The New Zealand marine oil spill risk assessment 1998

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Abstract

As part of the New Zealand Marine Oil Response Strategy, a detailed risk assessment was carried out in 1998 for the Maritime Safety Authority. A quantitative risk model was developed for the purposes of predicting likely sizes and return times of oil spills into the marine environment. The model included offshore exploration and production activities and the associated export of crude oils and condensates from Taranaki, as well as crude oil imports to the refinery, domestic distribution and import of finished products, and the bunkers carried by all classes of shipping. This information was to be used as a basis for reviewing spill preparedness and response planning, determining the relative contribution to the risk profile of each activity or sector and identifying the various factors that affect the risk. The risk assessment methodology and the modelling techniques are described and the outputs briefly discussed.

Introduction

The Maritime Transport Act 1994 requires the Director of Maritime Safety to develop and maintain the New Zealand Marine Oil Spill Strategy. This sets out how New Zealand will efficiently and effectively minimise the impact on the marine environment of oil pollution from ships and oil transfer. The Strategy recognises the need for the national spill response capability to reflect the current risk profile and so it requires that a comprehensive national risk assessment be carried out at least every six years. The assessment should focus on both existing contributions to risk from the maritime sector industries and reasonably foreseeable new or potential activities.

A national oil spill risk assessment was first carried out in 1992. In early 1998, Woodward-Clyde (NZ) Ltd was commissioned by the Maritime Safety Authority to prepare a new national assessment of marine oil spill risks. This paper gives a brief description of how that national risk assessment was carried out and the quantitative risk model developed by Woodward-Clyde for that study.

This work was carried out between March and October 1998. The study also included an assessment of the state of preparedness in New Zealand at that time, and a review and comparison with international practice.

Objectives

One of the primary objectives of the risk assessment was to establish the probability of oil spills occurring in the marine environment (in terms of oil type, source, location, spill size and return period). This was to be used as a basis for assessing the adequacy of preparedness and the required response capability to deal with that risk.

The risk assessment would be required to identify the relative contributions of the various activities or sectors to the overall regional and national risk profiles and the main factors affecting the risk. The risk model used must provide a structured and transparent methodology for analysis so that it could be updated at regular intervals to reflect any significant changes in maritime activity that might affect the risk.

Risk concepts and measures

Any assessment of risk must comprise two key elements – likelihood and consequence, with the risk being dependent on both. For numerical estimates of risk this is often expressed as:

Risk = frequency x consequence

In this case, two measures were used to characterise the risk – the return period for spills exceeding a certain size and the average quantity of oil spilled per unit time. These will be discussed in more detail later on.

Data collection

Sources of data

The first part of the exercise involved developing a comprehensive picture of the movement of oil in the New Zealand maritime environment, both as cargo and fuel (or bunkers). An extensive data gathering exercise was initiated. A large number of organisations involved in oil storage and transportation, oil spill planning and response, shipping, fishing, oil exploration, production were surveyed. These included:

- port companies;
- Regional Councils;
- oil companies (producers, refiners and marketing companies);
- tanker operators;
- international shipping companies;
- coastal shipping operators; and
- fishing companies.

In order to provide a consistent national basis for comparison, data on oil tonnages handled and shipping movements were gathered for the year 1st January to 31st December 1997. All this information was collated to provide input data for a spill risk model.

Activity level

The following figures derived from this survey illustrate the level of activity. For the year 1997, there were:

- over 100 shipments of crude and condensate to Marsden Point refinery (domestic and imported);
- over 400 tanker deliveries of finished products to New Zealand ports (including shipments from the refinery as well as direct imports);
- around 700 cargo transfer operations involving crude oil or finished products – over 13 million tonnes; and
- over 9,000 bunkering operations throughout New Zealand handling nearly 700,000 tonnes of bunker fuels.

NZ oil spill record

Oil spill records for all regions and for the NZ Exclusive Economic Zone (EEZ) were obtained from the MSA database and cross-checked against the Regional Council spill registers for completeness. Historically oil spills in New Zealand have been small and infrequent. Records prior to 1995 were incomplete, but in the period to June 1998 there had only been 9 spills on record exceeding 1 tonne, the largest of which was around 6.5 tonnes. This data therefore did not provide a particularly useful basis for predicting the likelihood of much larger spills which could occur.

Incidentally, the sinking of the trawler Dong Won 529 near Stewart Island in October 1998, which spilled around 300 tonnes of gas oil, occurred shortly after the risk assessment was completed.

NZ maritime accident record

A review was also made of maritime accident records held by the MSA over the period 1993 to 1998, to identify incidents that either resulted in oil spills directly or had the potential to do so. This information was used in the development of plausible spill scenarios. Again there were very few significant spills that occurred as a direct result of maritime accidents, however there were some notable incidents which could have resulted in major oil spills. These included:

- the collision of the cargo vessels Washington and Han Tao Hao off Mt. Maunganui in 1995;
- the grounding of the bulk carrier Alltrans at the entrance to Bluff Harbour in 1995 - an empty fuel tank was holed and the vessel took on water; and

Group	Specific gravity	Description and examples
I	< 0.8	Light distillates Maui and Kapuni condensate Gasoline blendstocks Motor spirit (RMS/PMS), Avgas Jet A1, kerosene
II	0.80 - 0.85	Middle distillates and light crudes Gas oils Light crudes
III	0.85 - 0.95	Medium – heavy crudes, fuel oils LFO Medium – heavy crudes
IV	0.95 - 1.00 or high pour point crudes	Heavy crudes and residues HFO Residues Fletcher blend, Maui F sands below pour point Lube oils and lube blendstocks
V	> 1.0	Very heavy fuel and bunker oils HBFO Bitumen

Table 1: Oil classifications.

- the fire on board the tanker Australian Achiever off the Poor Knights Islands in 1992 - the vessel was carrying 38,000 tonnes of crude oil.

Oil characteristics

For the purposes of this study, specific oil types handled in New Zealand were split into five categories that broadly represent the characteristics of the oil when spilled on water. This ranking was based on the work of Allen (1997)[1], which in turn is largely derived from classification systems used by NOAA (National Oceanic and Atmospheric Administration) and ITOPF (The International Tanker Owners Pollution Federation).

While the persistence of oils in the marine environment generally correlates with specific gravity, light waxy crudes with high pour points, such as those found in onshore Taranaki and Maui F sands, were treated as Group IV because of their behaviour on contact with water.

These groupings were used to assess the potential impact of spills outside port areas, where the effect of prevailing winds and weathering of spilt oil was taken into account. For the purposes of response planning, these groupings were reduced to just two main categories – persistent and non-persistent oils.

Potential sources of oil spills

Using the collated data, the main potential sources of oil spills were identified. These were generally characterised by activity and vessel type:

Vessels

- tankers (large crude carriers, overseas/product, coastal);
- international cargo/passenger vessels;
- coastal cargo/passenger vessels;
- fishing vessels; and
- small craft.

Non-vessel sources

- offshore oil/gas exploration and production;
- bulk oil transfers and bunkering operations;
- bulk storage terminals; and
- wharf pipelines and bunker lines.

Spill scenarios

Coastal Areas

The approach to modelling the oil spill risk was based on identifying and quantifying a number of representative spill scenarios for each port and section of coastline. The coastal waters around New Zealand were split up into 17 areas, largely based on similarity of coastal character and shipping activity (Figure 1).

Vessel categories

A number of representative vessel categories were developed, characterised by oil type and capacity.

A matrix of shipping activity vs. coastal area was then used to identify the potential spill sources, spill sizes and oil types for each area based on the types of vessels operating in those areas (Figure 2).

Vessel type	Oils types carried	Average load (max.)
Tankers		
Large crude carriers	Crude oils and bunker oils	90,000 tonnes (125,000)
Crude/condensate tankers	Indigenous crude (waxy) and condensates	31,000 tonnes (45,000)
Foreign product tankers	Motor spirit, gas oils	20,000 tonnes (45,000)
Coastal product tankers	Motor spirit, gas oil, LFO, HFO, bitumen	31,500 tonnes (45,000)
Other Shipping		
International cargo and passenger	HFO, gas oil	1100 tonnes (4400)
Coastal cargo and passenger	LFO, gas oil	300 tonnes (600)
Fishing	Gas oil	100 tonnes (250)
Small craft	Gas oil	20 tonnes (25)

Table 2: Vessel Categories and Parameters Used in Risk Model.

[1] Allen, A A and Dale, D H, 1997. *Oil Slick Classification: A System for the Characterisation and Documentation of Oil Slicks*. 1997 International Oil Spill Conference.

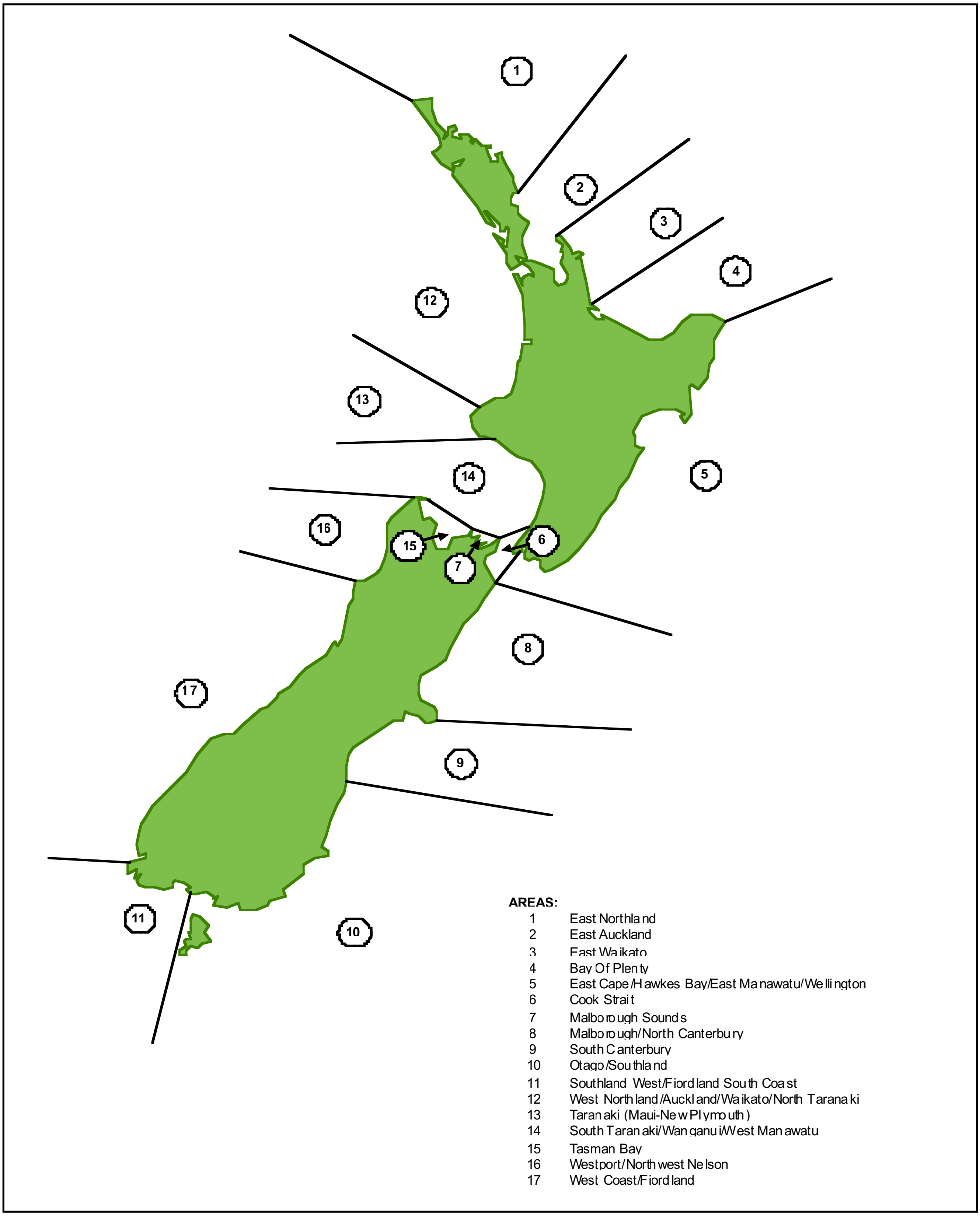

Figure 1: Coastal Areas Used in Spill Risk Model.

A similar process was followed for ports. Sixteen main ports were assessed, including the Maui FPSO (Floating Production, Storage and Offtake facility), which was treated as a special case for the purposes of this study. A ports matrix was also generated to characterise potential spills, based on vessel types, cargo transfers, bunkering operations and bunker fuels available.

Spill scenarios

A range of spill scenarios was developed for each coastal area and port.

Coastal regions

Vessel incidents:

Area		Large crude carriers	Crude/condensate tankers	Foreign product tankers	Coastal product tankers	International cargo & passenger	Coastal cargo and passenger	Fishing	Small craft
	EAST COAST								
1	East Northland	X	X	X	X	X	X	X	X
2	East Auckland			X	X	X	X	X	X
3	East Waikato			X	X	X	X	X	X
4	BOP			X	X	X	X	X	X
5	East Cape/Hawkes Bay/East Manawatu & Wgtn			X	X	X	X	X	X
6	Cook Strait			X	X	X	X	X	X
7	Malborough Sounds					X	X	X	X
8	Marlborough/North Canterbury			X	X	X	X	X	X
9	South Canterbury			X	X	X	X	X	X
10	Otago/Southland East			X	X	X	X	X	X
11	Southland West/Fiordland South Coast			X	X	X	X	X	X
	WEST COAST								
12	West Northland/Auckland/Waikato/North Taranaki		X	X	X	X	X	X	X
13	Taranaki (Maui - New Plymouth)		X	X	X	X	X	X	X
14	South Taranaki/Wanganui/West Manawatu			X	X	X	X	X	X
15	Tasman Bay			X	X	X	X	X	X
16	Westport/Northwest Nelson			X	X	X	X	X	X
17	West Coast/Fiordland					X	X	X	X

Figure 2: Coastal shipping matrix.

- Collision with another vessel
- Grounding
- Fire/explosion or structural failure
- Foundering

Other:

- Ship-to-ship transfers
- Illegal discharges
- Offshore oil production (Taranaki only)

Ports

Vessel incidents:

- Collision with another vessel
- Grounding
- Fire/explosion or structural failure
- Impact with wharves

Transfer incidents (cargo):

- Overfilling tanks (NZRC & NP only)
- Hose/line failure
- Poor housekeeping

Transfer incidents (bunkering operations):

- Overfilling tanks
- Hose/line failure
- Poor housekeeping

Wharf pipeline leaks

Storage terminal releases

Structure of risk model

The spill risk model comprised two distinct parts:

- a model for spills in ports; and
- a model for spills in coastal waters

These two models were developed as a set of linked computer spreadsheets. The general structure of each model is a set of worksheets containing common inputs and modelling parameters. These feed data into individual worksheets for each port or coastal area in which the risk calculations for that area are performed.

Results for individual areas were then aggregated to provide overall summaries. These could then be analysed by spill location, oil type or source as required.

The models were structured so that key inputs (both common and port or coastline specific) were all easily identifiable and accessible, with a consistent set of logic being used for the risk calculations for each port or coastal area, ensuring a consistency of approach.

Use of event trees

Event trees were used for the modelling of spill scenarios. This involved specifying a top event (such as a vessel grounding or collision) and estimating an annual likelihood of occurrence based on international shipping accident rates and the level of New Zealand activity or exposure. The event tree then has a number of branches which look at the subsequent outcome – whether a spill occurs or not, the prevailing weather and wind direction, and the proportion of the total cargo or bunker fuel carried that is likely to be spilled (Figure 3).

Various factors affect these probabilities. For example, a collision involving a tanker is more likely to result in a spill than one involving only cargo or passenger ships, as ships' fuel tanks are generally located in the bottom of the hull. Similarly, a cargo vessel grounding has a greater chance of leaking fuel than if the vessel is involved in a collision. In this event, the spilled oil will by definition almost all come ashore, whereas for a spill offshore, the oil, depending on type and weather or sea conditions, may disperse to some extent.

Risk measures

Two quantitative measures of oil spill risk were used. These complement each other and need to be considered together when assessing the spill risk attributable to a given coastal area or port, or source of oil spills.

The first is *the return period for a spill exceeding a given size* (Figure 4). For example, for a given section of coastline or a given port, the return period for a spill of 1000 tonnes might be 800 years. This means that an oil spill of 1000 tonnes or greater can be expected to occur on average once every 800 years in that location. This information can be used further to derive a probability that a spill of a given size will occur within a specified period e.g. the probability of a

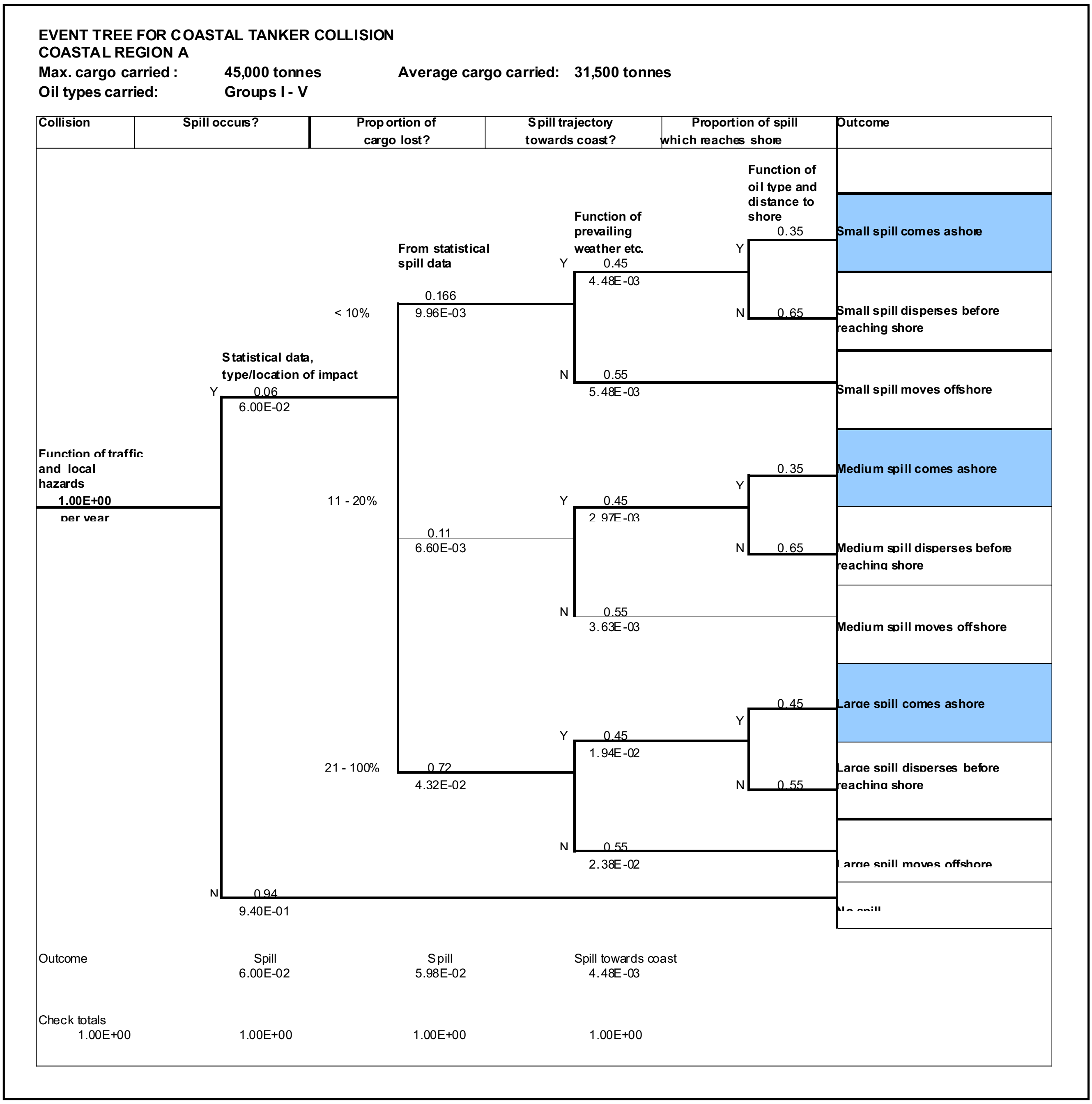

Figure 3: Event tree for coastal spills.

spill exceeding 1000 tonnes within the next 50 years, such as might be used for earthquake prediction.

As expected, the return period curves display a high incidence of smaller spills and a very low incidence of large spills. The bottom end of the curves (up to around 50 tonnes) largely reflect cargo transfer operations and small vessel and fishing vessel activity. The top end of the curves (above about 2000 tonnes) reflect tanker operations whereas the intermediate range represents the coastal and international shipping. Bunkering spills will generally never exceed 20 tonnes and 90% will be less than 1 tonne.

The second measure of risk is *the risk-weighted average spill rate*, expressed as tonnes of oil spilled per annum. For a given area, risk creator or oil type etc., this figure represents the quantity of oil that can be expected to be spilled over a long period, averaged over all spill sizes, and expressed as an annual spill rate.

It is important to note that this is not a real number, and does not predict the quantity of oil likely to be spilled over some short period in the future, but rather it is a measure of the contribution to the overall spill risk from each particular area or source. This figure does not reflect spill size and one-off large spills will distort it. However, when taken in conjunction with the return periods for different spill sizes it provides a valuable picture of the comparative spill risk.

This is illustrated in Figure 5 which compares spill risks for some of the main ports. Of the five ports, Wellington has the lowest return period (i.e. the highest annual probability) for a spill exceeding 100 tonnes and this is a reflection of the high number of coastal vessel movements (inter-island ferries). However its average annual spill rate is lower than for other ports – its contribution to the overall risk is lower.

The annual probability for a 5000-tonne spill for Wellington is higher than that for Auckland, but is lower than that for Westgate (New Plymouth) or Marsden Point/Whangarei. This reflects the relative number of tanker movements and size of tankers at these ports.

Application and limitations

The risk model was designed primarily to predict the incidence of large oil spills of the size that have not historically occurred in New Zealand. As such it relies on international data as an input. International oil spill databases generally have minimum cut-offs for reporting in terms of spill size, which represent quite large spills in New Zealand terms. The model used a lower limit of 20 tonnes as the basis for analysis (equivalent to around 6,500 US gallons or 160 barrels).

In general terms, the spill risk for coastal areas has been assumed to be a function of vessel exposure (expressed as vessel-years for each area) which in turn relates directly to vessel movements. Within ports, the vessel spill risk is a function of port movements and the non-vessel risk a function of the number of bunkering and transfer operations. These are therefore the key inputs to the risk model.

Another key input is the average quantity of oil carried by each vessel type. Estimates were made based on the available data to determine a representative figure for each vessel group. However, it is recognised that some of these groups cover a wide range of vessel sizes e.g. international cargo vessels, fishing vessels etc. so the estimates have generally erred on the high side. As a consistent calculation method has been used for each port and coastal area, uncertainties in the common inputs are carried through the model and so should not significantly affect the relative risk between different areas.

Figure 4: Plot of spill size vs. return period

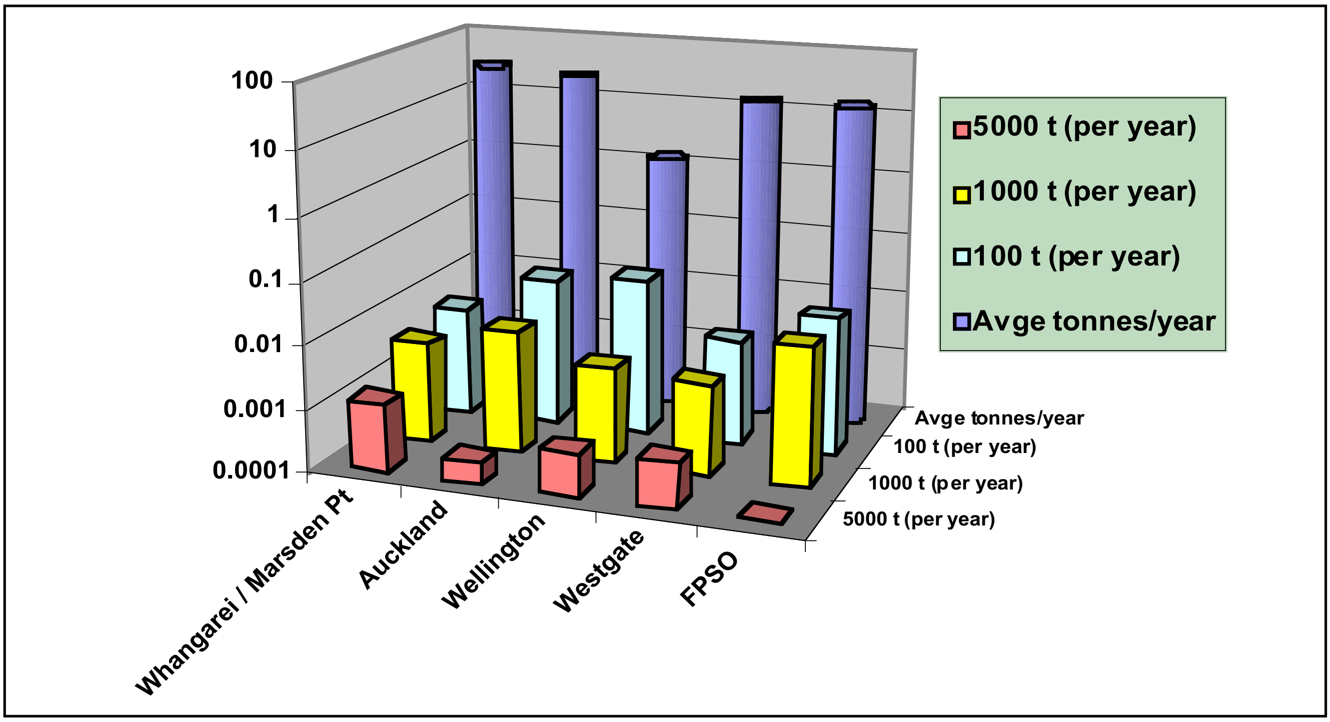

Figure 5: Port spill risk.

Quantitative risk analysis is not an exact science – a combination of mathematical relationships, professional judgements and often incomplete data is used to build a simplified model of reality, in order to make predictions about events in the future.

The use of a defined logic and a stated set of assumptions throughout ensures that the methodology is transparent and consistent. There are inherent sources of error and so the absolute value of the results may only be accurate to +/- one order of magnitude. However the real strength of this technique, in all fields to which it can be applied, lies in its use as a comparative tool, and just as importantly, in the structured approach to the analysis of risks that it brings.

It is therefore very effective for comparing the spill risk for different ports and coastal areas, sources of spills and maritime industry sectors, in identifying the contribution that each makes to the overall risk profile, as well as for determining the relative frequency of occurrence of small and large spills.

Conclusions

This study has formed the basis for the ongoing review of the New Zealand Oil Spill Response Strategy. It has provided a rationale for setting priorities and allocation of resources to specific geographic areas of New Zealand, as well giving a better understanding of the risks posed by the various risk creator groups.

This type of study is a useful tool to industry and legislators in assessing the impacts of their operations or activities, be they safety, environmental, or financial impacts. Such an approach allows specific risks to be identified, objectively assessed and compared, facilitating the prioritisation of actions and optimising the use of resources to manage those risks.

Authors

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CHRIS PRATT is an environmental scientist with over 11 years experience in New Zealand and the UK. This includes researching the impacts of oil spills and oil industry activities, and more recently involvement in oil spill contingency planning for regions, ports and oil exploration activities. He has been with Woodward-Clyde in NZ since 1992, and specialises in assessing environmental effects for resource consent applications.