Oil Spill Model Development and Verification

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1. Executive Summary

1.1 Introduction and Background

Although Thailand has been fortunate not to suffer a major oil spill, in recent years there have been many smaller spills and the volumes of oil being moved in and out of Thailand are increasing. The Thai Government has responded to the threat of oil spills with the Committee on the Prevention and Combating of Oil Pollution formed under the Prime Minister's Regulation on the Prevention and Combating of Oil Pollution. In 1995 the Regulation and the Committee were revised and a National Oil Spill Response Plan was implemented. Under this Plan the Pollution Control Department (PCD) under the Ministry of Science and Technology holds responsibility for providing all academic and technical support during oil spill response.

In order to ensure that PCD can properly execute its role during an oil spill this major project was commissioned to develop a set of plans and handbooks supported by integrated software systems.

The diversity and complexity of project objectives resulted in the requirement for a team of consultants with the multi-disciplinary skills to execute the studies and provide the various project deliverables. The project team for the study was as follows;

- **Babtie BMT (Thailand) Co. Ltd. - Lead Consultant**
- **AEA Technology plc.**
- **International Response Corporation Inc.**
- **STS Engineering Consultants Co. Ltd.**

1.2 Scope of Work, Objectives and Project Output

The project requirements defined by PCD in their Terms of Reference (TOR) set out the following scope of work and key objectives;

- The development of a mathematical model to predict the movement of oil spill in the Gulf of Thailand, Andaman Sea, major rivers and river mouths during an oil spill accident.
- The preparation of a computerised database of natural resources, oil spill response equipment storage and other information relevant to oil spill prevention and response.
- The preparation of a risk assessment system for oil spill events which may be brought about by shipping incidents in the sea, major rivers and river mouths.
- The preparation of a damage assessment system for all natural resources including an economic evaluation of such environmental damage.
- The preparation of an environmental recovery plan in order to recover the polluted area as soon as possible.
- The preparation of an emergency plan for oil spill prevention and response.
- The preparation of regulations for the use of chemicals for oil spill response.

In addition to the submission of project reports and annexes the project output has comprised the following.

Software Systems: Database, Oil Spill Model, Decision Support System, Marine Risk Assessment.

Handbooks: Chemical Handbook, Oil Spill Emergency Plan, Oil Spill Natural Resource Damage Assessment Handbook, Oil Spill Environmental Recovery Plan.

Media Information: A 15 minute video and a series of brochures describing the key elements of the project.

Seminars and Training: A programme of seminars, training sessions and a desk top exercise.

The project output and final deliverables to PCD are described in detail in Section 1.4.

1.3 Structure of the Project

The project has comprised the following key elements.

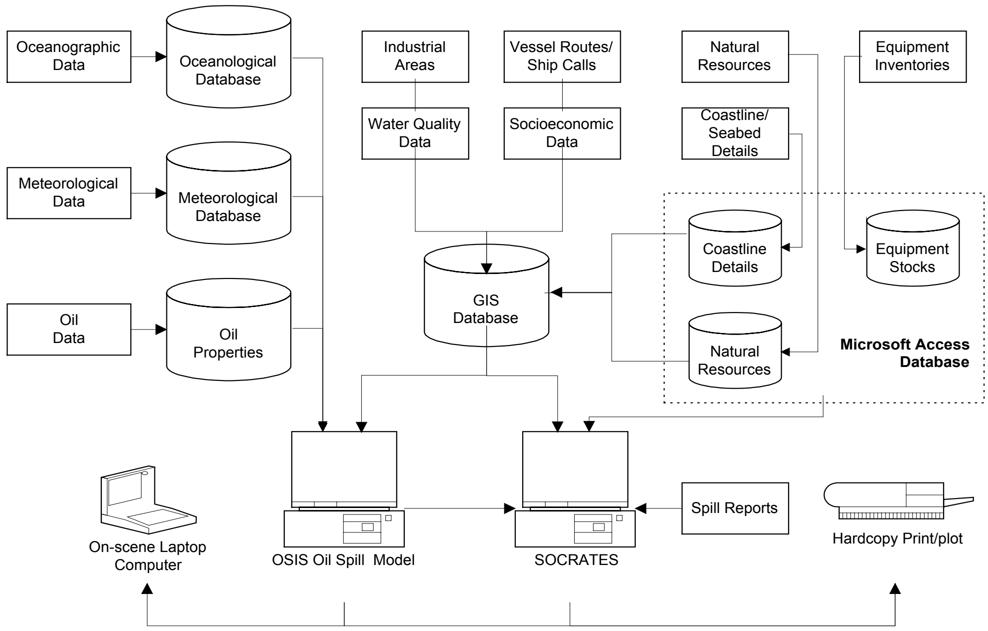

Figure 1 Structure of the Project

1.3.1. Data Collection and Collation

Data collection and collation has been a major project activity extending over a 14 month period. A large amount of relevant data has been identified and obtained by the project team.

Throughout the data collection and collation phase, the following three controls have been applied to all data sets obtained;

- *Relevance.* The relevance of data to oil spill response has been a fundamental test on all data collated for this project. This is particularly important for the system database development where, during emergency operations, staff cannot cope with large volumes of irrelevant data. In some cases data has been processed or filtered by the project team to increase or focus its relevance for oil spill response.

- *Quality.* All data has been examined for quality. In most cases the quality has been acceptable for the purpose to which the data is being used.

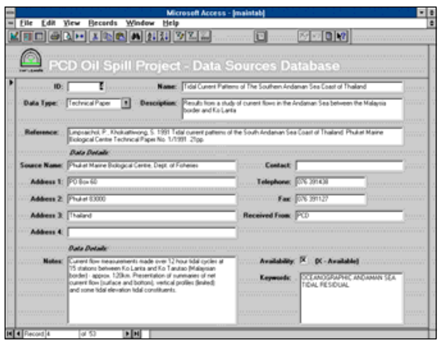

Figure 2 PCD Oil Spill Database

- *Completeness.* The project team have tried as far as possible to identify complete datasets or to build complete datasets from information taken from different sources. This data has then had to be harmonised so that it can all be presented in the Geographical Information System (GIS) in a common format.

At the outset of the project, it was decided to establish an electronic database of references and data used for the project. Although this database was outside the scope of the project defined by PCD, the database has proved to be an excellent tool for the project team and will also be highly beneficial to PCD's ongoing management of their oil spill related datasets. The database has over 300 individual references with details of the reference and keywords which allow searches of the database to be conducted. Once the references are identified they can be accessed in the archive by their unique reference number. The database has been used by the project specialists in conducting their studies. This has allowed the entire project team to be able to have access to all the reference material available. The complete database has been delivered to PCD as part of the information systems deliverable.

1.3.2. Oil Spill Model Development and Verification

Version 2.2 of the Oil Spill Information System (OSIS), the world's leading oil spill modelling system, is being implemented under this project. The system is in widespread use with oil companies, oil spill response organisations and national governments. OSIS has a long history of development starting 25 years ago with the research programme at Warren Spring Laboratory (now AEA Technology) which pioneered many of the modern methods for oil spill response. In 1992, BMT joined the development team to provide oceanographic and software engineering expertise. The new OSIS system won the 1994 international Seatrade Award for Countering Marine Pollution. OSIS has also been extensively validated using trial spills. These are licensed by the UK Government and involve the dumping of up to 20 tons of oil at sea to study its movement and weathering. Furthermore, OSIS has been validated against actual spill incidents, most recently with its use for the 'Sea Empress' oil spill.

The following list summarises features provided as standard in the system;

- Full oil spill trajectory, spreading, weathering and beach impact models
- Integrated GIS with continuous co-ordinate tracking and distance/bearing measurement
- Ability to model developed spills by defining the spill extents
- Ability to backtrack spills to identify sources
- Batch mode model runs with recording of results for later replay
- Graphical entry of weather forecast with import facility
- Status panel display of oil spill parameters
- Integrated units system allowing complete user set-up of preferred units
- Ability to move spill on-screen to accommodate observations during an incident
- Comprehensive results facilities including graphs of oil properties, spill reports and spreadsheets (all using Microsoft applications e.g. Word, Excel)
- Resource Damage Assessment to identify oiled resources
- Full colour printout and screen copy facilities

- Full on-line help system as well as professionally written system manual
- Unique Easyspill© system for non-experienced users and emergency

OSIS is implemented under this project with an advanced statistical modelling system. The stochastic model takes user entered wind speed/direction data in the form of a wind rose. This is then combined with a defined spill scenario to produce a large number of model runs which are run automatically by OSIS with no requirement for user intervention. Following the model runs, the results are statistically analysed to provide the user with the following statistical analyses;

- Maps of initial oil beaching sites
- Maps of all oil beaching sites
- Graphs of initial beaching times on a probability basis e.g. 8% probability of a 31 hour beaching time
- Maps of sea surface oiling probability
- Maps of shoreline oiling probability
- Spreadsheet analysis of model runs and calculation of total percentage beaching probability

The development of the model is based on the configuration of the following 4 key databases;

- Oceanographic database
- Meteorological database
- Oils database
- Geographical Information System

The oceanographic database is the most technically complex database prepared under this project and included the development and validation of numerical hydrodynamic models of the Gulf of Thailand and the Andaman Sea. The meteorological database has been developed from the latest annual sets of data for coastal meteorological stations obtained from the Meteorological Department. The oils database supplied under the project contains over 100 international crude oils and petroleum products . The Geographical Information System is shared between OSIS and the oil spill decision support system which has also been developed by BMT - Shoreline Oil Cleanup, Recovery and Treatment Evaluation System (SOCRATES)

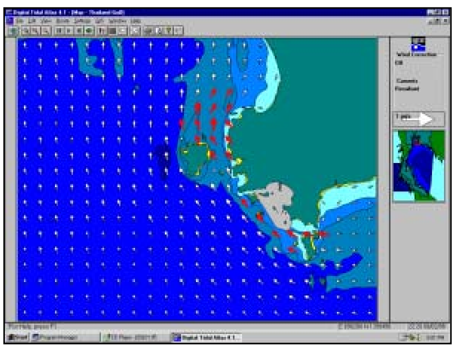

Figure 3Oil Spill Model Screen Dump

Comprehensive verification of the model has been carried out by previous comparisons between field experiments and real spills, and the model predictions. In addition, the oceanographic databases in OSIS have been validated by detailed comparisons between the model and data collected and collated as part of the project.

1.3.3. Geographical Information System Development

The Geographical Information System (GIS) implemented for this project is integrated with the OSIS and SOCRATES systems. The GIS has been developed by BMT over the past five years and has been specifically designed for emergency response systems. The design has focused on the provision of essential functionality and, above all, ease of use.

The GIS uses the same basis of operation as all other GIS systems with data stored in layers which are arranged thematically. The layers are 'stacked' on top of each other so that different layers can be examined and compared. On each layer, data is stored as objects. These objects can be polygons filled with a reference colour, symbols, text and lines. Each object can have a name added. Each object can also have attribute data added which can take the form of text, such as descriptions or statistics, or graphical images.

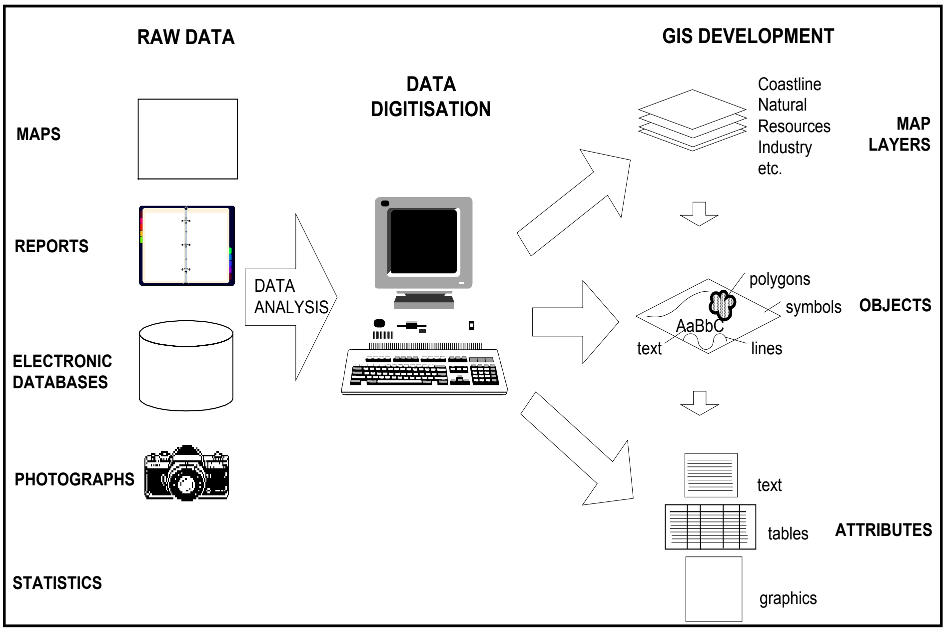

Figure 4 GIS Data Processing and Development

The layers have been categorised in the following categories;

Land	Land boundary
Risk Zones:	Marine terminals, tanker moorings, berths, offshore oil and gas facilities, storage facilities, power stations, ports
Natural Resources:	Coral reefs, seagrass beds, mangroves, shoreline type, marine national parks
Wildlife:	Sea birds, marine mammals, turtles
Economic Resources:	Tourist locations, aquaculture zones, spawning grounds, fishing grounds, coastal land use types

Supporting Data:	Economics, demographics, development plans, provincial boundaries, oceanographic data (salinity, temperature), water quality monitoring stations, seabed type
Logistics:	Roads, airports, coastal access locations, equipment bases
Response Guidance:	Resource priority, dispersant use zones

The BMT GIS provides the full range of data storage, analysis and display features that users are likely to require. These include the following facilities.

- Full zoom facilities
- Distance and range/bearing measurement
- Interrogation of map objects
- Storage of attributed data with map objects including notes and photographic images. Microsoft Access used for data storage
- User definition of new objects including lines, regions and text
- User addition of symbols from pre-defined symbol palette or user designed
- Object properties editing e.g. colour
- Importing of new maps from dxf format
- Full colour printing facilities

1.3.4. Risk Assessment System

A key element of the project has been to examine shipping operations within the study area and to develop a risk assessment system in order to provide quantitative estimates of the marine risks from potential oil spills. Such a system requires an estimation of the oil spill frequency, and the consequence in terms of spill size, separately for the Gulf of Thailand, the Andaman Sea and the main navigable rivers and river mouths which have industrial facilities and oil cargoes. In each area, spills can be caused by a number of initiating accidents, such as collisions, groundings, fires/explosions etc, which all contribute to the total spill frequency and which will vary for the different sea areas.

The main aim of the risk assessment study has been to construct a model that will predict future oil spill risk, in terms of spill frequency and size, in the study area as a function of further shipping traffic patterns and other relevant parameters. The model is based on the ARC/INFO Geographical Information System enabling the co-ordinates of shipping routes to be entered and plotted, and numerical attributes of these routes. Statistical analyses of the data can then be carried out in order to determine the factors which have the most significant influence on accident rates for use in the model. The system takes account of long term factors (10 to 20 years) and allows interaction by PCD in order to examine the effects of future changes in shipping patterns, vessel traffic densities and the nature and location of marine facilities. Interpretation of the results of the study provides guidelines for the mitigation of oil spill risk including the

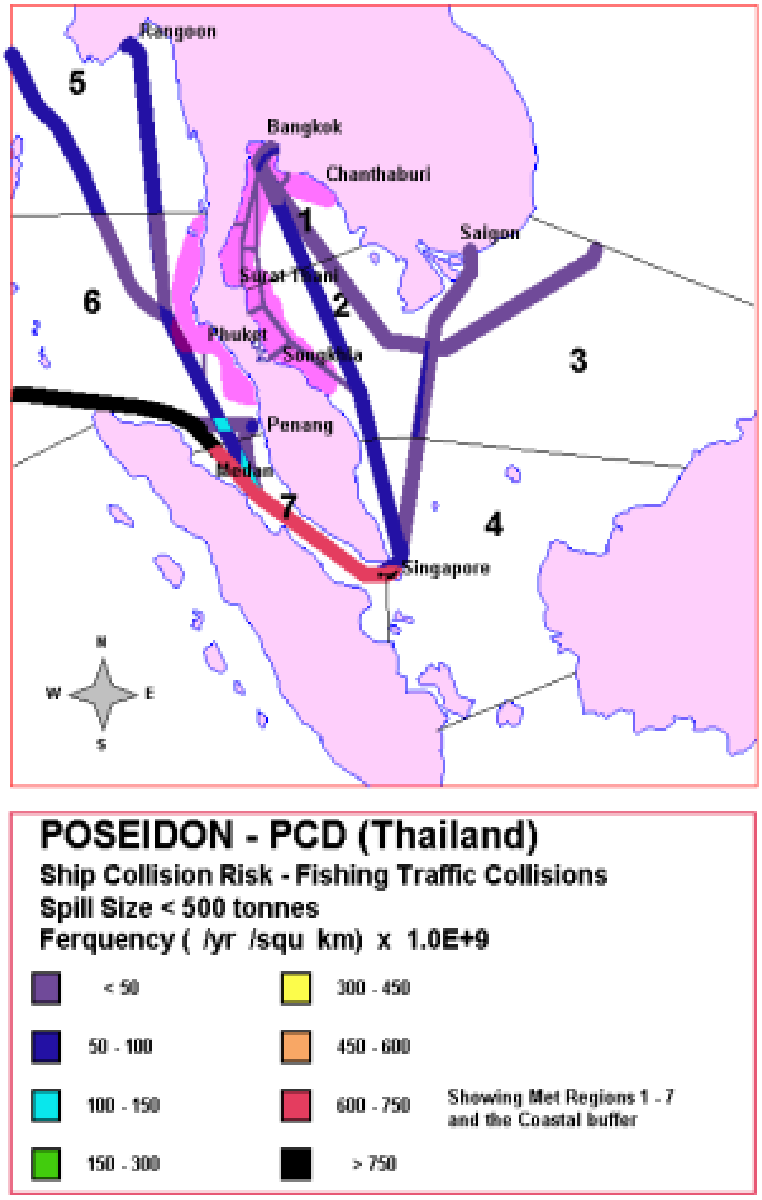

Figure 5 Ship Foundering Risk

assessment of options for the implementation of vessel traffic management procedures. The data is presented in a computerised format for use within the oil spill information systems.

As part of the project, a marine oil spill risk assessment tool named POSEIDON has been specifically developed for application in Thai waters. The model predicts the frequency of accidents for ships of various types, characterised by size, flag state, etc., at any location in Thai territorial waters for various encounter scenarios and prevailing circumstances. The prediction is based on accident records, traffic flows and various influencing factors such as local weather conditions, type of ship etc. From the cargo inventory of the ships the frequency of oil spills of a given size is also predicted at any given location. The POSEIDON software interfaces with the Geographical Information System (GIS) ARCINFO which is an effective medium for access of geographical data and provides graphical display of model inputs and outputs. Risk maps of initiating oil spill events are constructed on ARCINFO and the colour-coded risk plotted.

A User Guide has been prepared which includes an overview of the POSEIDON methodology and its implementation on ARCINFO together with a description of the primary features of the model, details of the software and other user considerations. An initial analysis of the flow of shipping traffic has been carried out in order to identify areas of greatest concern with regard to oil spill risk and advice has been provided with regard to vessel traffic management procedures.

The Port of Bangkok remains the gateway for international seaborne trade in Thailand although its role is declining following the development of the Port of Laem Chabang which first became operational in 1991. Bangkok Port has also been affected by the steady rise in containerised transport in Thailand and the policy of the Thai Government to restrict future throughput of containerised cargoes at the port in order to ease congestion at Klong Toey and to encourage utilisation at Laem Chabang.

Extensive data on shipping traffic in Thailand's waters has been obtained from the Harbour Department and the Ministry of Transport and Communications. The shipping statistics demonstrate the predominance of the key ports of Bangkok and the private wharves along the Chao Phraya River together with the Chonburi Province ports of Sri Racha and Laem Chabang and the anchorage at Ko Si Chang. In addition, the industrial port of Map Ta Phut on the Eastern Seaboard and the port of Songkhla in the south handle significant volumes of import cargo while Khanom in Nakhorn Si Thammarat Province and Krabi are important export ports.

Although the Port of Bangkok is likely to maintain a predominant role as a result of its proximity to the Bangkok metropolitan area, the economic development of the Eastern Seaboard region will lead to an increasing emphasis on the supporting regional ports located in Chonburi and Rayong Province. Phased deep water port expansion plans are presently under consideration at MapTa Phut and Rayong in order to serve the increasing development of industrial estates and factories along the southern coastline of the Eastern Seaboard including refineries, steel and steel products plants and associated power stations.

For each accident category POSEIDON calculates the frequency of a spill event of a given size in a locational area involving ships of given types as the product of the frequency of the accident event and the probability of a spill of the specified size given the occurrence of the accident event. This calculation is summed over all scenarios, ship types and accident circumstances.

The accident scenarios may be divided into powered and drifting scenarios. When a vessel is disabled through mechanical failure and lies idle in the water, it will drift subject to the forces of wind, waves and tide. At present the model addresses only wind forces since this is adequate for Thai waters. The ten scenarios considered are:

A(i) powered collision between ships crossing at lane intersections;

A(ii) powered collision between ships meeting within the same lane;

A(iii) powered collision between ships overtaking in the same lane;

A(iv) powered collision between ships in a lane and ships moving randomly within a specified area;

B(i) ships grounding under power;

B(ii) ships running aground while drifting;

C(i) powered collisions between ships and offshore structures;

C(ii) collisions between drifting ships and offshore structures.

D foundering

E fire / explosion

Accident frequencies in a given area are dependent on the type of environment in which the area is located. The model takes account of open sea, coastal zone, river or harbour locations.

1.3.5. Chemical Dispersant Use

The project has included the development of guidelines for the use of oil spill dispersants in responding to oil spills in Thai waters. These have been based on the IMOP/UNEP Guidelines on Oil Spill Dispersant Application including Environmental Considerations (IMO 1995) modified for the operational and environmental considerations specific for the use of oil spill dispersants in Thai waters. Background information has been provided on oil spills and their potential consequences together with an overview of response options including the use of dispersants. Facts with regard to the nature of dispersants have also been provided along with methods of application and the relative advantages and disadvantages of their use. The principles and limitations of dispersant use, and potential toxicity aspects are discussed for applications in freshwater or at sea and comparisons have been made with regard to alternative methods of response. Specific recommendations have been made with regard to the planning for the use of dispersants in Thailand including decision-making processes and potential zones for dispersant use. In general, the advantages and disadvantages with regard to the use of dispersants are set out below.

Advantages

- Dispersants can be used in stronger currents and greater sea states than containment and recovery;
- Dispersant spraying, especially from aircraft, is often the quickest response method;
- By removing the oil from the surface it helps to stop the wind effect on the oil slick's movement that may otherwise push the surface slick towards the shoreline;
- It reduces the possibility of contamination of sea birds and mammals;
- It inhibits the formation of water-in-oil emulsions;
- It increases the surface area of oil that is available for natural degradation.

Disadvantages

- By introducing the oil into the water column, it may adversely affect some marine organisms which would not otherwise be reached by oil;
- Dispersants are not effective on all types of oil under all conditions.
- If used on shore, it may increase the penetration of oil into the sediments;
- It introduces an additional quantity of extraneous substances into the marine environment;
- There is a limited time window when dispersants can be used.

The purpose of any oil spill response method is to reduce that damage (environmental or economic) that would be caused by the oil spill if no response were undertaken. With some response options, such as mechanical containment and recovery, it is obvious that removing the sea surface will limit the further damage that this oil will cause. However, the damage that the oil has already caused cannot be undone and mechanical recovery can be a slow process for medium or large oil spills.

When used effectively, oil spill dispersants will rapidly transfer oil from the surface of the sea into the water column. To date there have been no incidents where dispersants have in themselves caused toxicity problems. However, successful dispersant use will cause a marked but temporary increase in the oil concentration in the water and as the oil components can be toxic to marine organisms this may be undesirable in shallow water.

On the basis of the categorisation of resources dispersant usage zones have been drawn up for Thailand which are split into two categories:

- ***Zone for pre-approved for dispersant application***. For those zones which contain the resources where there is not a high sensitivity to dispersed oil and where the water depth is greater than 10 metres allowing rapid dilution.
- ***Zone sensitive to high dispersed oil concentrations***. For those zones, such as those waters less than 10 metres in depth, where it is known that there are resources which are sensitive to dispersed oil and where dispersant use is only recommended if the response is likely to result in an overall net environmental benefit.

These zones have been identified around for the coastal waters of Thailand and are entered into PCD’s Geographical Information System

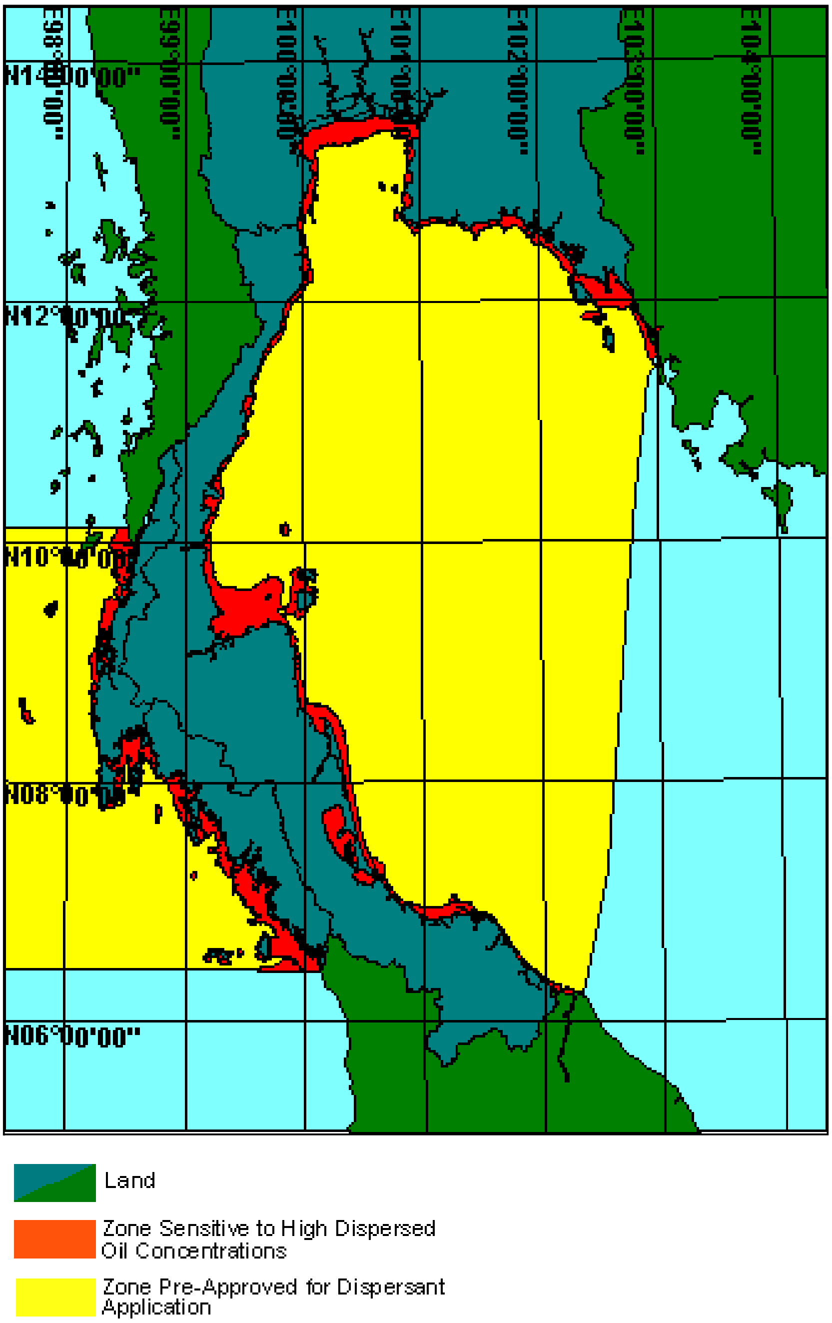

Figure 6 Dispersant Use Zonation on the Gulf of Thailand and Andaman Sea

As a result of the detailed study the following recommendations have been put forward for consideration with regard to the future use of dispersants in Thailand.

- It is important that the Thai National Contingency Plan be updated to incorporate the recommendations and procedures outlined in the “Guidelines for the Use of Oil Spill Dispersants in Thai Waters”.
- In line with IMO, it is recommended that Thailand adopt the list of approved dispersants for the UK (this includes dispersants on the USA approved list). Toxicity

and efficiency testing has been carried out on all the dispersants on this approved list.

- Treating oil spills in freshwater could result in high local concentrations of dispersed oil. Thus, dispersants are not a commonly used response method for freshwaters. In addition, many dispersants that are formulated for use at sea are not effective in fresh water because the low salinity adversely affects the performance of the surfactant molecules. With the sensitive resources in the region of Thailand's rivers, and the lack of effective freshwater dispersants, it is not recommended that dispersants should be considered a prime response to oil spills in freshwater at present. With research continuing in this area this area should be reviewed in the year 2000.
- Weathering and dispersibility of oils carried out in Thai waters is not well understood. The appropriate weathering and dispersibility studies carried out as part of the Thai National Contingency Plan would provide the information required to identify oil-specific time windows for dispersant use. The oil characterisations could also be used in mathematical models, such as the PCD model, to provide real time predictions of the time window for dispersant use during an incident itself. It is therefore, recommended that PCD work with the upstream and down-stream (IESG) oil industry in Thailand to ensure that oil weathering and dispersibility studies are carried out for crudes transported in Thai waters.
- Incidents such as the Diamond Grace spill in Tokyo Bay where the scale of the spill was over-estimated by an order of magnitude demonstrate the importance of correctly estimating the volume of oil on the sea surface at the initial stages of a spill. This is a critical part of making the right choices for response action and using observers with experience in observing actual oil spills on the sea surface are essential. If dispersants are to be used then this estimate is also used in determining the maximum volume of dispersant to be used..
- Once the dispersant response has been mounted PCD will have the role of assessing whether the dispersants are being effective. This will require trained PCD representatives in both aircraft and boat operations:
- The change in volume of surface oil after a dispersant response is difficult to interpret since breaking of emulsions can result in an increase in the surface area of the thick oil (determined for example visually and using Infra Red cameras). Training of experts over real and experimental spills is essential.
- In addition, the absence of a visible dispersed oil plume from aircraft does not necessarily indicate that the dispersant is ineffective, aerial surveillance must be coordinated with monitoring from boats.
- The levels of dispersed oil in the water column measured by monitoring teams on boats before and after dispersant use will be dependent on many factors such as the oil type, the degree of weathering, the type of dispersant, the sea state, and the degree of mixing. Therefore, it is not possible to generalise on the levels of dispersed oil which signify a successful dispersion. The monitoring team must measure the levels of dispersed oil before treatment and then determine whether dispersant treatment results in a significant increase in the rate of the natural dispersion process. It is essential for PCD to use trained monitoring personnel who are used to monitoring oil levels below both treated and untreated oil slicks.
- Monitoring for oil in the water and sediments by trained PCD representatives is also required as part of the procedure for estimating environmental impact.

1.3.6. Oil Spill Environmental Recovery Plan

The project has included the development of an Oil Spill Environmental Recovery Plan including guidelines for monitoring and assessment. The marine and coastal resources of Thailand are rich and varied and extremely important to the economic and environmental health of the country and its people. Many of these resources are vulnerable to short-term and possibly long-term damage in the event of an oil spill. However, this vulnerability varies considerably, as does the economic importance of the various resources. It is, therefore, possible to prioritise those resources in a spill area which would most benefit from protection and clean-up. Protection and clean-up of the various resources is not a simple procedure, however, and each may require a very different response.

The damage caused by a spill and any clean-up activity is not always obvious or easily quantified, particularly where there has been no recent baseline description of the resource. However, a structured approach of surveys and monitoring of specific features can provide valuable information from which to assess the overall impact. The key aim of this plan has been to concentrate on the twenty three individual resource types and their prioritisation for protection and clean-up. Integral to these descriptions is the concept that each type of resource varies greatly in its quality, its extent and its vulnerability to oil spills. Furthermore, the characteristics of the oil spill will also affect the vulnerability of the resource. The coastal ecosystems are complex and it is therefore essential that anyone assessing priorities has a good understanding of the most important factors involved.

The primary aims of the Oil Spill Environmental Recovery Plan (ERP) are therefore to provide the following:

- a description of the vulnerability of the various coastal and marine resources to oil spills;
- a simple system for prioritising each resource for protection and clean-up;
- guidelines on the most appropriate techniques for their protection and clean-up;
- guidelines for carrying out impact surveys and for monitoring the recovery of damaged resources

Use of the ERP will be closely linked with the various other elements of the PCD oil spill system. The SOCRATES database will provide information on the distribution of the various resources around Thailand and can produce listings of the resources present in the area affected by a spill. The Chemical Handbook provides information on the use of dispersant chemicals on oil slicks and is therefore referred to in the ERP where dispersants are either appropriate or inappropriate for protection and clean-up of particular resources. The Natural Resource Damage Assessment, which is described below, cross-refers to the ERP for information on the various resources and methodologies for assessing damage.

The Oil Spill Environmental Recovery Plan is in two parts:

- The operational plan - which provides a simple structured layout of the prioritisation system and the various guidelines
- The main report - which provides more detailed information and methodologies from which the operational plan was prepared. This report is also fully referenced to allow the reader to access relevant literature and manuals on the

marine and coastal resources of Thailand, effects of oil spills elsewhere, shoreline clean-up techniques and marine and coastal survey methodologies. Cross-references to the literature in the PCD reference database are also made.

The Oil Spill Environmental Recovery Plan (ERP) handbook has been carefully designed to integrate closely with a suite of other tools for oil spill response in Thailand.

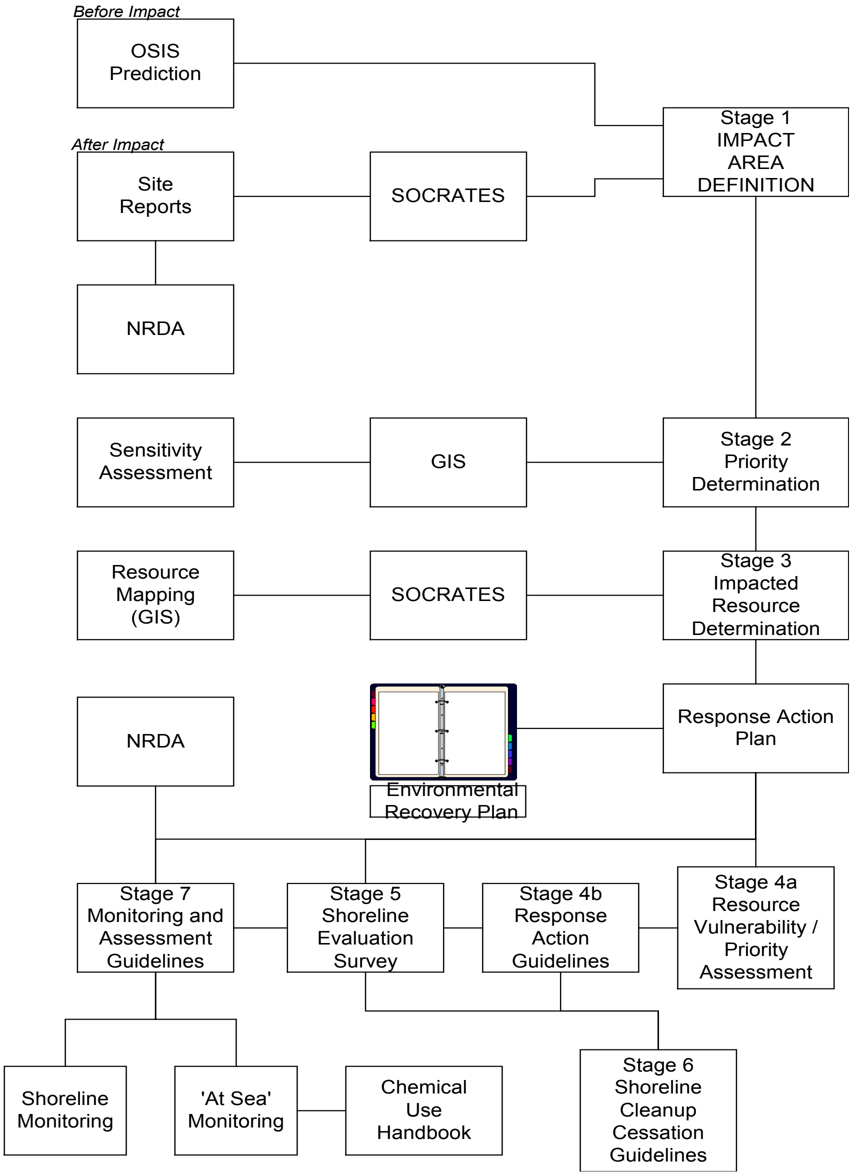

Figure 7 Use of the Oil Spill Environmental Recovery Plan in oil spill response

There are the following seven essential stages to the ERP methodology. When used for pre-spill contingency planning the order of these stages may be changed as appropriate but in a post-spill operational situation the order would normally remain as described.

- **Stage 1 – Impact Area Definition:** The impact area definition stage is where the actual coastline or coastal waters directly impacted by oil are identified.
- **Stage 2 – Priority Determination:** The next stage is to determine the priority of resources that may be, or have been, impacted by the oil spill. To create the priority categorisation given in the GIS layer a simple priority matrix for generic resource types has been developed and applied to sections of the coast in Thailand.
- **Stage 3 – Impacted Resource Identification:** The third stage combines Stages 1 and 2 to provide a listing of all impacted resources within the spill impact zone.
- **Stage 4 – Response Action Plan:** The response action plan is developed based on the impacted resource listing produced in Stage 3. Each individual resource category (e.g. mangrove, amenity beach, shrimp pond etc.) is presented in the Oil Spill Recovery Plan. The response guidelines are presented in the following two parts:

  Stage 4a: Assessment of specific resource vulnerabilities: For each resource, a description is given with comments on its sensitivity and vulnerability to oil pollution and a list of the factors which are important for assessing vulnerability to oil spills.

  Stage 4b: Guidelines for response: For each resource a concise list is prepared of important actions to mitigate the spill impact and actions to be avoided in order to prevent further damage.

- **Stage 5 – Shoreline evaluation surveys:** This stage is a continuous process which links closely with the shoreline clean-up response and many other elements of the ERP including prioritisation assessment and monitoring.
- **Stage 6 – Cessation of clean-up:** This stage of the plan provides a process including a decision tree to assist in determining when to stop the clean-up activities for specific resources.
- **Stage 7 – Monitoring and Assessment:** This stage is divided into 'at sea' and 'shoreline' assessment. The shoreline monitoring and assessment follows on from the Response Action Plan with guidelines for monitoring each resource.

Table 1 Priority Matrix. The priority of the section is the maximum priority given in the matrix for the resources found in significant quantities within the section, or is otherwise defined as 'Low'.

Coastal Resource	***Priority***
Coral reef - nearshore, high quality, shallow reefs	*High*
Seagrass beds - large beds of known importance	*High*
Mangroves - Conservation zone or Economic 1 zone	*High*
Mangroves - Economic 2 zone	*Medium*
Mudflats (not associated with mangroves)	*Medium*
Ports - large and active with ferry terminals	*Medium*
Fish nursery areas - areas of national importance	*Medium*
Shrimp ponds - large numbers of ponds and intakes	*Medium*
Shellfish farms - large areas of intertidal or shallow water farms	*High*
Amenity beaches - international importance	*High*
Amenity beaches - regional importance	*Medium*
Turtle nesting sites - areas with large numbers of nests	*High*
Turtle nesting sites - areas with some nests	*Medium*
Wetland bird sites - international importance	*High*
Marine Protected Areas (with coral reefs, seagrass beds, mangroves or turtle nesting sites)	*High*

Oil spill clean-up is expensive and can itself cause considerable damage to environmental resources. Natural clean-up processes can be very effective in many habitats without doing further damage, and once the bulk oil has been removed it is often better for the environment to continue the process without further human action. The efficiency of natural clean-up is often underestimated. It is therefore necessary to maintain a constant vigilance on clean-up operations to ensure that over-enthusiastic workers and supervisors do not waste time and money and do not go beyond the point at which their actions cause inappropriate levels of damage. However, in many situations the level of appropriate clean-up action may not be obvious to the worker or supervisor. Some may assume that a 'clean' beach means that there is absolutely no oil visible, while another may be less fussy as long as the remaining oil does not stain or stick to skin or clothing.

Definitions of 'clean' and different approaches to the issue of when it is appropriate to stop cleaning have been subject to expert review and appropriate criteria have been drawn up for guidance.

Table 2 Criteria for Determination of CLEAN

Resource	***Definitions of clean***
Food organisms (e.g., fish, shellfish, seaweed) and water that may be abstracted for human consumption.	*Must meet statutory quality specifications (chemical tests), and pass sensory tests for taint.*
Amenity beaches and structure (e.g., jetties and slipways)	*No visible oil. No oil that rubs off on people or boats.*
Water surface (as used by birds and mammals).	*No visible oil slicks or sheens that could adhere to feathers of fur.*
Subsurface water (as habitat for fish, corals, seagrasses, aquaculture species, etc.).	*Oil concentrations should not exceed normal background levels, Must not be toxic to key species.*
Shoreline (as habitat for algae, mangroves, molluscs, crustaceans, etc.).	*Need not be visibly clean, but remaining residues must not inhibit ecological recovery through toxic or smothering effects.*
Shoreline (as an ecosystem interacting with other aquatic nearshore ecosystems).	*Remaining residues must not be mobile such that they will leach out into nearshore waters.*

These criteria alone do not necessarily provide the clean-up organisers with a means of deciding when to stop their activities, since the criteria do not take account of natural clean-up processes or the damage that man's clean-up can cause. For example, the criteria given for mangroves that 'remaining residues must not inhibit ecological recovery through toxic or smothering effects' is not the go ahead for extensive clean-up activity. In many cases it will be appropriate for an area to be left alone and simply monitored to see how quickly the natural clean-up processes can work. Further clean-up activity may come later if natural recovery is too slow, with techniques based on specific practical recommendations.

Once the initial removal of bulk oil from surface slicks, sandy beaches and strandline areas has been achieved it is essential that clean-up decisions for more sensitive areas are not rushed. An assessment of the environmental and economic benefits of continued clean-up should be made. Unfortunately, every area will have unique characteristics which complicate the assessment and there will never be as much information as one would like on which to base the decision. However, any decision that is based on some understanding of the environmental sensitivities of a resource, its values for human use and its potential for recovery, will be preferable to a decision based purely on short term political/economic perceptions. The study was set out a simple procedure when provide a means to determine the point at which further clean-up is inappropriate;

Termination of Clean-Up Flow Chart

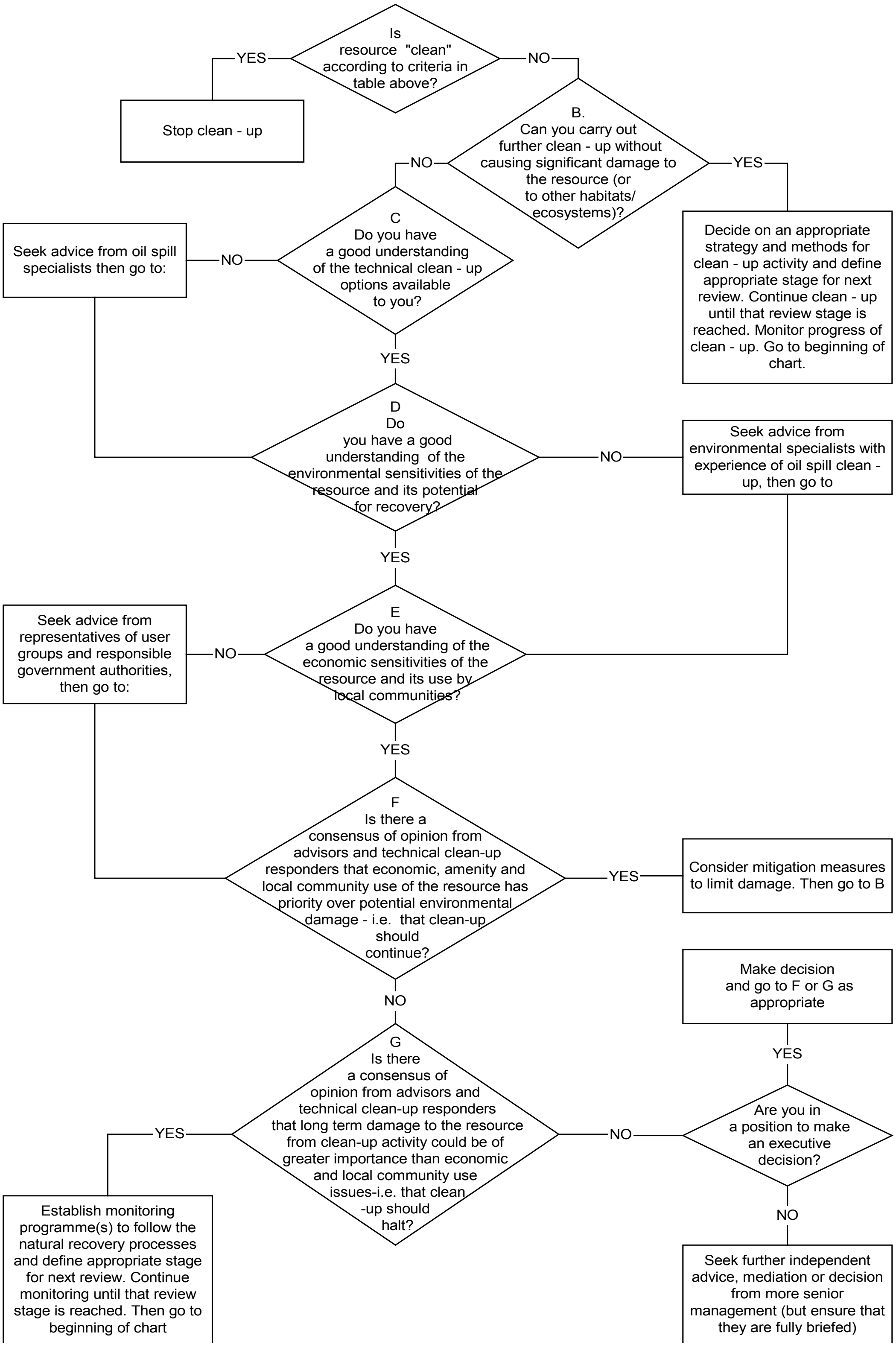

Figure 8 Terminaton of Clean-up Operation

1.3.7. Natural Resource Damage Assessment System for Thailand

A Natural Resource Damage Assessment (NRDA) system for Thailand has been developed as part of the project and submitted to PCD in the form of a handbook. During project preparation, background information has been provided on the development of NRDA's including inherent difficulties, international experience and conventions. A regulatory authority for Thailand has been discussed and a framework for assessing natural resource damage has been described based on the evaluation of costs for restoring natural resources which may be lost or damaged as a result of oil spills.

In spite of the many efforts to reduce the frequency and the consequences of oil spills, significant injury to natural resources can still occur. It is appropriate for governments to make claims to the spiller for damages to natural resources, to make the public whole. Yet, in the past, claims have been paid only for lost profits or earnings by private persons, not for damages to public natural resources. The Government of Thailand has now decided to make claims for natural resource damages as part of the overall oil spill planning and response program developed by the Pollution Control Department (PCD). The objective of the NRDA manual which has been prepared as part of this project is to outline a natural resource damage assessment system for PCD to follow. PCD will provide technical and scientific support during development of claims for damages to natural resources.

The NRDA system has the following three primary components:

- A process and framework for deciding if and how to conduct a NRDA for a specific incident.
- A handbook with protocols for collecting the necessary field data to support the NRDA.
- Valuation tables and a primer on how to calculate damages using compensation schedules.

There are the following three main phases of the process and the decision-making framework for natural resource damage assessments.

- ***Preassessment Phase****:* The objective is to decide if there is a need to conduct an NRDA for a specific incident. If there is a need, then the NRDA approach is selected.
- ***Damage Assessment Phase****:* The objectives are to quantify the injuries to natural resources and develop feasible and cost-effective restoration options.
- ***Restoration Phase****:* The objective is to implement the preferred restoration action(s).

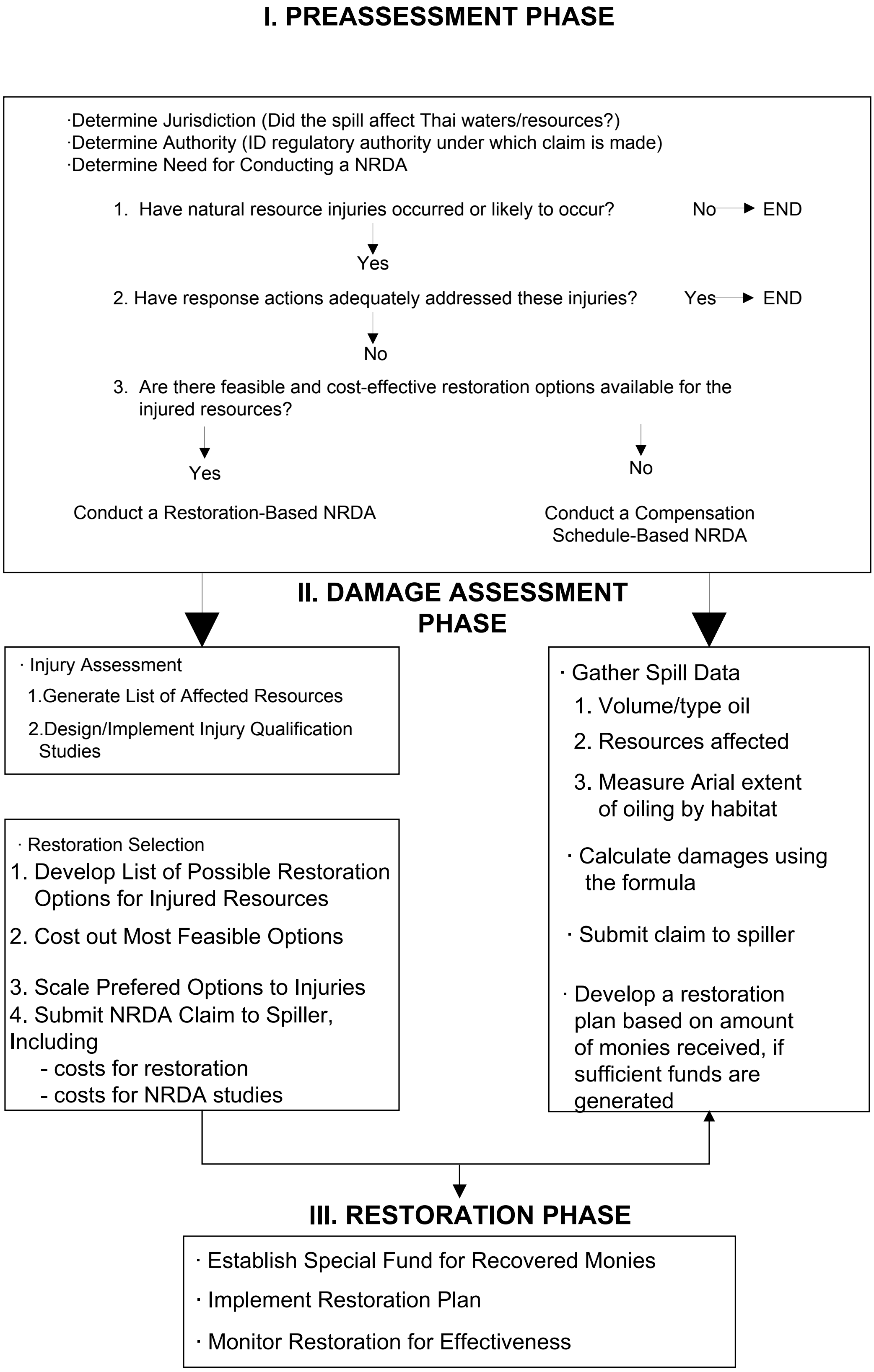

Figure 9 NRDA process and decision-making framework Preassessment Phase

For Thailand it is recommended that the Preassessment Phase for a specific incident should begin with a meeting of agencies with management responsibility for the natural resources potentially impacted by a spill, called the NRDA Government Committee. The following agencies should be considered for participation on the NRDA Government Committee:

- National Park Division (Royal Forest Department)
- The Tourism Authority of Thailand
- Mineral Resources Department
- Office of Environmental Policy and Planning
- Harbour Department
- Department of Lands
- Provincial Representatives (for all provinces affected by the spill)
- Department of Fisheries
- Other relevant agencies

The NRDA Government Committee should meet soon after an oil spill to review the available information on the known environmental effects of the spill and response actions taken to minimize these impacts. The NRDA Government Committee makes the decision that the State of Thailand has jurisdiction to pursue an NRDA claim, that is, the oil spilled entered Thai waters and the release affected Thai resources. There may be a need to coordinate with other countries with resources also damaged by the incident.

It is recommended that the NRDA Government Committee be formed as soon as possible, to start the process of planning for the conduct of NRDA of oil spills. It will take some time for representatives from the various agencies to become familiar with the concepts and methods for NRDA. Thus, it is important to begin discussions on NRDA in Thailand.

For effective operation of the NRDA Government Committee, one agency should be designated as the Lead Administrator (LA), by mutual agreement among the agencies. The LA's responsibilities are mainly administrative and include:

- Scheduling NRDA meetings;
- Preparing agendas and procuring space or other needs for meetings;
- Acting as a central contact point for agencies involved in the NRDA;
- Liaison with those conducting the oil spill response;
- Establishing and maintaining records for the Government Committee; and
- Contact with consultants or experts to assist in the NRDA.

The NRDA Government Committee should determine if there is a need for conducting an NRDA using the following procedure.

Step 1. List all of the potentially impacted resources in the first column; the worksheet includes those likely to be injured by a spill in Thai waters.

Step 2. Indicate the likely magnitude of injury, using three relative terms of low, medium, and high.

Step 3. Indicate the expected natural rate of recovery.

Step 4. Determine whether response actions have adequately addressed the injuries.

Step 5. Determine feasible and cost-effective restoration actions to remedy the injuries.

Step 6. Agree on the list of resources for which further NRDA consideration is needed.

Step 7. Select which NRDA method is to be followed, and proceed accordingly.

It is important to document the information used to make the decision on if an NRDA is appropriate and which approach is to be used. With such documentation, eventually it will be possible to develop more specific guidelines for selecting an approach.

1.3.8. Emergency Plan

An essential element in the response to an oil spill is the contingency plan. The wide range of impacts and considerations which may arise as a result of a major oil spill often means that numerous government and private sector organisations are involved in the response efforts. This can lead to considerable confusion and general inefficiency in the clean up operation without a well structured plan which clearly defines the roles and responsibilities of the various organisations. As a consequence, the project has included the development and delivery to PCD of an Emergency Plan for oil spill response. The aim of the plan is to provide PCD with the background information and structure to perform its role in oil spill response as set out by the Office of the Prime Minister's Regulation on the Prevention and Combating of Oil Pollution (1995). As part of the study, the role and responsibilities of PCD have been further refined and developed as summarised below:

Provision of Expertise on Oil Behaviour and Monitoring

The role of PCD includes the key responsibility of providing predictions on the movement and behaviour of oil spills in the marine environment. This is achieved through a combination of computerised modelling and aerial observation. PCD will maintain OSIS (Oil Spill Information System), a coupled oil spill model and Geographical Information System (GIS). The GIS is shared with the Shoreline Oil Clean-up, Recovery and Treatment Evaluation System (SOCRATES) which has been described earlier and contains the databases of reference data such as natural resources, equipment stockpiles, coastline & seabed types, water quality data, socioeconomic data, shipping and port data

The OSIS model forms the basis for PCD's ability to predict a number of behavioural characteristics of an oil spill occurring anywhere within Thai waters. A full explanation of how OSIS is operated is provided in the OSIS USER MANUAL held by PCD.

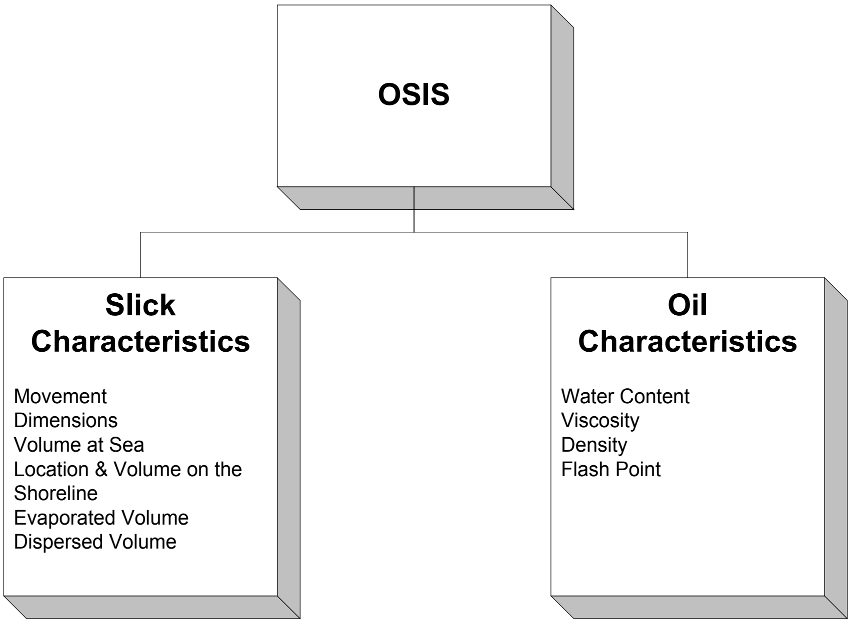

Figure 10 Oil Spill Characteristics Predicted by OSIS

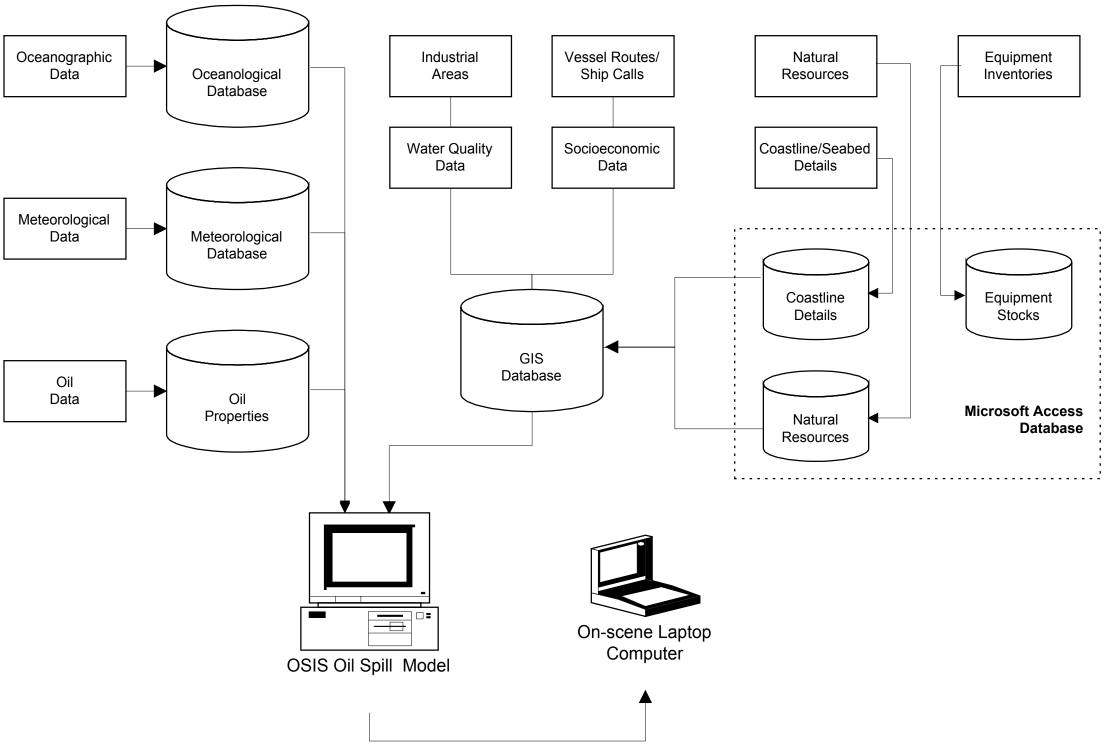

Figure 11 OSIS Configuration & Associated Databases

During model runs, OSIS predicts the weathering characteristics of the oil as well as displaying the extents of the oil against the reference map. PCD will use OSIS to provide predictions of the movement of oil to the appropriate agencies. This software is maintained on one PC desktop within the Marine Pollution Management Sub-Division and on a Lap-top computer which is in the possession of the Chief, Marine Pollution Management Sub-Division during office hours and the Duty Officer outside of office hours. The Duty Officer will fully trained in the use of the OSIS and SOCRATES systems. This enables spill predictions to be run on the OSIS model at any time of day or night.

In the event of a spill, in order to provide a prediction of the movement PCD will quickly ascertain the following information:

- the location of the spill,
- the quantity and type of oil spilled
- the weather conditions in the region

Current conditions are already incorporated within the OSIS system. Although the model contains typical wind data in order to provide a rapid predictions in the early stages of a spill, actual wind conditions will need to be sought quickly to provide reliable predictions. The ACTION PLAN described below sets out the procedures to be followed and information to be collected to run the model.

In order to verify the trajectory predictions being given by OSIS and make any adjustments that may be necessary, trained PCD personnel will take part in aerial observation performed by the Harbour Department and/or RTN.

Identification and Classification of Sites Sensitive to Oil Spills

Having predicted the likely movement of the oil through the operation of the OSIS model, PCD will be able to identify resources that are at risk from the oil. The following list sets out the main resources contained within the GIS and accessible through OSIS.

- Shoreline Type (sandy, rocky, mud)
- Mangrove
- Seagrass
- Coral
- Marine Mammals
- Birds
- Fisheries
- Turtles
- Aquaculture
- Tourist Beaches
- Industrial Areas (e.g. Power Stations)

OSIS provides the operator with the ability not only to identify these resources, but to access further information on the particular resources in question. Such resources include natural resources (e.g. seagrass, coral reefs, mangroves) and economic resources (e.g. tourist areas, aquaculture zones, fishing areas). Data is stored as thematic layers in the GIS. Each individual resource is represented as a polygon, symbol or line and these objects can be interrogated to access textual information such as descriptions or statistics, and graphical information such as photographs for identification purposes.

In addition to the shoreline sensitivity analysis of the Thai coastline which is contained in the GIS, the information provided by PCD on the resources at risk will be of major importance for the Command Centre as it forms the basis to the prioritisation of response strategies and will provide invaluable first-hand information for the OPERATING UNITS to select the most appropriate response technique when they may not have had an opportunity to survey the shoreline.

The physical and chemical properties of the spilled oil have a significant impact on the effectiveness and approach taken for different response techniques. OSIS will be used to provide the Command Centre with guidance on the changing characteristics of the oil in order that the most effective response techniques can be adopted.

In some circumstances, a spill may be identified without the source of the spill being known. In this case, OSIS can be used to attempt to “back-track” the oil in to identify the source. This is particularly useful in the case where the release is not continuous and hence difficult to identify from the air. Where appropriate, these predictions will be used to support prosecution of the spiller.

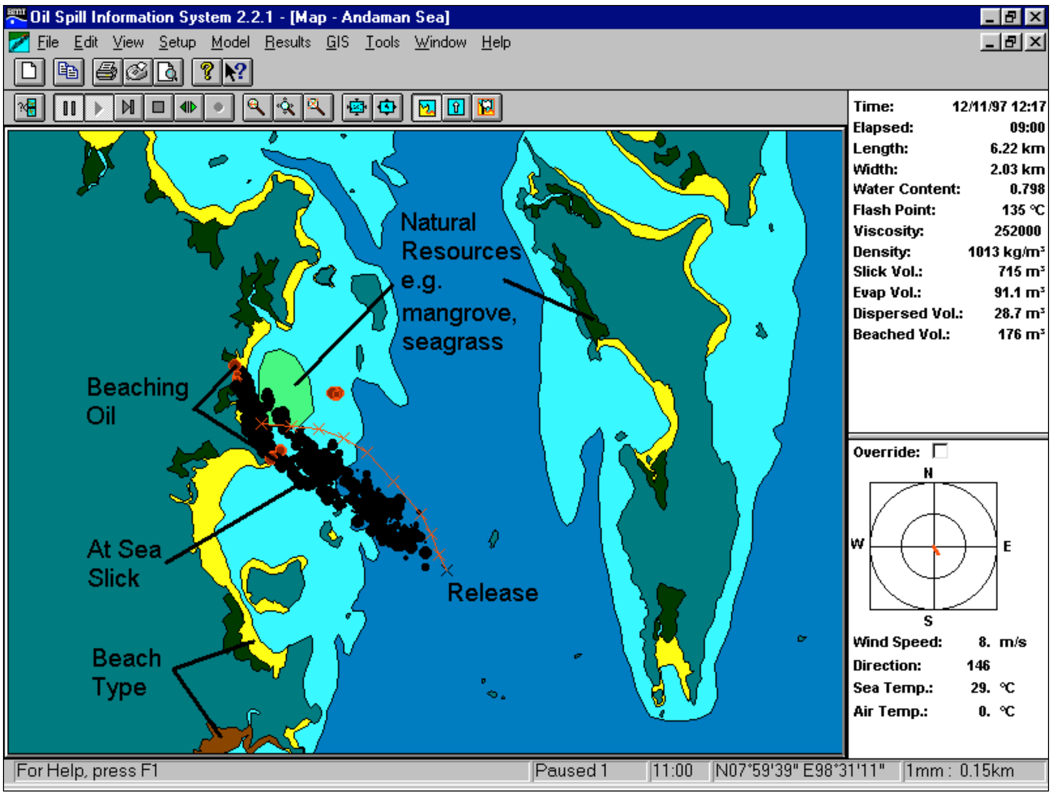

Figure 12 Example Oil Spill Trajectory Analysis

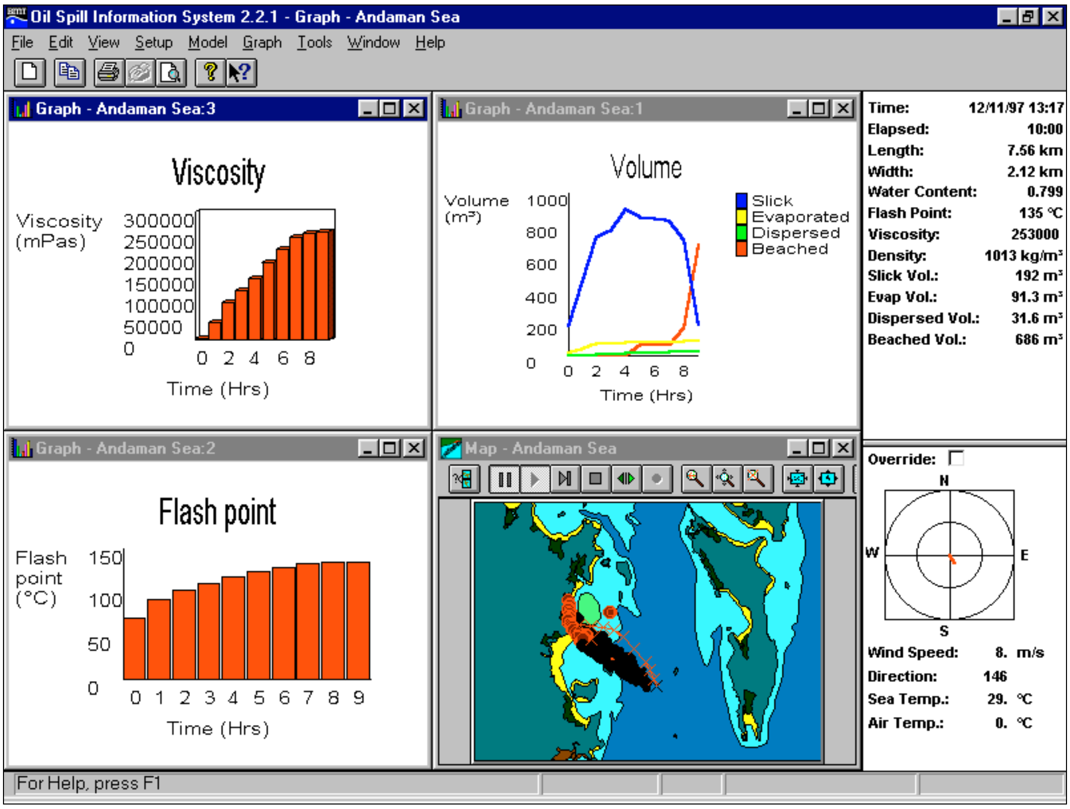

Figure 13 Example Oil Spill Property Predictions

Technical and Scientific Support on Oil Spill Clean-up and Environmental Recovery

Guidance on the clean-up and recovery activities is provided in the **Oil Spill Environmental Recovery Plan (ERP).** The ERP will be used by PCD personnel both in the field and in the office to provide input into the selection and implementation of clean-up operations. The ERP will be taken by PCD who attend a spill as an essential reference document.

The primary aims of this Oil Spill Environmental Recovery Plan (ERP) are to provide:

- a description of the vulnerability of the various coastal and marine resources to oil spills;
- a simple system for prioritising each resource for protection and clean-up;
- guidelines on the most appropriate techniques for their protection and clean-up;
- guidelines for carrying out impact surveys and for monitoring the recovery of damaged resources

Use of the ERP is closely linked with the various other elements of the PCD oil spill system:

- The SOCRATES database provides information on the distribution of the various resources around Thailand and listings of the resources present in the area affected by a spill.

- The Chemical Handbook provides information on the use of dispersant chemicals on oil slicks and is therefore referred to in the ERP where dispersants are appropriate (or not appropriate) for protection and clean-up of particular resources
- The Natural Resource Damage Assessment cross-refers to the ERP for information on the various resources and methodologies for assessing damage.

The seven essential stages to the ERP methodology, are described and marked on the flowchart included in Section 1.3.6 of this Executive Summary.

Advice and Monitoring of the Use of Chemicals in Oil Spill Response

In carrying out its responsibilities with regard to the use of dispersants, the PCD adheres to the following general principles:

- *The dispersant used should be pre-approved by PCD:* PCD has a list of pre-approved dispersants for usage in Thai waters. The granting of final approval will be carried out by the **Director General, PCD** or in his/her absence, the Director, Water Quality Management Division.
- *Use of dispersant must produce net environmental benefit*: PCD carries out the assessment of net environmental benefit by examining all relevant environmental implications, and by balancing the advantages and disadvantages of dispersant usage and comparing them to other response methods.
- *The quantities of dispersant used should be in proportion to the Incident:* A number of factors should be considered when reviewing the use of dispersants in order that their usage is appropriate to the circumstances. These include -the size of the spill, the dispersibility of the slick, the severity of the threat to sensitive resources and the effectiveness of natural dispersion.
- *Dispersant usage should be constantly monitored to take into consideration the changing characteristics of spilled oil.* A monitoring programme of the dispersant operation as set out in the Oil Spill Chemical Use Plan will be mounted by PCD in significant incidents in order to determine at which point the spraying operation becomes ineffective or when the oil is adequately dispersed. In the initial stages of an aerial spraying operation, aerial monitoring will be performed by PCD. In the later stages of the aerial operation or during shipbourne spraying, monitoring will occur both from the air and from boats**.** The spraying operation should not wait for the monitoring operation.

It is essential that the dispersant application procedures are expedited as rapidly as possible in order to maximise the effectiveness of the dispersant.

Assessment of Damages to the Natural Environment

Natural Resource damage Assessment (NRDA) deals with the assessment and valuation of damages to the public natural resources of Thailand. The detailed approach to the NRDA system is set out in the NRDA Handbook and the role of PCD is described in the above Section 1.3.7 of this Executive Summary.

The following are some examples of the types of damages that would be covered under the NRDA process:

- Damage to mangrove forest resulting in reduced productivity and ecological function as a result of death of seedlings, juveniles and adult trees.
- Damage to seagrass beds resulting in reduced productivity and ecological function as a result of dieback, or reduction in biomass and species abundance or density.

- Damage to coral reefs due to physical destruction due to grounding or mortality of reef organisms from oil exposure.
- Death of mammals and birds from direct contact with oil, or reduced reproduction rates from direct oiling or contamination of prey.
- Death of sea turtle eggs, hatchlings, juveniles and/or adults
- Reductions in fish populations
- Reduced primary and secondary productivity of intertidal and subtidal habitats.
- Loss of use by the public of beaches or other coastal recreational sites because of closure or avoidance by users.

Private third-party losses relating to economic damage to natural resources (fishing, commercial exploitation of mangrove, tourist industry) are not covered by NRDA.

Development of Compensation Claims for Damage to the Natural Environment and Claims Advice to Third-Party Claimants

PCD's responsibilities with regard to the claims formulation and negotiation are as follows:

- Technical and scientific input into the development and negotiation of claims based on the NRDA process.
- The formulation and presentation of claims for the costs incurred by PCD itself in performing its role as a result of the oil spill incident.
- Advise to private third-party claimants on formulation and presentation of claims (e.g. commercial fisheries, commercially exploited mangroves, hoteliers, etc.).

The Emergency Plan sets out the policy of PCD and the actions to be performed by its staff in the response to oil spills in Thai waters referred to above. In general, contingency plans should follow a similar layout to enable them to be easily understood and compatible with plans of other organisations. The plan, therefore, has a fairly standard structure consisting of three main sections: the STRATEGY PLAN, the ACTION PLAN and the DATA SECTION.

During a spill, reference should be made to the STRATEGY PLAN for clarification of PCD's general policy for performing the tasks assigned to it. This defines the structure and organisation for response to oil spills and how PCD links to the National Response Organisation and to co-operative agreements between Thailand/Malaysia and other countries within the ASEAN region. A clear explanation is provided of PCD's internal organisation and its procedures for oil spill response. The responsibilities and resources of the Operation and Support Units within Thailand are also defined including: Harbour Department, Royal Thai Navy, Industrial Environmental Safety Group (IESG), Port Authority of Thailand, and other relevant central and provincial government departments. Guidelines have been provided with regard to liaison and public relations during an oil spill response and clean up operation with particular reference to how information produced by PCD, such as oil spill trajectory predictions, assessments of damage to natural resources and advice on recovery options may be disseminated to the press and public.

The ACTION PLAN sets out step by step procedures for oil spill response under the key task headings of Initial Report, Notification, Incident Evaluation, Response Decisions and Response Operations. Where appropriate, these procedures are accompanied by standard forms, which are to be completed and distributed by PCD representatives, and the relevant contact details specific to the tasks in question. The importance of procedures for linking the ACTION PLAN with the other handbooks and computer software which have been produced as part of the project are emphasised. Significant cross-referencing exists within the text of the Emergency Plan to allow rapid access to relevant information by PCD staff during an oil spill incident. Specific reference is made to the Oil Spill Environmental Recovery Plan, the Oil Spill Chemical Use Plan, the NRDA Handbook and the OSIS and SOCRATES oil spill information and response systems.

The DATA SECTION contains the contact details of relevant government and private organisations including PCD Internal Contacts, Government Operating Units (including Provincial Government), IESG Members, Support Units and Private Contractors/Consultants.

1.4 Project Deliverables to PCD

On completion of the project PCD have been provided with computer systems integrated with geographical information databases for the prediction of oil spill movement and the management of response and clean up operations. The study components of the project have provided deliverables covering the assessment of oil spill risks throughout Thai waters, the financial damage which may be sustained following an oil spill, environmental recovery plans to recover polluted areas and the preparation of an emergency plan for oil spill incidents including a handbook for the use of chemical response during oil spills. The use of video and printed media including the preparation of appropriate publications have been addressed under the project in order to ensure mutual understanding between the public and relevant organisations. In addition to the submission of project reports and annexes as the project has progressed, a summary of the project deliverables held by PCD following completion of the project is set out below.

1.4.1. Software Systems:

- ***Microsoft Access Data Sources Database***

To facilitate the management of the growing library of data obtained for use in the studies, a Microsoft Access Database has been prepared. During the course of the project all reference data has been entered into the system together with brief descriptions of the data and key word search facilities. This has been delivered to PCD allowing rapid searches for data sources to be carried out by PCD staff.

- ***OSIS (Thailand)***

The Oil Spill Information System (OSIS) providing oil spill trajectory, weathering and fate modelling of oil spills has been developed for Thailand allowing the monitoring of oil spills in Thai waters. The model is fully operational and validated and incorporates relevant geographically based information in the system's Geographical Information System (GIS). This model is to be held and operated by PCD.

- ***SOCRATES (Thailand)***

SOCRATES is a computer based oil spill decision support system which allows the management of beach clean up operations and spill data. SOCRATES is populated with the latest available data and integrated with the central GIS. This system is to be held and operated by PCD.

- ***POSEIDON (Thailand)***

The marine risk assessment model, POSEIDON, which has been specifically developed for this project, predicts the frequency and potential oil spill consequences of shipping incidents which may occur within Thai waters. The POSEIDON model has been developed to interface with PCD's GIS system ARCINFO. The system is to be held and operated by PCD.

1.4.2. Handbooks

- ***Chemical Handbook***

This handbook provides guidelines for the use of dispersants in response to oil spills in Thailand. It is based on the IMO/UNEP Guidelines on Oil Spill Dispersant Application including Environmental Considerations (IMO 1995) modified for specific application in Thai waters.

- ***Oil Spill Emergency Plan***

The Emergency Plan sets out the policy of PCD and the actions to be performed by its staff in the response to oil spills in Thai waters. The plan consists of three main sections: the STRATEGY PLAN, the ACTION PLAN and the DATA SECTION which contains all contact details for relevant government and private sector organisations.

- ***Oil Spill Natural Resource Damage Assessment Handbook***

This handbook provides guidelines and procedures to help PCD assess the damage to natural resources as a result of an oil spill and to assist in the recovery of financial compensation from the responsible party.

- ***Oil Spill Environmental Recovery Plan***

This handbook provides guidelines on the considerations, prioritisation and decision-making processes for the clean up and recovery of impacted resources which may result from an oil spill incident. The plan includes procedures for impact surveys and future monitoring of damaged resources.

1.4.3. Media Information

- ***Video***

A 15 minute video has been produced, in Thai with English subtitles, which covers the description of the project, its aims and objectives and the key tasks involved in its execution. Film excerpts are shown of the effects of major international oil spills together with video footage obtained during the project covering Thai coastal waters, shoreline installations, shipping activities, potential sources of oil spill and natural coastal areas and marine resources at risk. The video goes on to illustrate the work involved in carrying out the project including footage of field work, interaction with coastal users and the general public and graphical description of the project tasks. The video will be held by PCD.

- ***Brochures***

The following series of brochures have been prepared and submitted to PCD under the project.

Development and Verification of a Mathematical Model for Oil Spill Movement

This brochure provides an overview of the project for those not familiar with the work that is being carried out and its objectives. The brochure includes brief description of the OSIS and SOCRATES models, the environmental database and the Geographical Information System with colour material used to illustrate the various aspects of the project.

Oil Spill Response Systems

This brochure provides an overview of computer systems that are now available to support oil spill response. The brochure describes oil spill models, databases, expert systems, and the use of GIS. As examples of their use, the systems developed for PCD are described. The brochure makes use of screen graphics from the PCD software applications to illustrate the text.

Thailand's Natural Resources

The aim of this brochure is to provide education on the natural resources in Thailand which are potentially at threat from oil spills. The natural resources at threat are described and illustrated. The work carried out by PCD to evaluate these resources and plan for their protection is also described and illustrated e.g. by maps showing the results of the sensitivity analysis.

Oil Spill Response in Thailand

This brochure describes the measures in place in Thailand to combat the threat of oil spills. The Government structure for oil spill response is set out together with an explanation of the role of PCD. The equipment available for fighting oil spills is described and illustrated and mitigation measures such as pollution monitoring flights are discussed.

Oil Spill Technology

The main aim of this brochure is to cover the wider theme of the use of technology in oil spill response. The brochure describes both current and emerging technologies including, but not limited to, those already in use in Thailand. Clean-up technologies are discussed including techniques such as bioremediation and monitoring technologies such as satellite and aircraft mounted remote sensing.

1.4.4. Seminars and Training

Project dissemination has included the presentation of a series of seminars, training sessions and a desk top exercise for key PCD staff involving a simulation of an oil spill event. The software systems for risk assessment, oil spill modelling and response have been installed at PCD and training courses have been provided for PCD staff on their operation and use.

1.5 Recommendations

The project's key recommendations and conclusions are summarised below:

- The databases contained within the project's Geographical Information System need to be maintained on a regular basis.
- Meteorological data is provided for the last complete year (1996). Data for future years should be obtained and the systems updated accordingly.
- The database for SOCRATES is not complete due to lack of certain types of data particularly the operational characteristics of beaches and some of their physical characteristics. Although some of this data can be collected during a spill incident, a programme of specific data collection for this data should be considered.
- The data provided on historical marine oil spill incidents was sparse. It is recommended that comprehensive data should be collated on all future marine oil spill incidents.
- It is recommended that PCD establish close liaison with Harbour Department and the Ministry of Transport and Communication with regard to the future collation and analysis of local and international shipping statistics and records of marine incidents which may occur in Thai waters with particular regard to oil spill events.
- PCD and the Harbour Department should also give consideration to the marine risk assessment capability which now exists within PCD and how this can be developed to reduce marine risk to full advantage. Aspects to be reviewed include vessel traffic management systems including traffic separation and the possible use of harbour radar systems.
- Regular staff training including induction training for new staff should be carried out for the oil spill information systems in order to maintain staff expertise in the use of the systems.
- New versions of the software applications are always under development to ensure that the software is maintained at the forefront of research understanding and software technology. PCD should ensure that the software is upgraded accordingly.
- Following the expiry of the software warranty period, software support contracts should be taken up in order to provide the level of technical and software support needed to maintain the systems for emergency response preparedness.
- It is important that the Thai National Contingency Plan be updated to incorporate the recommendations and procedures outlined in the "Guidelines for the Use of Oil Spill Dispersants in Thai Waters".
- In line with IMO, it is recommended that Thailand adopts the list of approved dispersants for the UK which includes dispersants on the USA approved list.
- Treating oil spills in freshwater could result in high local concentrations of dispersed oil. With the sensitive resources in the region of Thailand's rivers, and the lack of effective freshwater dispersants, it is not recommended that dispersants should be considered a prime response to oil spills in freshwater at present. With research continuing in this area it is recommended that the use of dispersants should be reviewed in the year 2000.
- Weathering and dispersibility of oils carried in Thai waters is not well understood. It is, therefore, recommended that PCD work with the upstream and down-stream (IESG) oil industry in Thailand to ensure that oil weathering and dispersibility studies are carried out for crudes transported in Thai waters.