cleaning up operations in coastal areas of Peninsular Malaysia.

Oil spill data, infrastructure utilities and access, and protection information has been built and placed in the GIS database for rapid access, retrieval, and analysis

purposes. Remotely sensed data especially from optical satellites such as Landsat TM, SPOT Multispectral Scanner (XS), SPOT Panchromatic, and AVHRR have been collected and analysed in order to derive the valuable information about the spillage cases. Information could be acquired from images such as the location of the oil spills, the size of oil spills, and the distribution of this oil spill in the affected area. Hence, the remotely sensed data has played a spatial input role to the GIS database in providing position information to oil slick prediction.

A simple linear oil slick movement model has been incorporated into this GIS database environment for predicting oil slick movement direction and the time takes to reach the shoreline or sensitive areas. Wind, current and tide are the main parameters for this model. This prediction provides a basic guidance of slick flow to the response co-ordinator in containing emergency spillage.

With the development of these three component: GIS database, oil spill identification from remotely sensed data, and oil slick movement prediction, this GIS-based oil spill detection and monitoring system can be used to locate the dense areas in a slick, and permitting clean-up vessels to detect the oil to be cleaned in rapid circumstances. Besides, this system allows new opportunities for assessment, multiple resource planning, viewing of natural resources, improving decision making, and providing a baseline for future assessments.

Objectives

The project aims to develop a GIS-based oil spill detection and monitoring system for coastal areas in Peninsular Malaysia with the integration of remotely sensed data and trajectory model for predicting oil slick movement.

The specific objectives are:

1. to develop an information system for managing oil spill problems;
2. to identify oil slick using images acquired from satellites;
3. to predict oil slick movement.

CHAPTER II

LITERATURE REVIEW

Geospatial Technologies and Oil Spill Management System

Management requires information. Geospatial technologies such as GIS, remote sensing (aerial and satellite imaging of Earth, radar and sonar), global position systems (GPS), automated mapping and facilities management (AM/FM), and digital navigation are found applicable in most of the diverse disciplines and national missions associated with coastal management. Coastal management is one type of spatial management. Spatial management means the distribution and allocation of space, ultimately of parcel of land, to alternative uses or activities, or the control of processes that in turn may affect space, such as emissions (Fedra and Feoli, 1998).

Mckee et al. (1998) explain that geospatial technologies are important in coastal zone management because of resources, activities, and natural conditions can be represented digitally. This means that information about them can be:

1. collected by means of remote sensing using wireless communication to devices with sensors. The devices may be fixed firmly, or mobile with wireless communication devices reporting their GPS determined locations and sensed values.