"Oil Spills in the Australian Marine Environment: Environmental Consequences and Response Technologies"

Abstract

Oil spills in the marine environment can have wide spread impact and long-term consequences on wildlife, fisheries, coastal and marine habitats, human health and livelihood, as well as recreational resources of coastal communities.

The Australian Maritime Safety Authority has recently undertaken a series of new initiatives involving new technological developments to assist in oil and chemical pollution response in the marine environment. This paper will discuss the risk and impact of oil spills and the new technologies being employed for improving spill surveillance, modelling of slick trajectories and the development of geographic information systems to support spill response decision making. The use of advanced chemical fingerprinting techniques for the identification and prosecution of oil polluters will also be discussed.

Environmental Consequences of Marine Oil Spills

The impact of oil spills on coastal and marine environments can be both short and long term. The degree of the damage caused by an oil spill event depends primarily upon the quantity of oil spilt, the chemistry and properties (type) of the oil and the sensitivity of the biological resources impacted.

The effects on sea birds and other marine life by an oil spill can be due to the smothering and physical contamination or due to the toxicity of the chemical components of the oil. The persistence of the oil is a significant factor on its fate in the environment. Impacts of spills on foreshores also depend heavily upon the form and exposure of the coastline eg protected mangroves and salt marshes are extremely sensitive to oil spills yet rocky exposed coastlines naturally self clean and are less sensitive to oil spills.

Oil spills could impact coastal and marine environments in many ways, and can include;
- mortality or long term impacts on sea birds, marine mammals and other sea life,
- physical damage or permanent loss of foreshore and marine habitats,
- impacts on the health, viability and diversity of coastal ecosystems,
- damage to aquaculture stocks, facilities and tainting of commercial seafoods,
- smothering of, and damage to, intertidal biota and vegetation,
- contamination of coastal infrastructure and amenities leading to impacts on tourism and other recreational activities,
- shut-down or damage to power station cooling water, desalination plant intakes or salt pans,
- economic loss at both the regional and national level,
- adverse media and political attention on the oil and shipping industries and their operations.
The environmental impacts of oil spills at sea are usually temporary but it must be recognised that only a few major oil spills internationally have had extensive post spill monitoring studies undertaken to gauge the extent of long term damage to wildlife populations and sensitive marine and coastal ecosystems. One of the world's most extensive environmental surveys on the long term effects of an oil spill has been carried out in Prince William Sound, Alaska after the Exxon Valdez oil spill.

On Feb. 9, 1999, the Exxon Valdez Oil Spill Trustee Council released a report on the long term impacts of the Exxon Valdez oil spill which in 1989 spilled 11 million gallons (37,415 tonnes) of crude oil in Prince William Sound Alaska. The report concludes, that most of the fish and wildlife species that were injured have not fully recovered. (1) Also the report states, After 10 years only two out of the 28 species, the river otter and the bald eagle, listed as being 'injured' from the 1989 spill are considered to have recovered. (1)

The executive director of the Exxon Valdez Oil Spill Trustee Council in a press interview stated. "Ten years after the spill, there has clearly been a lot of progress toward recovery...but it is equally clear that for several species and the ecosystem in general, there is a long way yet to go." (1)

The report summary states that eight species are considered to have made little or no progress toward recovery since the spill, including killer whales, harbour seals and common loons. Several other species, including sea otters and Pacific herring, have made significant progress toward recovery, but are still not at levels seen before the accident. According to the Trustee report, the Exxon Valdez oil spill killed an estimated 250,000 seabirds, 2,800 sea otters, 300 harbour seals, 250 bald eagles, and up to 22 killer whales. (1) It should be noted that this report has been criticised by some organisations, including Exxon, for its conclusions and is still subject to scientific scrutiny.

**Oil Spills Risk Worldwide and in Australia**

**Classes of Oil Spills**

Oil spills in the marine environment can be considered in three broad classes.

Firstly, small oil spills which are associated with berthing, bunkering and other terminal operations, and accidental discharges of oily water mixtures from the bilges of machinery spaces. Such spills usually occur in port and tend to result from accidents, equipment failure or poor work practices.

The second class of oil spills occur as a result of major shipping incidents like collisions, groundings, fires or other forms of damage. Undersea pipelines, drilling rigs and platforms are also potential sources of oil pollution by damage or accident eg severe weather events like cyclones, blow outs or fires on off shore rigs. Spills resulting from damage to an oil tanker, off shore structures or pipelines tend to produce the isolated intensive/large scale spill, whereas in port spills tend to be slight to moderate in size but can still result in extensive environmental and economic damage.

The third class of spills I refer to as the "dishonourable discharges" or "midnight dumpers" who intentionally dump waste oil and oily waters into our marine environment to save money or time. Maritime accidents are understandable but these intentional spills are essentially criminal actions and can not be excused as "operational discharges" by vessel or rig personnel.
Statistics on Oil Spills, International and Australia

Major oil spills from exploration and production activities worldwide, both offshore and on land, are relatively rare compared to vessel and pipeline spills. The International Oil Spill Database of Oil Spill Intelligence Report (OSIR) reports that over the last 35 years only 171 spills of more than 10,000 gallons (34 tonnes) have been reported from exploration and production facilities, compared to more than 2,600 vessel spills and more than 3,700 pipeline spills. (2) That is less than 3 percent of the number of significant oil spills reported worldwide are from oil exploration and production facilities and these have usually involved well blowouts.

Since the 1960s around 1,444,000 tonnes of oil has been spilled by oil well blowouts and well failures worldwide compared to 7,325,000 tonnes spilled from vessels during the same period. (2)

To date Australia has been fortunate in that it has recorded very few large oil spills over 1000 tonnes. Only two major oil spill incidents (ie of over 1,000 tonnes) have occurred since 1970, the OCEANIC GRANDEUR (approx 1100 tonnes) and the KIRKI (17,700 tonnes). There were a total of 1556 confirmed oil discharges sightings and oil spills in Australian waters reported to AMSA in the five year period to June 1998. The distribution of reported oil spill incidents around the Australian coast is represented in figure 1. The sources of 930 sightings during the period were not identified, although the majority are assumed to be ship sourced. (3)

Figure 1.

During the 1997/98 financial year, the Australian Maritime Safety Authority received reports of 251 marine oil spill sightings. Some 71% of these spills occurred within port limits and in these cases any necessary clean up action was undertaken by the port authority or relevant oil terminal. In 9 cases, clean up or response action of some description by the National Plan to Combat Pollution of the Sea by Oil and Other Noxious and Hazardous Substances was needed. (3)

The extent of shipping movements around Australia is extensive with over 12,000 ship visits to Australian Ports per annum. Over a twelve month period commercial vessel routes can be visualised by the geographic location of reports received under the AMSA AusRep Ship Reporting system. (Figure 2)
Figure 2. Location of ships reporting to AMSA over a 12 month period.

Marine Pollution Response in Australia.

Since October 1973 Australia has had in place a pre-planned national strategy to respond to marine spills. The original strategy dealt only with oil spills and was known as the National Plan to Combat Pollution of the Sea by Oil. In April 1998 the strategy was extended to deal with the response to maritime chemical spills in Australian waters and is now known as the National Plan to Combat Pollution of the Sea by Oil and other Noxious and Hazardous Substances (National Plan).

The National Plan is a national integrated Government and industry organisational framework enabling effective response to marine pollution incidents. The Australian Maritime Safety Authority (AMSA) manages the National Plan, working with State/Northern Territory (NT) governments, the shipping, oil, exploration and chemical industries, emergency services and fire brigades to maximise Australia's marine pollution response capability. Funding, equipment and training programs to support National Plan activities are coordinated by AMSA on advice from the National Plan Advisory Committee (NPAC).

The responsibilities of National Plan participants are clearly defined in the National Plan Administrative Arrangements. These include access to equipment and dispersant stockpiles, equipment maintenance and storage, funding and joint use of resources. Based on these arrangements, the Commonwealth's role, through AMSA, is coordination, training, and the provision of technical and logistic support, equipment, materials and finance.

AMSA has initiated a number of major technology projects to improve the provision of environmental, scientific and technical decision support to the National Plan. These projects include:

- an improved Australia wide computer based Oil Spill Trajectory Model
- Geographic Information System based Oil Spill Response Atlas
- investigation into the development of a Satellite Remote Sensing Capability for the Detection of Oil Spills
- and the National Oil on the Sea Identification Database for the improved chemical fingerprinting of marine oil spills.

**Improved Oil Spill Trajectory Modelling**

When an oil spill occurs in the marine environment the first major concern of responders is; where will the oil go? That is, the slick direction, speed of movement and spreading characteristics of the oil at sea.

In near-shore marine environments the tracking of oil spills, which are likely to impact the shore line, is of prime importance in the effective deployment of oil spill response equipment to protect environmentally sensitive areas and in clean-up planning.

Oil spill trajectory models (OSTMs) provide this decision support but must meet a number of requirements to be of use to responders. They must provide:

- accurate spill prediction for both forecasting and hindcasting,
- rapid output of results regardless of spill geographic location,
- ability to adjust inputs considering changing conditions and field observations,
- use in remote field locations or effective transmission of model outputs to field operators,
- user friendliness of the software and its outputs

For the safety of mariners, and for the protection of the marine environment from oil pollution the detailed observation of the weather and sea conditions, the rapid transmission of the data and the ability of meteorologists to predict future weather conditions is still a vital component of the safe operation of vessels throughout the world. Ships and mariners at sea not only benefit from these developments but are also an essential source of meteorological ocean observations for meteorological organisations.

In conjunction with AMSA’s Australian Search & Rescue unit (AusSAR) the Marine Environment Protection Services business unit developed a joint Search and Rescue/ Oil Spill Trajectory Model (SAR/OSTM) technical specification for the provision of near real time meteorological and oceanographic data as well as drift and trajectory modelling capabilities for Australian waters. From an oil spill response perspective the primary area of interest is Australia’s coastal regions, whereas from a marine search and rescue perspective a much wider area needs to be covered by a drift model. The present Australian SAR area of responsibility is depicted in Figure 3 and corresponds to one-ninth of the world’s ocean surface.
The successful tenderer is a consortium headed by the Australian Bureau of Meteorology, Special Services Unit and includes the National Tidal Facility, CSIRO Marine Laboratories and the Australian Institute of Marine Sciences (AIMS) who are providing the OILMAP modelling software and Global Environmental Modelling Services (GEMS) who provide GCOM3D, a 3-dimensional continental shelf hydrodynamic model.

Over the past few years there has been a dramatic increase in the accessibility of satellite derived data of the oceans and the use of more sophisticated weather models which are ideally suited to providing the near real time information required in the new system. The main phase of the project involves the development of near real time access to a vast array of land based, in-situ and satellite derived oceanographic and meteorological data to cover over Australia’s territorial waters, the Australian EEZ as well as the entire Australian Search and Rescue area of some 47 million square kilometres.

Data inputs including direct data feeds to the AMSA SAR/OSTM model will include:
- high resolution bathymetric data sets
- tidal amplitudes and phase constants across the SAR region
- sea surface winds (actual and forecast)
- outputs from the Bureau’s global and regional weather models
- altimeter data from the Topex-Poseidon satellite
- deep ocean current data base from CSIRO
- satellite derived sea surface temperatures
- inputs from real time tide gauges etc. \(^{(4)}\)

To demonstrate the power of oil spill trajectory modelling of the GCOM3D/OILMAP software, the July 1995 *Iron Baron* oil spill off the northern coast of Tasmania was modelled by GEMS and AIMS. The model is based as close as possible to the circumstances at the time, ie a spill of a total of 300 tonnes of bunker fuel oil over a period of 72 hours from the grounding, and using actual wind speed and direction measured at the site. (Figure 4.)
Figure 4. Simulation of Iron Baron spill northern Tasmania after 72 hours

Oil Spill Response Atlas - Geographic Information System

When an oil spill occurs in the marine environment the other major concern of responders is;
- what environmental impact will the oil have? That is, what coastal and marine
environmental resources may be at risk from the spill?

Coastal and marine resource atlases, in a computerised Geographic Information System (GIS)
form, are an essential tool in contingency planning and in decision making during marine
pollution incidents. They provide a quick and efficient means of determining marine and
coastal areas of environmental, economic and strategic sensitivity that could be impacted in
the event of an oil pollution incident, and also provide valuable resource and logistical
information for combat authorities.

On the 12th of August, 1998, the Federal Environment Minister, Senator Hill, announced the
allocation of $1 million under the Natural Heritage Trust to the Australian Maritime Safety
Authority (AMSA) to fast track the production of a computerised Oil Spill Response Atlas for
Australia, due for completion in December 1999. The National Oil Spill Response Atlas
(OSRA) project, managed by AMSA on behalf of the National Plan in conjunction with the
States and Northern Territory, will focus primarily on fast tracking the data collation, data
capture, the digitisation and integration of the diverse environmental atlases into a uniform
and National Geographic Information System (GIS) structure for use during maritime oil and
chemical spill incidents.

The major outcome of the project will be to produce a complete and uniform Oil Spill
Response Atlas for Australia in a computerised GIS format able to be conveniently accessed
and operated by spill response organisations, planning and clean up teams, environmental and
wildlife agencies and other emergency organisations.
The National Oil Spill Response Atlas program’s prime aim is to systematically compile all relevant geographic and textual data into a standard GIS format for the majority of Australia’s maritime and coastal environments.

OSRA datasets will include:

- biological, environmental, wildlife and man-made resources present Australia wide,
- geomorphological mapping and shoreline sensitivity to oil spills,
- human-use resource considerations,
- logistical and infrastructure information to support a spill response.

OSRA will provide non-strategic environmental layers for distribution through the Australian Coastal Atlas (ACA) State/NT Internet computer nodes provided by ERIN. OSRA will also be linked with AMSA’s maritime search and rescue and spill trajectory models as well as emergency contact lists and other decision support systems.

Examples of the outputs from the GIS atlas are shown in figures 5 and 6. In Figure 5 a section of Western Port Bay is reproduced showing the location of seagrass beds, coastal types, botanical sites and important bird colonies. Each environmental theme or data layer can be switched on/off panned, expanded or reduced depending upon user scale and needs.

Figure 5. Example of Western Port Bay Oil Spill Response Atlas.

In Figure 6 an example of the northern section of Port Phillip Bay is reproduced with a simulated oil slick from an oil off loading facility, bird habitats, seagrass beds, abalone beds overlayed on an aerial photograph.
During a spill response the positions of oil contamination on foreshores, logistical and response information can be incorporated into the atlas by the user for recording and planning of response operations.

Investigation into the Development of Satellite Remote Sensing Capability for the Detection of Marine Oil Spills

AMSA, in conjunction with the Australian Centre for Remote Sensing (ACRES), has been investigating the use of satellite sensing technology to support oil spill response and surveillance activities for marine pollution regulatory enforcement activities. The focus of this initial investigation has been on the use of satellite based Synthetic Aperture Radar (SAR) technology.

The advantages of SAR remote sensing is its unique ability to see through clouds, dust, haze and it can supply imagery both in daylight and at night. Radar sensors are an "active sensor" which acts independently of the sun and light condition offering 365 days of imaging capability across all Australian waters and coastal regions, a capability not available with most optical sensors.\(^{(6)}\)

The deployment of the Canadian RadarSat satellite recently, adds the flexibility of a "programmable sensor" which provides various beam modes, angles of incidence, resolution and customer designated ground footprints. Improved satellite tasking and digital data supplied via the Internet to the customer means faster access and use in emergency and disaster support. ACRES is in the process of establishing a ground receiving station in Alice Springs to allow direct down loading of satellite data to Australia.

A trial of RadarSat capability for the detection of vessels off the Port of Newcastle was carried out by ACRES and AMSA in October 1997.\(^{(6)}\) The RadarSat imagery for offshore Port Newcastle (figure 7) has been superimposed with the location of sensitive commercial fisheries and protected bird habitats from the Oil Spill Response Atlas to demonstrate the integration of the two decision support systems.
A number of commercial vessels can be seen as bright white objects. In this high angle mode, vessel and objects at sea are more apparent than in low angle imagery that highlights oil on the sea surface.

In Figure 8 the location of an oil spill in the Straits of Malacca can be seen. This image was taken at a time of significant atmospheric pollution from forest fires in the region obscuring conventional optical satellites and aerial surveillance. Yet the RadarSat satellite was able to penetrate the smoke haze and map the location of the spill within the Straits.
The high cost of imagery, the frequency of revisit of the satellite to the incident scene and the timely delivery of imagery to users are issues that constrain the use of this technology on a routine basis. Future work is required to improve the systems and delivery of remote sensing imagery for marine environment protection purposes.

**Chemical Fingerprinting of Oil Spills**

1998 was the United Nations International Year of the Oceans. As a major initiative to protect the oceans from oil pollution the Australian Maritime Safety Authority (AMSA) and the Australian Geological Survey Organisation (AGSO) jointly released in late 1998 the National Oil on the Sea Identification Database (NOSID) to assist the fight against oil pollution. The NOSID project was an initiative of the National Plan and involved three years of development by AGSO.

When a vessel runs aground or an oil rig has suffered damage in a storm it is obvious who is spilling oil. But the majority of oil spill incidents reported to AMSA involve illegal dumping or the accidental discharges of oil at sea most of which are not reported by the spiller as required by law. Therefore it is difficult to identify the source of the pollution or bring the polluter to account for environment damage or to pay the clean up costs.

In order to provide unequivocal identification of a certain vessel or off shore facility as the source of an oil spill evidence must be provided that the oil slick has the same unique characteristics as that of the oil carried by the vessel or produced by that well. Without the help of eye witnesses or photographic evidence in oil spill incidents, chemical analysis of the oil itself provides the only assistance in identifying the source of a spill.

This involves the chemical matching of the oil slick to samples taken from the suspect vessel to positively identify the polluter. Where a suspect vessel or oil is not available to investigators, a library of reference oil samples will assist the laboratory in identifying the ship or other source of the spill. This is similar to forensic scientists taking fingerprints at the scene of a crime and matching them against a database of suspect criminals.

NOSID consists of oil fingerprinting data sets on CD-ROM, hard copy documentation and an Oil Identification Reference Kit which includes unique standards. The advantages of NOSID over the present analytical capabilities is that the project now provides:

- a source of well characterised oil reference samples;
- full documentation on oil characterisation techniques, including powerful biomarker techniques and traditional methods;
- evaluation of state-of-the-art oil biochemical markers that overcome problems of weathering and degradation of the slick prior to collection;
- a structured analytical database and quality control procedures in which an analyst can build and update with their own data.

The NOSID database consists of 30 reference oils which represent:

- oils currently transported around Australia;
- crude oils being produced in Australia's offshore basins;
- natural oil seeps which commonly strand on the Australian coast after being transported on ocean currents.

Improved, standardised and effective laboratory analytical fingerprinting techniques for oil spill source identification will provide regulatory agencies with legally defensible information
for the identification and prosecution of offending vessels and land based facilities involved in marine oil pollution. It will also provide a valuable deterrent to vessel operators who may be “potential polluters” from intentionally discharging waste oils into the Australian marine environment.

Conclusion

AMSA is actively pursuing the development and implementation of new technology to carry out its pollution response and search and rescue coordination functions.

New technology developments in oceanography, meteorology, numerical modelling, high speed computing, satellite remote sensing, geographic information systems and advanced chemical analytical techniques are providing response planners and response organisations with new and improved tools for surveillance of Australian waters, the identification of polluters and improved decision making in pollution response operations.

References cited


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