IPIECA

International Association of Oil & Gas Producers

Response strategy development using net environmental benefit analysis (NEBA)

Good practice guidelines for incident management and emergency response personnel



IPIECA

The global oil and gas industry association for environmental and social issues

5th Floor, 209–215 Blackfriars Road, London SE1 8NL, United Kingdom
Telephone: +44 (0)20 7633 2388   Facsimile: +44 (0)20 7633 2389
E-mail: info@ipieca.org   Internet: www.ipieca.org

International Association of Oil & Gas Producers

International Association of Oil & Gas Producers

London office
5th Floor, 209–215 Blackfriars Road, London SE1 8NL, United Kingdom
Telephone: +44 (0)20 7633 0272   Facsimile: +44 (0)20 7633 2350
E-mail: reception@iogp.org   Internet: www.iogp.org

Brussels office
Boulevard du Souverain 165, 4th Floor, B-1160 Brussels, Belgium
Telephone: +32 (0)2 566 9150   Facsimile: +32 (0)2 566 9159
E-mail: reception@iogp.org   Internet: www.iogp.org

IOGP Report 527

Date of publication: 2015

Response strategy development using net environmental benefit analysis (NEBA)

Good practice guidelines for incident management and emergency response personnel

Cover photographs are reproduced courtesy of (left and right): OSRL; (centre): IPIECA, 2000.

Preface

This publication is part of the IPIECA-IOGP Good Practice Guide Series which summarizes current views on good practice for a range of oil spill preparedness and response topics. The series aims to help align industry practices and activities, inform stakeholders, and serve as a communication tool to promote awareness and education.

The series updates and replaces the well-established IPIECA 'Oil Spill Report Series' published between 1990 and 2008. It covers topics that are broadly applicable both to exploration and production, as well as shipping and transportation activities.

The revisions are being undertaken by the IOGP-IPIECA Oil Spill Response Joint Industry Project (JIP). The JIP was established in 2011 to implement learning opportunities in respect of oil spill preparedness and response following the April 2010 well control incident in the Gulf of Mexico.

The original IPIECA Report Series will be progressively withdrawn upon publication of the various titles in this new Good Practice Guide Series during 2014–2015.

Note on good practice

'Good practice' in the context of the JIP is a statement of internationally-recognized guidelines, practices and procedures that will enable the oil and gas industry to deliver acceptable health, safety and environmental performance.

Good practice for a particular subject will change over time in the light of advances in technology, practical experience and scientific understanding, as well as changes in the political and social environment.

Contents

Introduction

In all its operations, the oil industry takes extensive steps to prevent spills from occurring. New research and lessons learned are continually incorporated to improve spill prevention. In spite of these actions, the industry recognizes that spills may still occur. Significant effort is therefore applied to the development of measures to mitigate potential impacts from spills.

Net environmental benefit analysis (NEBA) is a structured approach used by the response community and stakeholders during oil spill preparedness planning and response, to compare the environmental benefits of potential response tools and develop a response strategy that will reduce the impact of an oil spill on the environment.

NEBA is one of the considerations used to select spill response tools that will effectively remove oil, are feasible to use safely in particular conditions, and will minimize the impact of the spill on the environment. The scope of what is included varies considerably around the world. For example, in the USA the US Environmental Protection Agency (US EPA) uses NEBA to evaluate the environmental benefits of a response tool, minus any environmental injuries resulting from the use of that tool. (See, for example, US EPA, 2013.) In other countries, the term NEBA is used in a variety of ways, and may include an analysis of net benefits to people, as well as the environment. Some countries may conduct a net environmental and economic benefit analysis (NEEBA), which also includes the consideration of socio-economic sensitivities and costs. (See, for example, ASTM, 2013 and Fingas, 2011.) In all cases, the aim is to support the selection of an agreed strategy for oil spill response, which has been informed by a systematic assessment and evaluation of multiple factors, with input from a number of stakeholders. NEBA may be used during pre-spill planning and during a response:

- NEBA is an integral part of the contingency planning process, used to ensure that response strategies for planning scenarios are well informed.
- During a response, the NEBA process is used to ensure that evolving conditions are understood, so that the response strategy can be adjusted as necessary to manage individual response actions and end points.

The NEBA process comprises four stages:

1. **Compile and evaluate data** to identify an exposure scenario and potential response options, and to understand the potential impacts of that spill scenario.
2. **Predict the outcomes** for the given scenario, to determine which techniques are effective and feasible.
3. **Balance trade-offs** by weighing a range of ecological benefits and drawbacks resulting from each feasible response option. In some countries this will also include an evaluation of socio-economic benefits and costs resulting from each feasible response option.
4. **Select the best response options** for the given scenario, based on which combination of tools and techniques will minimize impacts.

Multiple stakeholders are involved in the NEBA process, which relies on cooperation among governments, industry and communities to ensure that informed response decisions can be made which take all perspectives and viewpoints into account.

Open lines of communication, transparent decision making, clarification of policies and realistic expectations of response outcomes are key to successful oil spill preparedness and response planning and execution.

Box 1 *When were NEBA principles first used?*

NEBA has been used in practice for many years following lessons learned from spills in the 1980s. An early clear expression of NEBA arose during the response to the *Exxon Valdez* incident in Alaska in 1989, for the evaluation of a large-scale mechanized rock washing proposal which advocated the mass removal of oiled shoreline material. Disagreements between regulatory agencies on its application led to NOAA casting the deciding vote. The proposal was rejected when it was determined there was 'no net environmental benefit to be gained by shoreline excavation and washing' and that 'this technology has the potential of aggravating the injury to the environment caused by the spill.'

Given the broad range and scale of oil spill planning scenarios, the diverse perceptions of value of ecological and socio-economic sensitivities and the innate realities of oil spill response in the field, there is no single NEBA tool or methodology which is suitable, or indeed appropriate, for application in all situations.

Depending on the scale and complexity of the spill scenario under consideration, the NEBA process may range from a brief review and straightforward weighing up of a few simple options by a contingency planner, to more substantial analysis including a wide-ranging series of engagements with multiple stakeholders.

Source: OSRL

Exposed rocky shorelines have natural self-cleaning properties by virtue of the high energy wave environment. NEBA informs the planner that a monitoring and evaluation strategy will take primacy for such impacted coastlines with minimal clean-up intervention.

Overview: response strategy development using NEBA

NEBA is applied before and during a spill to aid the selection and optimization of response options. Irrespective of the stage during a spill at which it is employed, the NEBA process does not change.

- Before a spill, it allows the parties to identify potential spill scenarios that arise offshore, nearshore, onshore or inland. The selection of response options will vary depending on where the oil spill occurs.
- During the contingency planning phase, NEBA is used to identify and agree on response strategies for each selected scenario.
- During a spill it allows these strategies to be validated and adjusted as conditions evolve.[1]

Figure 1 illustrates the process of developing a response strategy using a NEBA that includes an evaluation of socio-economic benefits and costs. This can be adapted for use in countries that do not include socio-economic factors in their NEBA process.

Figure 1 *Response strategy development using NEBA*

	Compile and evaluate data	Predict outcomes	Balance trade-offs	Select best option(s)
Before a spill	A wide range of data is compiled and evaluated to understand the area potentially affected, and to identify and prioritize environmental and community assets within it, based on environmental sensitivities and social values.	Planning scenarios are used to assess the potential effects on the environment. For specific locations, feasible response options are identified from the 'response toolbox'.	The advantages and disadvantages of the potential response options are evaluated and weighed against the environmental and social effects of each to understand and balance trade-offs.	Data, information and viewpoints are taken into account to select the combination of response options that will create the greatest net environmental benefit. This allows a full response strategy to be developed encompassing detailed plans, capability development and approvals.
	If no pre-spill planning work has been undertaken, or if analogue planning scenarios cannot be adjusted to correlate with the specifics of a spill, response strategy development using NEBA follows an expedited version of the process above. In this instance, it is possible that the data which forms the basis of the analysis may be incomplete or limited, thus necessitating a greater reliance on professional judgement to correctly balance the trade-offs and select the best options, especially given the time-pressured nature of a response.			
During a spill	Based on the specifics of the spill, a range of data is evaluated to assess anticipated effects.	Response options identified in the pre-spill planning stage are reviewed against the actual spill conditions and anticipated effects, and the list of feasible response options considered.	The balancing of trade-offs carried out in the pre-spill planning stage is adjusted and confirmed against the actual conditions of the spill. Continued re-evaluation and re-balancing of trade-offs takes place to address evolving conditions.	The response strategy is developed based on the optimum response options for the conditions. The strategy is implemented and continually monitored and adjusted based on ongoing evaluations. Pre-spill planning work facilitates rapid decision making during a response, minimizing delays.
	The ongoing application of the NEBA process throughout a response allows clean-up end points to be determined and agreed to by stakeholders early and in a systematic manner. This helps to avoid unnecessary clean-up activities which could result in additional detrimental effects on the environment.			

[1] Some people propose to use a NEBA process to evaluate alternative ways to restore natural resources that are damaged by an oil spill (for example see Efroymson *et al.*, 2003). However, this is not a common use of NEBA, and it is outside the scope of this Guide.

NEBA Stage 1: Compile and evaluate data

Compile and evaluate data ▶ Predict outcomes ▶ Balance trade-offs ▶ Select best option(s)

The information collected during this stage informs all subsequent considerations. Obtaining high quality data reduces assumptions and provides greater confidence in the selection and optimization of response options.

The data are directly linked to the planning scenarios under consideration, and include the following:

Oil properties

For the scenarios used in oil spill contingency planning, a range of oils may be considered. The oil properties of particular interest are those which can be used to estimate weathering (e.g. evaporation, natural dispersion, emulsification) and influence potential toxicity. When an oil sample is available, laboratory testing can quantify the key parameters, which may then be used in predictive models. When no oil sample is available, or there is uncertainty about the parameters, the properties of a range of potential oil sources can be used in planning and to inform the selection of a suitable analogue oil for use in oil spill modelling. During a spill, these assumptions would then be updated to reflect the properties of the oil that is actually released.

Oil spill trajectory modelling

Oil spill models offer predictions of how an oil with known properties may behave when released into the environment, based on various input parameters which include the oil properties, weather patterns, water currents and other data. Oil spill models are used to predict the geographic areas that may be affected in a given spill scenario, and to develop a spill response plan that addresses that scenario. If there is a spill, the model would then be updated to reflect the weather, water and other conditions that are encountered during the incident.

Source: OSRL

Source: IPIECA, 2000

Far left: shoreline sensitivity assessment exercise in the UK as part of a SCAT course to develop a shoreline response strategy.

Near left: shoreline sensitivity assessment being carried out in Tanzania during a sensitivity mapping workshop supported by IMO/IPIECA and managed by the Tanzanian National Environment Management Council.

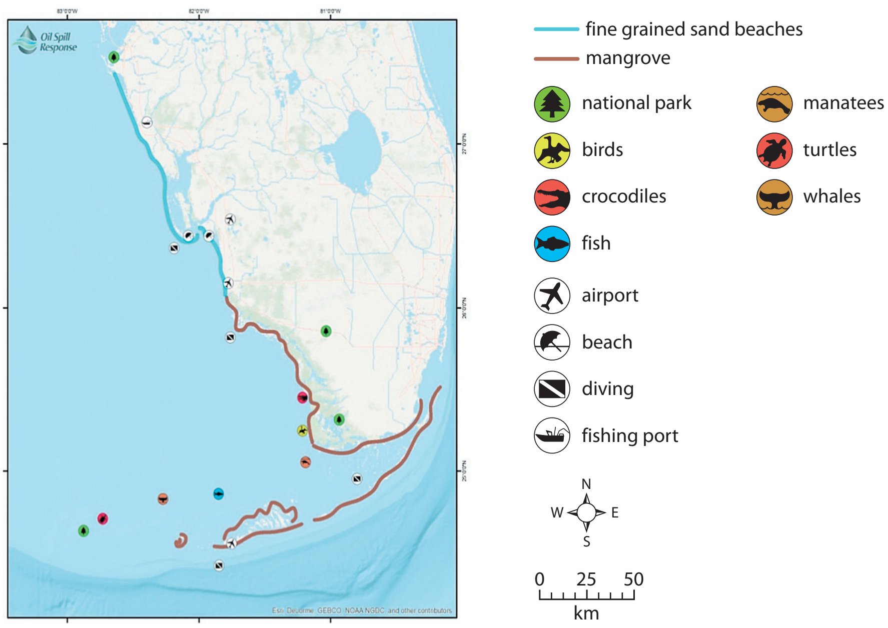
Sensitivity data

Underpinning the NEBA process, sensitivity maps (e.g. Figure 2) provide the foundation for an assessment of those resources which may be affected by the spill trajectory.

Sensitivity maps should include:

- **Baseline information** such as coastline and bathymetric depth contours, rivers and lakes, towns and villages, administrative limits, place names and roads, railways and main infrastructure.
- **Shoreline types and their general environmental sensitivity** to an oil spill—different types of shorelines may be ranked using the basic principles that sensitivity to oil increases with: increasing shelter of the shore from wave action; penetration of oil into the sediments; natural oil retention times on the shore; and biological productivity of shoreline habitats. Typically, the least sensitive shorelines are exposed rocky headlands, and the most sensitive are sheltered marshes and mangroves. Habitats affected by natural oil seeps may be less sensitive.
- **A formal sensitivity index** may be adopted to represent the relative potential significance of sensitive shoreline areas. For example, the NOAA Environmental Sensitivity Index (ESI) provides a recognized rating basis from 1 (low sensitivity) to 10 (very high sensitivity), which integrates the:
  - shoreline type (grain size, slope), which determines the capacity of oil penetration and/or burial on the shore, and movement;
  - exposure to wave (and tidal) energy which determines the natural persistence time of oil on the shoreline; and
  - relative biological productivity and sensitivity.
- **Sensitive ecosystems, habitats, species and key natural resources**, such as coral reefs, seagrass and kelp beds, and wildlife such as turtles, birds and mammals.
- **Sensitive resources that have commercial or recreational value**, for example fishing areas, shellfish beds, fish and crustacean nursery areas, fish traps and aquaculture facilities. Other

Figure 2 *Example oil spill sensitivity map*



features include boat facilities such as harbours and slipways, industrial water intakes, recreational resources such as amenity beaches, and sites of cultural or historical significance.

Further guidance on sensitivity mapping can be found in IPIECA/IMO/IOGP, 2012.

Identification of potential response options

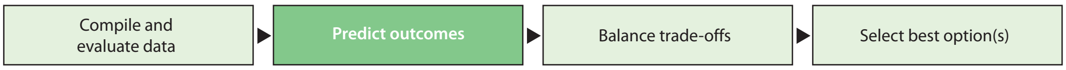
During this phase of the analysis, an identification of potential response options takes place. This begins with evaluating all potentially applicable response options and shortlisting those for further consideration in later stages of the process.

Factors that need to be considered during this evaluation and shortlisting process include:

- **Effectiveness**—which response tools and techniques will achieve the desired results?
- **Feasibility**—which response tools and techniques are viable and safe given the expected climatic and operational conditions?
- **Regulations**—which tools and techniques are permitted within the regulatory framework?

The modelling outputs, sensitivity information and response options are evaluated in the second stage of the NEBA process—predicting outcomes.

Stage 2: Predict outcomes

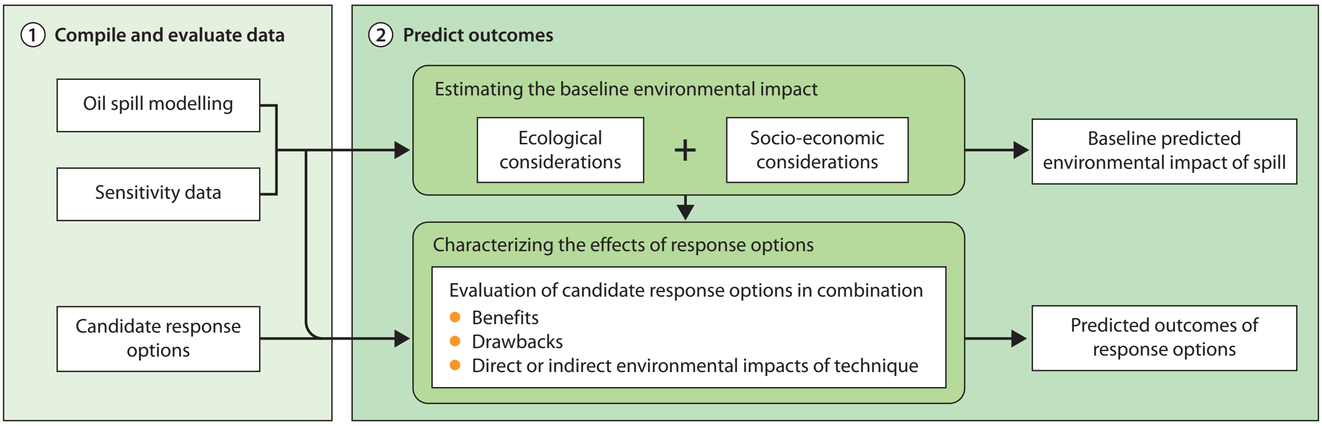


In this stage, planners and responders assess potential outcomes by using the information compiled in Stage 1 to review potential spill trajectories, and the environmental resources that may be affected, in a spill scenario where no response activities are applied. Consideration is then given to how different combinations of response options may change these impacts, in order to enable trade-offs to be characterized and balanced in the next stage of the process.

Impacts on the environment can be broadly grouped into ecological impacts, which are evaluated in all forms of NEBA, and socio-economic impacts and costs, which may also be evaluated in some countries using an expanded NEBA. The second grouping recognizes the linkages between the natural and human environments—for example, considering whether the potential impact of an oil spill on fish stocks is likely to impact people who fish, including subsistence, recreational and commercial fishermen. Both allow for the impacts to be characterized in such a manner that trade-offs take all aspects into consideration and response options can be selected based on a holistic view of the greatest overall net environment benefit.

Figure 3 on page 10 illustrates how data from NEBA Stage 1 informs NEBA Stage 2 when socio-economic benefits and drawbacks are included in the analysis. This process can be adapted for countries that do not include socio-economic factors in their NEBA.

Figure 3 *How data from NEBA Stage 1 informs NEBA Stage 2*



Estimating the effect of a 'no action' scenario

Each NEBA includes an evaluation of the potential effect of a 'baseline' spill scenario where no response actions are taken. This baseline provides a basis for comparison of the benefits and drawbacks of different combinations of response options.[2]

This baseline scenario covers the timescale needed for the oil to weather and attenuate naturally. It identifies potential environmental effects at a general level, but does not attempt to quantify potential damage to environmental resources. With the number of variables involved, it is impractical to calculate the quantity of potential damage to any environmental resource in the NEBA process. Other methods can be used to assess actual damage to natural resources if an oil spill occurs.[3]

Overall, the NEBA process provides an estimate of potential environmental effects which is sufficient to allow parties to compare and select preferred combinations of response options. The involvement of experts in this process will help to generate the level of detail needed to make appropriately informed decisions when selecting response options. The response capabilities need to be developed with some flexibility, to account for unpredicted effects and evolving conditions that may arise during an oil spill response.

---

2 In some jurisdictions, 'baseline' is also used to describe the condition of environmental resources before a spill, or the condition that those resources would be in if the spill had not occurred. For example, see the US Oil Pollution Act, 33 USC 2701 *et seq.* In NEBA, the term 'baseline' can also have the opposite meaning, and describes the condition of environmental resources after a spill, if no response actions occur.

3 For example, see: the US Oil Pollution Act, 33 USC 2701 *et seq.*, which creates additional liability for damage to natural resources resulting from an oil spill in the USA; and the EU Environmental Liability Directive 2004/35/EC, which establishes a framework for remedying damages to natural resources in the European Union. Note that the EU Offshore Safety Directive 2013/30/EU amended the scope to cover damage to marine waters. Under these laws, separate assessment procedures are used to identify and determine the amount of damage to natural resources resulting from an oil spill.

Ecological impacts of oil

The initial ecological impact of oil on the environment can vary from minimal, such as light oil on the open ocean, to significant, such as crude oil in a mangrove's rich ecosystem. Factors to consider when assessing ecological impacts include the following:

- **Oil type:** lighter oils are more likely to cause severe short-term localized toxic effects. Heavy oils are generally less toxic but can contaminate surfaces over wide areas due to their greater persistence and smothering potential.
- **Oil loading:** thick oil deposits on shores are likely to smother plants and animals, and some types of oil may form persistent asphalt pavements.
- **Geographical factors:** damage is likely to be greatest in low-energy shallow enclosed waters and on sheltered shorelines, because these areas typically have high biological productivity and long natural cleaning timescales.
- **Weather:** wind speed and water temperatures affect changes in the evaporation and viscosity of oil and, in turn, in its dispersibility and toxicity.
- **Biological factors:** different species have different sensitivities, for example many shoreline seaweeds are relatively tolerant of oil while mangroves are particularly sensitive.
- **Seasonal factors:** the sensitivity of plants and animals can vary seasonally. For example, marsh plants are particularly sensitive at the seedling stage in the spring when small plants are in their most active growing period. Many animal species have seasonal breeding periods and are more sensitive to oil at early life stages (e.g. when they are fish eggs and larvae, or bird eggs and nesting chicks).

Ecosystem recovery times can vary from a few days to many years, and may not correlate directly with cleaning timescales—in some cases recovery can progress even in the presence of oil residues. Conversely, a shoreline area may be left looking clean but have reduced biological resources because a light product spill has caused rapid, severe toxic effects before evaporating. In such a case the recovery time will be determined by the rate of migration from unaffected areas, natural recruitment, settlement and growth.

The ways in which oil can impact various environmental and ecological resources and the factors that can influence these impacts are described in the IPIECA-IOGP Good Practice Guides on marine ecology (IPIECA-IOGP, 2015) and shorelines (IPIECA-IOGP, 2015a), and in 'Finding 6' of the IOGP Global Industry Response Group response to the Deepwater Horizon incident in 2010 (IPIECA-IOGP, 2013).

Socio-economic impacts of oil

In jurisdictions that consider socio-economic impacts, factors to consider may include the following:

- **Lost commercial fishing because of the risk of fouling boats and gear or of the tainting of catch**: finfish and shellfish may become tainted and deemed unfit for sale if oil-derived substances absorbed by the tissues impart unpleasant odours and flavours. Fishery exclusion zones may be imposed until the species are free from contamination or taint. Farmed fish and shellfish may have to be destroyed if they cannot reach the market at the right time because of tainting.
- **Amenities and tourist facilities including beaches and coastal park areas**: marinas and jetties provide facilities for pleasure boat use, and some fishing and angling activities serve the tourist trade. Oil may temporarily render such resources unusable. Marine and land-based sites may

Mangrove swamps, such as this one in Nigeria, are typically important both ecologically and socio-economically (e.g. for shellfish production). They are also vulnerable to damage by oil.

Source: IPIECA, 2000

have cultural or historic significance and can be affected in a variety of ways. These sites include historic structures, monuments and artefacts. While the oil spill itself may physically contaminate these sites and cause damage, the most significant impacts often arise from disturbances during a response.

- **Facilities that rely on water intakes**: many industries use water intakes for cooling or other purposes; some countries rely on sea water intakes for their desalination plants. Oil entering these intakes may have serious negative impacts. The probability of such impacts can be minimized by placing booms around the intakes to keep oil out or by designing the intakes for subsurface operation.

Further guidance on the socio-economic effects of an oil spill is provided in the IPIECA-IOGP Good Practice Guide on economic assessment and compensation (IPIECA-IOGP, 2015b).

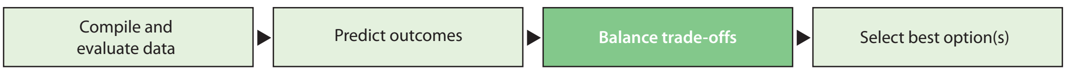
Characterizing the effects of response options

Once the baseline is established for a given spill scenario or incident, the effects of response options can be characterized and evaluated. There is no single methodology or mechanism for doing this, and the involvement of varied experts and stakeholders is important to ensure a common understanding of the effectiveness, feasibility and limitations of response options.

The shortlist of response options needs to be evaluated for each oil spill scenario. Evaluation criteria need to be developed to allow a prediction of how each response option would mitigate established baseline impacts. It is important for planners not to consider each response option in isolation, but to remain mindful of the ways in which multiple techniques might impact and interact with each other and how they change over time in response to evolving conditions.

By virtue of the complexity of predicting outcomes which are subject to a number of variables and degrees of uncertainty, the understanding gained at this stage can seem somewhat subjective and relative. It is important that experienced planners and responders remain engaged throughout in order to avoid the temptation to quantify everything and, in the process, create potentially unrealistic expectations of what can be achieved during a response.

Stage 3: Balance trade-offs



NEBA Stage 3 requires a range of stakeholders to reach consensus on the relative priority of environmental sensitivities, and to understand, balance and accept the trade-offs inherent in the available response techniques. This common understanding informs the final stage of the process, in which the optimum response strategy is selected to achieve the greatest overall net environmental benefit.

The ideal of any response strategy would be to prevent all negative impacts; unfortunately it is not usually possible to achieve this in practice. No two oil spill scenarios are the same because of the variation in oils, locations, sensitive environmental and socio-economic resources and other operational conditions such as weather, logistics and legalities.

Discussions around balancing trade-offs necessarily require compromise among parties. For this reason, the identification and involvement of key stakeholders and the transparent presentation of facts (including assumptions and uncertainties) are important in order to enable these complex discussion to take place. A simplified example of such a trade-off discussion for a marine oil spill scenario would be the discussion that takes place concerning the use of dispersants to disperse floating oil into near-surface waters, wherein short-term potential impacts to exposed aquatic organisms need to be balanced against longer-term potential impacts on coastal habitats and communities if the oil is not dispersed. The planning scenario will dictate what actually needs to be considered and the degree to which trade-off discussions need to be achieved.

Balancing trade-offs to understand priorities for protection and response

At all stages of spill preparedness and response, there will be differing and conflicting priorities, values and perceptions of the importance of sensitive resources. There is no universally accepted way to assign perceived value or importance to different environmental and socioeconomic sensitivities.

This is not a quantitative process, though approaches, such as those used in risk-based decision making, may allow stakeholders with disparate perceptions to compare diverse resources in order to facilitate reaching a consensus on the relative values of those resources in the absence of absolute values. The important point to remember is that the NEBA process seeks consensus among the various stakeholders.

Sensitivity maps and oil spill modelling help to establish which sensitivities are the highest priority for protection in a given oil spill planning scenario.

The priority for response is influenced by many factors including ease of protection, ease of clean-up, recovery times and importance for subsistence, economic value and seasonal changes in use. Areas that have the highest likelihood for potential impact, and which are also of highest sensitivity and perceived importance, should be targeted to be addressed first if at all possible. The focus is then broadened to address other potential environmental and socio-economic effects, consistent with the type of NEBA process used in the location in question.

Before a spill, especially where the potential impact area of a given planning scenario is significant, the protection priorities may be grouped or generalized.

During a spill, the actual priority for response is influenced by the realities of the spill. These realities reduce uncertainties in the predictions.

By setting environmental priorities for protection and response, planners and responders will have the information they need to develop an appropriate response strategy to maximize environmental protection and facilitate the most efficient recovery of impacted sensitivities.

Balancing trade-offs when selecting response options

Inherent advantages and drawbacks of available response options are assessed and trade-offs considered to allow for informed selection of the optimum response strategy or strategies.

For example, the benefits of physical removal of oil from a shoreline include:
- removal of oil from the impacted environment;
- prevention of the remobilization of bulk oil to another area, thereby reducing the potential for further contamination;
- reduction of secondary impacts on animals that utilize the shorelines; and
- if non-aggressive methods are used, minimal impact on shore structure and shore organisms.

However, drawbacks include:
- it can be labour intensive;
- significant waste storage capability is required;
- it may cause further damage to the environment due to aggressive removal methods (e.g. sand removal and cleaning) impacting the shoreline and shore organisms; and
- it may cause additional environmental damage as a result of heavy equipment and high foot traffic.

The potential benefits of oil removal should be weighed against the risks of potential additional harmful impacts from the clean-up technique. If oil is predicted to strand on a shoreline that is particularly sensitive, such as a mangrove or marshland, consideration needs to be given to the damage that a response effort may cause compared to leaving the oil to break down naturally. The photographs below provide an example of natural recovery.

Near right: contaminated mangrove in August 2010.

Far right: natural recovery of the mangrove in November 2010.

ITOPF

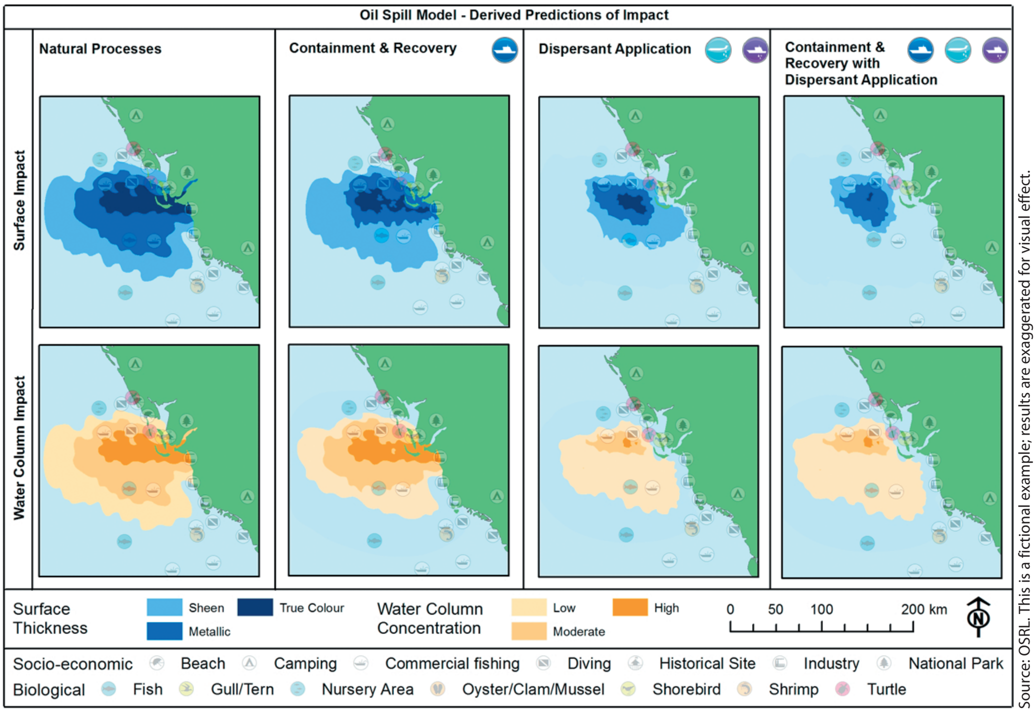
ITOPF

It is important, during the trade-off balancing discussion, to ensure that conversations are guided by the specifics of the planning scenario or spill, and based on expert judgement of the potential outcomes and compromises.

Figure 4 on page 15 depicts an example of a tool which uses oil spill modelling to predict the impacts of response techniques, illustrate the trade-offs and compare these with the 'natural processes' baseline to inform decisions about selection and optimization of the response strategy.

Table 1 on page 15 presents a summary of the benefits and drawbacks of common surface spill response options. Further detailed information can be found in Appendix 1 on page 33.

Figure 4 *Example of data from an oil spill modelling tool*



Oil spill modelling can be used to compare the impacts and trade-offs of different response techniques with a baseline.

Table 1 *The benefits and potential drawbacks of response options*

Option	Benefits	Drawbacks
Surface applied dispersant	Removes surface oil that could harm wildlife and keeps oil from spreading to the shoreline; enhances natural biodegradation of oil and reduces vapours on the water surface.	Dispersed oil has the potential to initially affect local marine life.
At-sea mechanical recovery	Removes oil with minimal environmental impact.	Mechanical recovery can be inefficient and resource-intensive, and restricted by water conditions, with typically no more than 10–20 per cent oil recovery.
Controlled (in-situ) burning	Removes large amounts of oil rapidly via controlled (in-situ) burning.	Burning presents a potential safety risk and localized reduction in air quality; burn residue can be difficult to recover. Effectiveness depends on oil characteristics and sea conditions.
Shoreline physical removal	Selectively restores environmental and social value at specific locations using a variety of tools.	Aggressive or inappropriate removal methods may impact ecosystems and individual organisms.
Natural processes	Takes advantage of natural processes for oil removal, including biodegradation, and avoids intrusive clean-up techniques that may cause further damage to the environment.	Natural removal can take more time to return the environment to pre-spill use than other response techniques.

Box 2 *Balancing trade-offs—some examples*

These examples illustrate the kinds of comparisons and trade-offs that could arise in oil spill scenarios. They are not intended to indicate an industry-preferred solution—all scenarios need to be considered on a case-by-case basis.

Both organisms and habitats need to be considered in NEBA. Priority protection for wildlife should be considered for species that are not able to swim or move away from the oiled area, and for the most sensitive, least abundant, slower-to-reproduce and slower-to-recover organisms and communities. Habitats may be given priority protection where the habitat is needed to support a variety of organisms and communities that could potentially be affected by an oil spill, and that are likely to recover more quickly if the habitat is largely maintained. NEBA allows the consideration of ecosystems as a whole, and guides the selection of the optimal approach in the circumstances.

In some jurisdictions, protection of fish and shellfish resources merits higher priority than amenity sand beaches, jetties and slipways. Protecting fish and shellfish from the risk of becoming tainted often takes precedence over protecting surfaces of concrete or firm sand, which can be cleaned and restored to usefulness relatively quickly.

Wildlife species may sometimes merit a higher priority than fisheries, notably in cases where dispersant spraying reduces the threat to seabirds at the expense of increasing the temporary exposure of fish to oil. The viability of most fish populations is less threatened by temporary exposure to dispersed oil than seabird populations are threatened by surface slicks.

Dispersant use (especially far offshore and subsea) can benefit and protect fisheries if it can prevent floating oil from reaching areas of high fish density, active fish spawning or sensitive life stages. The oil will dilute and biodegrade in a remote and less populated area instead of letting persistent oil slicks drift on the surface and into nearshore areas where sensitive species may be present in larger numbers.

Illustration

In a remote area with limited response capability, a spill scenario predicts that oil would impact a biologically diverse mangrove area in ~24 hours. The water depth is less than 20 metres. There are no shellfisheries in the area, but large (>500) numbers of waterfowl reside.

A NEBA analysis would consider the data, predict outcomes and balance trade-offs of the available response options, and would likely find that rapid dispersant spraying is the optimum response strategy, despite the potential downsides of spraying in shallow waters and potentially damaging seagrass and corals, to reduce the potential long-term impact on the sensitive mangrove plants and reduce the risk of surface oil impacting birds.

This example is based upon the Tropical Oil Pollution Investigations in Coastal Systems (TROPICS) experiment conducted in Panama (Ballou *et al.*, 1989), which found that, for a similar scenario, while dispersant spraying in deeper waters was likely to be the response option that offered the greatest net environmental benefit, where this is not feasible, spraying in shallow waters and accepting the trade-off of potential damage to seagrass and corals would be preferable to doing nothing and allowing the mangroves to be impacted.

Stage 4: Select Best Options

Compile and evaluate data ▶ Predict outcomes ▶ Balance trade-offs ▶ **Select best option(s)**

In this stage, data, viewpoints and trade-offs are taken into account to select the optimum response strategy for the planning scenario and prevailing incident conditions.

Before a spill, response strategies are defined for each of the planning scenarios, and response capabilities are designed and developed accordingly. These capabilities may include detailed plans, competent responders, stockpiles of equipment, contracts with oil spill response organizations, and gaining approvals for specific response techniques to be implemented.

During a spill, this stage of the NEBA process supports the deployment and adjustment of response resources as conditions change, and supports decisions about when response end points have been reached.

Optimizing the response strategy

The key objective of planning for, and executing, a response is to implement those techniques that, at any moment in time, have the greatest net benefit.

Example

In an offshore marine incident, treating or recovering as much oil as close to the source as possible, before it has had a chance to weather and spread out, will have the greatest benefit. As the oil weathers and spreads out, other response options will be less effective, increasing the chances of more oil reaching sensitive areas and the shoreline, and potentially crossing jurisdictional boundaries and borders.

To supplement this priority-driven approach, other response measures can be implemented further away from the source which are likely to have the greatest chance in those circumstances of improving the response outcomes.

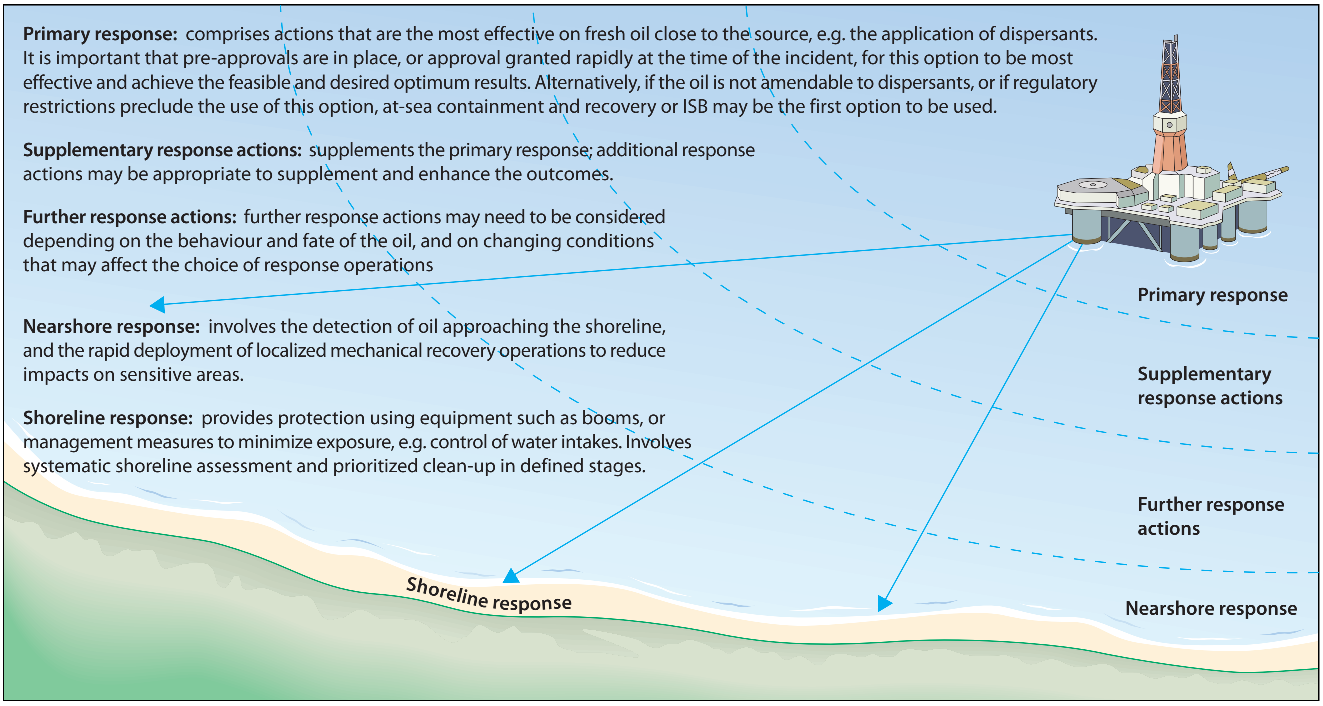
Nearshore operations would be carried out in areas of high priority to reduce potential impacts, and shoreline protection measures would generally be put in place where their success in protecting agreed priority sites is feasible.

On affected shorelines, oiling conditions should be systematically confirmed so that responders can determine priorities for clean-up and select the cleaning techniques that would achieve optimal results while minimizing further damage.

This approach is often referred to as the 'cone of response' where the most effective and advantageous response options are implemented closest to the source, and supplementary actions are taken radiating out from this location (see Figure 5 on page 18).

As an oil spill scenario continues to evolve and response measures have a positive effect, the remaining concentrations of oil will continue to be reduced. For each part of the response, there

Figure 5 *Optimized response options—sometimes referred to as the 'cone of response'*



comes a time when continuing with a particular response action offers marginal or no benefit and needs to be terminated, and in some cases other response options may be used instead.

The ongoing application of the NEBA process throughout a response allows response end points to be determined and agreed by key stakeholders early and in a systematic manner. This helps to avoid unnecessary clean-up activities which could result in additional detrimental effects on the environment.

For example, there often comes a point, particularly in shoreline clean-up, when continued clean-up activity could potentially cause more environmental damage than would arise from the remaining concentrations of oil being left to degrade naturally.

The hallmarks of an effective response strategy informed by NEBA are:

- being clear on the aims of the clean-up;
- understanding when the actions being taken have achieved as much as feasibly possible in the circumstances; and
- recognizing when continuing with the clean-up will potentially cause more harm than good.

How NEBA is applied

How NEBA is applied before a spill

A wide range of data is compiled and assessed during the initial stages of the contingency planning process which feeds directly into the NEBA process. This involves defining a balanced group of planning scenarios which collectively represent the range of oil spill risks and response challenges within the planning scope.

Planning scenarios are a recognized contingency planning basis for assessing oil spill risks. In essence, a scenario encompasses the depiction of an individual oil spill event and its envisaged evolution, including:

- the type of release, and actual or predicted properties of the oil;
- the predicted movement, behaviour and fate of the spilled oil; and
- identification of potential environmental effects, and potential socio-economic effects in jurisdictions that include them in their NEBA process, to assess their significance for prioritized protection and response.

With such a breadth of contingency planning scenarios being used for different oil industry activities, there is no single measure for the level of detail needed. Contingency planners should seek sufficient data to enable them to engage constructively with appropriate stakeholders in the development of the response strategy and in the NEBA process, and to be able to make informed decisions that can be justified if subsequently placed under scrutiny.

Scenarios developed during the contingency planning process seek to represent a range of possible spill events. However, even the best developed scenarios necessarily contain assumptions. For example, an oil company carrying out exploration activities may not have any samples of oil from which to determine the properties needed to conduct oil spill modelling. In such cases, an analogue oil may need to be selected from a database, based on a prediction of the product likely to be encountered. This prediction may rely on what can be modelled or inferred from analysis of seismic data, or data from nearby reservoirs. This approach requires a number of assumptions to be made and documented.

Where the NEBA process is conducted and a number of assumptions have been made in the underlying data, particular care needs to be given to ensuring strategy selection is made with flexibility and adaptability in mind.

Continuing the example above, where there is uncertainty in the oil type that might be encountered, an oil company may elect to build the offshore containment and recovery element of a response strategy around skimming equipment which can easily be adapted to work with the range of oil types that could be encountered.

ITOPF

Forums held to facilitate stakeholder engagement during planning and exercises contribute to more effective and efficient communication and relationships.

In understanding the potential impact of assumptions made in underlying data, it is important that experts work with stakeholders during the NEBA process to establish a common understanding, alignment and consensus of how the greatest net environmental benefit can be realized for a given spill scenario.

During the contingency planning process, there is sufficient time to enable numerous stakeholders to be engaged, and for trade-offs to be considered with science-based objectivity and without the raw emotional reactions that can sometimes unduly bias decision making during a spill.

The effective use of the NEBA process before a spill supports agreement on response options in advance, including gaining formal, conditional or less formal approval from regulators if needed. This means that, in the event of a spill incident, the underlying assumptions used in the original NEBA can be validated, and pre-approved techniques be implemented with minimal delay.

Table 2 *Examples of planning scenarios, response strategies and NEBA considerations that may be applicable in different circumstances*

Operational context: on-land crude oil storage tank facility	
Planning scenario 1:	Oil is spilled into a bunded area and contained.
Response strategy:	The strategy is clearly defined and straightforward, encompassing the entire planning scenario time scale. It requires limited techniques, e.g. pumping and temporary storage with on-site resources for mechanical/physical removal, and incident command.
NEBA considerations:	Stakeholders are limited to facility staff; sensitivities are minimal and known. There is limited scope for additional NEBA considerations during a response compared to those already carried out in the preparedness phase.
Planning scenario 2:	The spill overflows a bunded area, reaches surrounding area beyond the site boundary and enters a watercourse.
Response strategy:	The strategy involves a combination of inland response techniques, e.g. booming to minimize further spread, pumping of free floating oil, and careful physical removal from the ground surface and river banks.
NEBA considerations:	A wider range of stakeholders will need to be involved, including regulatory agencies and local communities. A variety of environmental resources and socio-economic sensitivities may require consideration for prioritized protection and appropriate clean-up.

Operational context: overland crude oil pipeline that crosses national borders	
Planning scenarios:	Multiple representative scenarios are involved, that include pipeline pumping stations, intermediate storage area, terminals, etc., and oil spill events that could affect rivers and water bodies, urban/industrial areas, and agricultural, amenity and ecologically important areas.
Response strategy:	High-level overarching response strategy for the pipeline with generic planning for different oil spill situations, and additional site-specific response planning and strategies for identified priority areas. Includes a range of response techniques appropriate for terrestrial and watercourse settings.
NEBA considerations:	There are extensive socio-economic and environmental sensitivities. There is potential need for a particularly broad range of stakeholder engagement, with NEBA considerations being addressed to support appropriate response decisions for the pipeline overall, and also for site-specific locations.

How NEBA is applied during a spill

When a spill occurs, the speed of selecting and optimizing a response strategy and deploying response assets is a critical success factor.

The NEBA process conducted during a spill is the same as that conducted during the planning phase; however there is only one scenario to address, and known incident conditions mean some uncertainties are reduced—for example, the type and quantity of product released can generally be ascertained quickly, and responders can gain access to actual and forecast metocean conditions, meaning that the potential effects of the spill can be predicted with a higher degree of confidence.

However, due to time pressures during a spill, decisions need to be made quickly, sometimes using incomplete data. In all but the most prolonged spills, the collection of additional significant data—for example on ecological or socio-economic sensitivities—is unlikely to be practical within the available time frame.

Even for spills where contingency planning has been conducted and stakeholders engaged throughout the process, the specifics of the incident may impact and change previously-agreed priorities for protection or acceptable trade-offs.

During a spill, the NEBA process is cyclical, and is repeated as data becomes available or is updated, or as conditions evolve. For example, surveillance and monitoring of the spill and response activities creates data that are incorporated into the NEBA process. This is used to support validation or adjustment of the response strategy, and ultimately in defining response end points.

Spills where contingency planning has been conducted

For spills where contingency planning has taken place and stakeholders have pre-approved various response options, the starting point for mounting a response is to achieve the best match between the specifics of the spill and the most representative planning scenario.

Where the spill closely matches a planning scenario, the underlying assumptions and parameters of the planning scenario and subsequent NEBA can be validated, enabling the pre-approved response strategies to be implemented quickly.

In the first stages of the spill, surveillance and trajectory modelling using actual and forecast metocean conditions allows a relatively high-confidence prediction to be made of the geographic area likely to be impacted by a spill. From this information, the prioritization of sensitive resources can be confirmed with stakeholders, while response resources can be deployed as prescribed in the response strategy.

For example, where oil spilled is amenable to dispersant and/or in-situ burning, being able to mobilize resources without delay, based on conditions that have been pre-agreed with stakeholders and regulators, maximizes the effectiveness of these techniques in contributing to the greatest net environmental benefit. Delays in deploying dispersant or conducting in-situ burns while approvals are being sought can lead to the window of opportunity being missed and other, less-effective techniques having to be used instead, resulting in a lesser overall net environmental benefit.

If a spill occurs that is significantly different to any of the planning scenarios, the NEBA outputs for the most representative scenario will be revised, using empirical data from the spill. Stakeholders will already be familiar with much of the underlying information, which will facilitate the process of updating the NEBA and making a new determination of the optimum response strategy to be expedited.

Spills where contingency planning has not been conducted

In spills where limited or no contingency planning has taken place, the role of NEBA in selecting response strategies does not change; however, the process needs to be conducted during a time-pressured setting, and the quality of the outcomes may be affected by limited availability of data upon which to base decisions. Nevertheless, there is still a reliable and substantial depth of prior knowledge and experience of how oil spills may potentially affect the environment and how different response options can offer benefit in a variety of circumstances.

Being that there may be limited data to inform the NEBA process, the response strategy may be selected on the basis of quickly deploying available response options which are likely to be effective, feasible and permitted by regulations, so as not to delay the response. Response strategy selection must rely heavily on the professional judgment of response specialists and informed stakeholders as to which options will result in the greatest net environmental benefit. Subsequently, once additional data is assimilated, a more detailed NEBA can be conducted and the initial response strategy adjusted.

In a spill with limited pre-planning, trajectory modelling can usually still be carried out with a degree of confidence; however there may be limitations in availability and quality of sensitivity information, thus potentially increasing the subjectivity of predicting the impact of the spill, and in the prioritization of sensitive sites for protection.

In such circumstances, the involvement of key stakeholders—in particular the regulator or other competent authority—is critical so that decisions can be made quickly. Reaching consensus during a spill about priorities for protection and the most appropriate balance of trade-offs is challenging if contingency plans are not in place or key stakeholders were not engaged in the contingency planning process.

It is important in this circumstance that the lack of available data does not delay response strategy selection and implementation. Delays in decision making may result in less than optimal response techniques being deployed; for example, in the initial days of a spill, windows of opportunity can pass quickly, limiting response options to those which may result in a lesser net environmental benefit.

In some circumstances it is not practical to conduct detailed contingency planning for the entire geographic area where a spill may occur. For example, when carrying out contingency planning for ship-source oil spills, which may involve shipping routes that are hundreds or thousands of

Box 3 *Response to the* Torrey Canyon *incident, 1967*

The *Torrey Canyon* tanker spill occurred in southwest England in 1967, and caused heavy oiling of a range of primarily UK and French shorelines.

Chemical agents that would not be used today were applied to rocky shoreline locations where they had little positive impact on the oil, but had a significant negative effect on limpets and other shoreline resources. Biological recovery of rocky shores affected by the incident took longer than recovery at other sites where less-intensive cleaning methods were used (Southward and Southward, 1978).

Numerous lessons were learned from the response to the *Torrey Canyon* incident, including how spilled oil may affect shoreline habitats, what clean-up methods are effective for different shoreline types and oiling conditions, as well as how to balance priorities and select the most appropriate techniques .

The response to the *Torrey Canyon* incident pre-dates the modern NEBA process. It illustrates how a lack of understanding of both the potential impacts of oil and the appropriate clean-up techniques prevented sound response decisions from being made, severely compromising the selection of a response strategy to optimize an overall net environmental benefit.

miles long, it would not be feasible to collect detailed sensitivity information for every location along the route. Unless overriding local regulations dictate otherwise, it is common practice for planners to make generalized NEBA assumptions and maintain access to a range of response capabilities that encompass a wide variety of potential circumstances. At the outset of an oil spill incident, a rapid assessment is made of the specific circumstances under consideration, and pre-selected response strategies are deployed quickly and flexibly.

Determining response end points

The NEBA process supports the definition of response end points by continuing to assess data gathered through ongoing monitoring of response effectiveness and evolving conditions.

Response end points are defined as the specific criteria assigned to a defined geographic area (e.g. a segment of oiled shoreline) which indicate when sufficient treatment effort has been completed.

The four stages of the NEBA process support the determination of response end points by:

- **Compiling and evaluating data** from monitoring programmes (e.g. SMART[4], SCAT[5]), and assessing the implication of any regulatory requirements or thresholds.
- **Predicting the outcomes**, i.e. comparing the effects of 'no response action' with different combinations of continuing/adapting response options.
- **Balancing trade-offs** of response options, especially considering whether continuing active clean-up may have reduced effectiveness and may cause undesirable environmental impacts.
- **Selecting the best option** by defining the point at which active response should cease.

When response end points are reached, the natural processes will continue, and a monitoring programme may be appropriate to monitor the ongoing conditions.

---

4 SMART = Special Monitoring of Applied Response Technologies

5 SCAT = Shoreline Clean-up Assessment Technique

Case studies

Case study 1: How NEBA has been applied during spills from vessels

This case study compares the responses to two major incidents involving crude oil tankers, each of which became grounded at the mouths of major sea ports in strong winds and heavy swell, releasing approximately 30,000 and 70,000 tonnes of crude oil, respectively. In the first incident, no contingency plan, and therefore no embedded NEBA process was in place; this is compared with the second incident for which NEBA was embedded in an established oil spill contingency plan.

The *Tasman Spirit* incident

The importance of considering the pros and cons of different response strategies and preparing for their use in advance of a real incident is highlighted by an incident that occurred off the coast of Karachi, Pakistan in July 2003. The laden tanker, *Tasman Spirit* became grounded outside the entrance to Karachi harbour. Attempts to refloat the tanker failed and, before all the oil could be removed, the ships' structure began to break up resulting in a spill of some 27,000 Mt of crude oil.

OSRL

The Tasman Spirit *became grounded in the entrance to the Karachi harbour, Pakistan in July 2003.*

Pakistan had ratified the OPRC Convention but did not have an effective National Contingency Plan (NCP) in place at the time of the incident. Hence, NEBA approaches were not part of the decision making process in advance of the spill. The national authorities received criticism for their lack of preparedness but a response was mounted in conjunction with the shipowner and their P&I insurers, assisted by the cargo owner, who was local.

The severity of the incident, the presence of monsoon winds, and the potential for the oil to reach the Indus Delta—an extensive area of mangroves and an important nursery ground for fisheries—warranted a NEBA evaluation of the use of dispersants. Plans for using dispersants in an emergency were not in place in Pakistan and it was necessary to seek approval in an ad-hoc fashion in order to bring the dispersant aircraft from Singapore and stockpiles of dispersant from the UK. The ship broke up the evening before the aircraft arrived and dispersants were applied to the floating oil the following day. Given the shallow waters and the proximity of the ship to the shoreline, it was necessary to apply NEBA principles constantly to evaluate whether the application of dispersants would provide a net environmental benefit. After a few sorties, dispersant spraying was terminated as most of the oil was leaking from beneath the waterline and was being dispersed naturally. It was also clear that oil stranded against the beach was unlikely to migrate to the Indus Delta as the grain size of the sediment effectively trapped the oil in the beach.

The shipowner also arranged for booms and skimmers to be flown to Pakistan to assist the authorities. As for the approval to use dispersants, customs clearance was achieved in an ad-hoc fashion but resulted in some delays, both when bringing the equipment in and, in particular, when trying to return it after the response. Attempts to deploy the equipment were hampered by inadequate local logistical support, and much of the equipment brought into Pakistan could not be used effectively.

The absence of an effective contingency plan embedding NEBA principles meant that the opportunity to engage stakeholders in planning for an incident such as this was lost. As the decision-making responsibilities of the different local and national authorities in Pakistan in an emergency were unclear, decisions about the response strategies to be used were made in conjunction with the authorities in an ad-hoc manner. NEBA had to be carried out on the basis of existing knowledge of the area and previous experience of using the different response strategies.

The *Sea Empress* incident

In contrast to the *Tasman Spirit* incident, the grounding of the *Sea Empress* oil tanker took place in the waters of an EU Coastal Member State that has NEBA approaches embedded in the decision making process. The *Sea Empress* incident occurred in UK waters on 15 February 1996 (SEEEC, 1998) and provides a useful case study for how an embedded NEBA approach can minimize the impacts of a significant spill from a crude oil tanker.

OSRL

The Sea Empress *became grounded at the entrance to the Milford Haven Waterway in Pembrokeshire, Wales on 15 February 1996.*

The oil was released over a period of seven days and, initially, the wind and tides combined to take the oil out to sea. Since dispersant use is part of the NCP, the properties of the spilled oil had been characterized in advance of the spill. Hence, the authorities knew that in the force 4–6 winds the crude oil would be amenable to being dispersed into the water column when applied to the freshly released crude oil for the first 48 hours or more on the sea surface.

In these sea states, the National Authority determined that mechanical recovery was unlikely to be able to recover more than 5–10% of the spilled oil; in practice, only 1–3% of the spilled oil was recovered at sea (SEEEC, 1998; Lunel *et al.*, 1996). Burning oil at sea was not an option considered under the UK NCP. Through modelling, it was determined that the winds and tides would drive the oil dispersed into the water column further out to sea where water depths are greater than 20 metres.

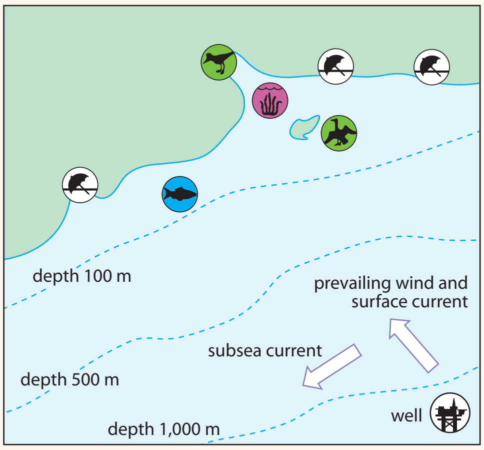
The National Authority decided that there is a net environmental benefit in mounting a rapid dispersant spraying operation, based on the fact that dispersed oil concentrations will dilute rapidly whereas, if left to emulsify on the sea surface, the surface oil slick could increase in volume by four- to five-fold. The Authority's NEBA analysis suggested that, as a result of the emulsification of oil that could not be recovered before the wind changed direction, there was a high probability that if they were to rely on mechanical recovery only, the oil would persist on the sea surface as a slick of around 100,000 tonnes, and would come ashore when the winds switched direction in a week's time. The NEBA analysis determined that the environmental and economic impacts of more 100,000 tonnes of water-in-oil emulsion coming ashore far outweighed the potential localized impact of dispersing 28,000 tonnes of crude oil into waters greater than 20 metres in depth (Lunel *et al.*, 1996). As a result of the oil type, the prevailing weather conditions and early mobilization of a dispersant operation to spray 445 tonnes of dispersant, only 2–6% of the spilled oil stranded on the shoreline (SEEEC, 1998; Lunel *et al.*, 1996).

Summary

Comparing the *Sea Empress* and *Tasman Spirit* case studies illustrates how an embedded NEBA approach in the National Contingency Plan plays a major role in allowing a well-prepared National Authority to effectively reduce environmental and economic impacts significantly in the event of a tanker incident.

Case study 2: How NEBA can be used to justify subsea dispersant injection

An exploration well suffers loss of control including failure of the blowout preventer. Crude oil and gas are released, with the oil estimated to be flowing at 3,000 m^3 (19,000 bbls) per day.



- The well is at a water depth of 1,100 metres.
- Surfacing oil slicks are drifting towards the shore under the influence of a prevailing 15-knot wind and surface current.
- The subsea current runs parallel to the coast.
- Wave height is around 1.5 metres.
- There are fishing grounds closer to the coast and seagrass beds in shallow water.
- Coastal resources that could be impacted by the oil include an estuarine mudflat that supports a large population of wading birds. An offshore island supports a seabird colony. There are three popular tourist resorts in the vicinity.

Summary of NEBA

Evaluate data

With no intervention, and under prevailing conditions, modelling predicts an 80% probability that surfacing spilled oil would reach the shore, and that the oil would reach the coast after 4 days. During this time the spilled oil would become progressively 'weathered' and emulsified. The spilled oil volume would initially decrease due to evaporative loss, but then increase due to emulsification. This could result in up to 10,000 m^3 per day of emulsified oil threatening the coast after 4 days. Gas released within the well fluids would dissolve before reaching the surface.

Predict outcomes

The nearshore and coastal sensitivities are very high and their protection from oil would result in high environmental benefit. The estuarine mudflat is biologically productive and difficult to either protect with booms or to clean up if oiled. The seabird colony does not contain threatened species but adds to the attraction of the area for tourists, with daily boat trips. The tourist resorts are a major part of the regional economy, relying on popular sandy beaches and watersports. The tourism is seasonal but this scenario falls within the main season. The threat to beaches would cause significant immediate disruption and has the potential to dent confidence in the area and reduce future reservations. The inshore fishery is locally important but economically small in relation to tourism.

Balance trade-offs

At-sea mechanical recovery or in-situ burning alone could not deal with the amount of spilled oil in the time available. Surface use of dispersant is possible; the crude oil is tested to be amenable to dispersant use prior to emulsification, with a window of opportunity of around 24 hours. The prevailing conditions of 1.5-metre wave height and 15-knot wind are good for dispersant use. However, the surfacing oil would rapidly spread and fragment, presenting challenges for targeting and encountering the floating oil even using a combination of vessels and aerial systems. Approximately 150 m^3 of dispersant would need to be applied each day, based on a dispersant to oil ratio (DOR) of 1:20. An aerial application system is available within 24 hours, capable of applying up to 100 m^3 of dispersant per day. First response is available from a standby vessel with a boat spray system and stock of 5 m^3 of dispersant.

Mobilizing a subsea dispersant injection system as part of a capping response would allow treatment to commence within seven days, with dispersant supplied from the global stockpile. Injection at the well head would greatly increase both the targeting of the dispersant operation and the volume of oil being dispersed. The DOR could be decreased to 1:50 or less, reducing the volume of dispersant used per day by more than 50%. Surface dispersant application could then be scaled down generally, and potentially restricted to the area around the well head site, if needed, to reduce VOCs to safe working levels for workers onboard vessels in the vicinity engaged in source control activities.

In this case study, we assume that the enhancement of subsea dispersed oil through dispersant injection would pose a heightened risk to marine life within a few kilometres of the well location. However, dilution of dispersed oil would (i) reduce concentrations to below anticipated toxicity levels in the wider area, (ii) enhance biodegradation and (iii) greatly mitigate gross oiling of the sensitive coastal zone.

It is anticipated that the well would be capped within 15 days.

Select best options

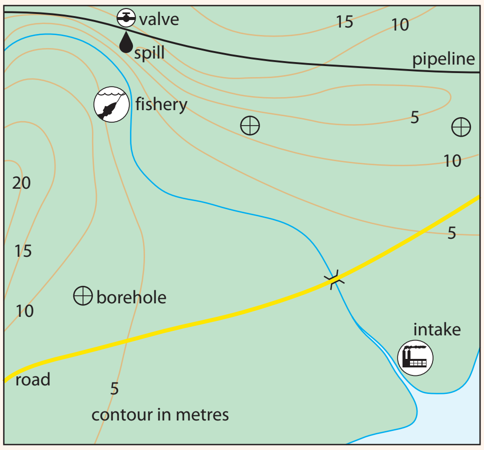
Initial surface dispersant use on the floating spilled oil, followed by subsea injection as soon as it can be mobilized, would be effective and would be the primary response tool.

Inshore containment and recovery operations would be mobilized and targeted around the ecologically sensitive areas.

Shoreline assessment and clean-up would be carried out on contaminated shorelines.

Case study 3: How NEBA could be applied in an inland pipeline spill

An overland pipeline carrying crude oil suffers damage at a block valve resulting in an estimated 100 m^3 of oil impacting the terrain. The pipeline pressure warning system failed to operate; a local farmer alerted the pipeline company.



- The pipeline is above ground.
- It is situated in a remote, rural area with difficult access.
- Crop farming is the primary land use in the vicinity.
- Boreholes are used for groundwater extraction to irrigate crops.
- The underlying geology is predominantly clay in nature.
- There is a slow flowing river 200 metres downhill, with high-value salmon fishing stock.
- The port is 6 km downstream of the river with industrial water intakes.

Summary of NEBA

Evaluate data

With no intervention, modelling predicts a high probability (>80%) of the river being impacted within 3 days and groundwater becoming polluted through vertical penetration in approximately 2 days.

Fisheries stocks are a high economic value to the region through local and international fishing tourists. Arable crops are of a relatively low yield and value in the area.

Predict possible outcomes and evaluate potential response options

Agricultural crops could be contaminated but, with a rigorous remediation plan, subsequent crops would not be severely affected in the long term (>3 years). River life may be impacted in the short term and also the long term if oil were to contaminate the water course. The salmon fishery would be impacted for >5 years due to habitat loss and the ongoing slow release of oil to the river from underlying and bordering land.

Protecting the river from contamination should be a primary response strategy to ensure the long-term survival of the salmon fishery and protect financial and environmental benefits. Limiting ground contamination would also reduce any potential impact on crops and livestock in the short and long term.

A *pooling* option would cover a surface area of ~8 m^2 at an average thickness of 1.5 m and a *spreading* option would cover a surface area of ~140 m^2 at an average thickness of 0.5 cm.

Balance trade-offs

Response strategy option 1 (pooling): Direct the oil to a natural depression between the pipeline and the river where it can pool to a layer of two metres. This would enable rapid containment of the oil, which would impact a smaller surface area and be easier to recover mechanically, with potentially less impact on crops/livestock. It would also result in a smaller volume of soil being impacted that would require longer-term treatment.

Response strategy option 2 (spreading): Allow the oil to spread in a thinner layer over a larger ground area near the damaged pipeline. This is potentially less likely to impact surface water and associated fisheries, and can reduce the potential impact on nearby agricultural watering wells and groundwater. It also serves to protect the river habitat, and reduces the need for prolonged groundwater remediation and monitoring.

Select best options

Local stakeholder views and priorities prevailed, i.e. to: contain the impacts of the spill to the smallest area possible; limit the damage to crops and livestock; and minimize the volume of soil to treat. Hence, pooling was selected as the preferred option. The main drawback of this approach was an increased risk of product soaking into the ground and potentially reaching groundwater. To mitigate this, a response capability was established to rapidly recover pooled product, starting within 48 hours; affected soil was to be treated on-site and a groundwater monitoring plan was established.

Stakeholder engagement

Oil spills may potentially affect a diverse range of sensitive environmental and socio-economic resources. It is important to consider which regulatory agencies, statutory consultees and other stakeholders may need to be engaged during the contingency planning process and/or during the response to an oil spill event. Generally, stakeholders may include:

- the responsible party;
- government entities;
- potentially affected parties and communities;
- subject matter experts; and
- first responders and response organizations.

Contingency planners and responders should establish a stakeholder engagement strategy to define stakeholder engagements and their level of contribution at various times. This is often driven by regulatory requirements for planning and/or for response. Effective and timely interaction should adhere to the following principles:

- open lines of communication;
- transparent decision making;
- clarification of policies (or clear policies regarding response options); and
- realistic expectations of response outcomes.

Industry should seek the following from designated regulatory agencies:

- Pre-approved response strategies in order to respond to a spill as rapidly and effectively as possible. Consider:
  - dispersant approval requirements;
  - in-situ burning approval requirements; and
  - stockpiled response resources or provisions to expedite their availability.
- Help to overcome barriers during a response through:
  - rapid, non-partisan decision making;
  - sharing of objective information; and
  - mobilizing of response capabilities to include the expedition of the cross-border transfers of people and equipment.
- Leveraged expertise before and during a spill through:
  - clearly predefined roles and responsibilities; and
  - the designation of operational authority only to appropriate response parties, thus removing distractions.

Conclusion

The process of developing an optimal response strategy using net environmental benefit analysis has continued to evolve since first adopted as a concept during the response to spills in the 1980s.

This Good Practice Guide illustrates how a systematic net environmental benefit analysis process can:
- establish an understanding of the potential effects of a spill on different environmental and other resources;
- help to select and develop various response options; and
- address the various trade-offs that may be needed to achieve the optimal response strategy.

This Guide also highlights the continued importance of the NEBA process once a response is under way, in monitoring the effectiveness of response activities and defining end points.

The hallmarks of a well-managed response include:
- safety at the forefront;
- NEBA regularly addressed as the scenario evolves;
- response strategy optimized through a balance of response techniques;
- government and industry working together cooperatively; and
- effective, timely and transparent communication.

Applied well, NEBA provides the foundation for an effective response strategy that achieves the overall desire of protecting human life and preserving environmental and community well-being during times of spills.

Appendix 1: Response options

<table>
<tr><th>Response option</th><th colspan="2">Benefits</th><th colspan="2">Drawbacks</th></tr>
<tr><td>Natural removal</td><td colspan="2">No intrusive removal or clean-up techniques that could further damage the environment.
Complements other response techniques.
Observations and data gained from monitoring inform response decisions and tool selection.
May be the best option if there is little to no threat to human or environmental well-being.
When used in certain areas and conditions, the environment can recover from the spill more effectively than it might when using other response tools.</td><td colspan="2">Oil may not be removed.
Winds and currents can change, sending the oil spill towards sensitive areas.
Residual oil can impact shoreline ecology, wildlife and economically-relevant resources.
Public perception that responders are doing nothing.</td></tr>
<tr><td>Dispersant: surface application</td><td>Lower manpower and logistical requirements than other response options.
Can be applied over a broad range of weather conditions.
Higher encounter rate compared to other surface options.</td><td rowspan="2">Reaches and treats significantly more oil than other response options.
Speeds up oil removal from the water column by enhancing natural biodegradation.
Removes or prevents surface oil, mitigating harm to sea birds, mammals, and other wildlife.
Reduces the amount of oil that spreads to the shoreline, reducing risk for sensitive shorelines.
Reduces the impact on community assets and local industries.
No recovered oil storage requirements.
Reduced vapours at the water surface improve responder safety.</td><td>May not work on high viscosity fuel oils in calm, cold seas.
May have a limited ‘window of opportunity’ for use.</td><td rowspan="2">Does not directly collect the oil from the environment but instead disperses it into the water column where it can be biodegraded.
Potential effects of dispersed oil on water column-dwelling marine life (anticipate short-lived and localized exposures).
Potential impact on fishing industries if the public misunderstands potential effects of dispersant on seafood.
Regulatory approval generally required before dispersant can be applied.
continued …</td></tr>
<tr><td>Dispersant: subsea application</td><td>Continuous operations, day and night, are possible.
Can be applied in all but very severe weather conditions.
High encounter rate possible.</td><td>Slower mobilization time compared to surface application.</td></tr>
</table>

Response option	Benefits	Drawbacks
In-situ burning	• Rapid removal of large amounts of oil. • Much less oil left for disposal. • High efficiency rates (up to 98–99%). • Less equipment and labour required; specialized equipment (boom) is transportable by air. • May be the only viable option (e.g. on marshes, ice). • No recovered oil storage requirements (except possibly for burn residue). • Effective over a wide range of oil types and conditions. • Minimal environmental impact. • Reduced vapours from oil at the water surface improves responder safety.	• Black smoke perceived as a significant impact on people and the atmosphere. • Limited 'window of opportunity' for spills on open water (emulsified oils do not burn). • Need to capture and contain sufficient volume of oil and slick thickness for in-situ burning to be effective. • Effectiveness diminishes for heavier oils and as oil weathers. • Burning presents a potential safety risk. • Burning presents a potential risk to offshore wildlife that must be managed. • Burn residue can be difficult to recover (may sink from burns of very heavy oils). • Special approvals required. • Localized reduction of air quality. • Potential for secondary fires during inland use. • Ineffective in inclement weather or high seas.
At-sea containment and recovery	• Removes oil with minimal environmental impact. • Well-accepted, no special approvals needed. • Effective for recovery over a wide range of spilled products. • Large 'window of opportunity'. • Minimal side effects. • Greatest availability of equipment and expertise. • Recovered product may be reprocessed.	• Inherently inefficient and often very slow. • Often cannot recover enough oil to prevent shoreline impact. • Harder to recover a lot of oil in larger spill cases. • Inefficient and impractical on thin slicks. • Ineffective in inclement weather or high seas. • Requires storage capability. • Typically recovers no more than 10–20% of the oil spilled. • Labour- and equipment-intensive.
Physical removal on shorelines	• Removes oil. • Reduces potential for oil spreading further. • Reduces secondary impacts on animals that come down to shorelines. • Prevents remobilization of the oil. • Non-aggressive methods can have minimal impact on shore structure and shore organisms. • Useful for detailed cleaning of nearshore environment in specific or sensitive areas.	• Potential for further damage to the environment: aggressive removal methods may impact shoreline and shore organisms (e.g. sand removal and cleaning). • Storage and waste disposal requirements. • Typically recovers no more than 10–20% of the oil spilled. • Labour-intensive. • Potential for heavy equipment and high foot traffic (trampling) can cause additional environmental damage. • Removal occurs after oil has already impacted the shore. • Shoreline response can require significant resources and logistical support.

Appendix 2: How NEBA fits into the contingency planning process

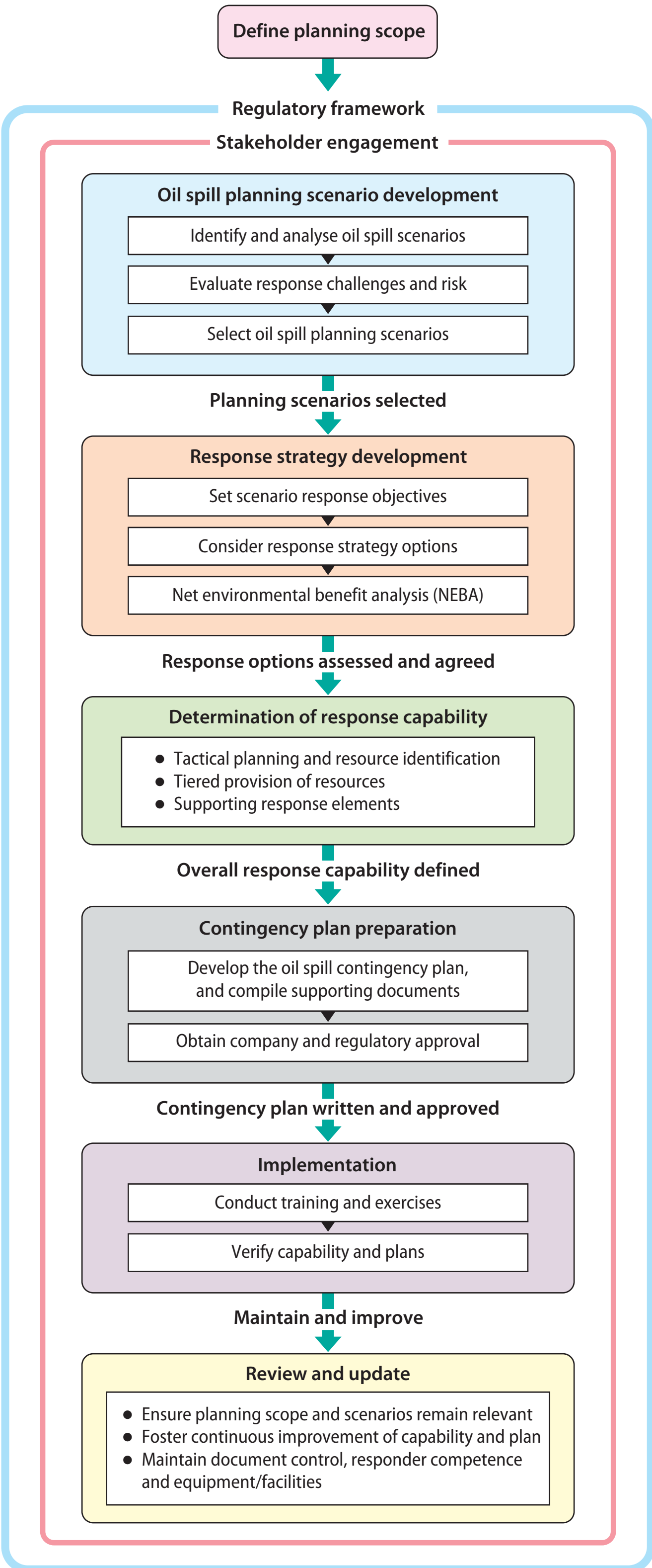
Oil spill contingency planning is the process of developing a suitable spill response capability that is in compliance with the regulatory framework and commensurate with the oil spill risks of an organization or facility. The response capability is defined in part by the response strategies selected as a result of the NEBA.

The contingency planning process includes the following stages :
- definition of planning scope;
- oil spill planning scenario development;
- response strategy development;
- determination of response capability;
- contingency plan preparation;
- implementation; and
- review and update.

NEBA is a fundamental part of the response strategy development stage. The NEBA process is fed by data collated and defined within the selected planning scenarios and provides the mechanism for systematically assessing and reaching consensus on the optimum response options for each planning scenario. This is taken forward in contingency plans and implementation of an appropriately tiered oil spill response capability.

Figure 7 illustrates the oil spill contingency planning process and where NEBA fits into this process. Further explanation of the process can be found in the IPIECA-IOGP Good Practice Guide on contingency planning for oil spills on water (IPIECA-IOGP, 2015c).

Figure 7 *The contingency planning process*



References and further reading

Addassi, Y. N, (2002). *Utilizing Net Environmental Benefit Analysis (NEBA) as a Tool for Evaluating Applied Response Technologies in Response to a Marine Oil Spill*. Office of Spill Prevention and Response, Department of Fish and Game http://www.slc.ca.gov/division_pages/MFD/Prevention_First/Documents/2002/Paper%20by%20Yvonne%20N%20Addassi.pdf

ASTM (2013). ASTM Standard number F2532 - 13: *Standard Guide for Determining Net Environmental Benefit of Dispersant Use*. ASTM International, West Conshohocken, PA. www.astm.org

BP (2015). *Restoring the environment*. Overview of BP's work with state and federal agencies to assess and restore natural resources injured as a result of the Deepwater Horizon incident. BP website: www.bp.com/en/global/corporate/gulf-of-mexico-restoration/restoring-the-environment.html

Baker, J. M. (1997). *Differences in Risk Perception: How Clean is Clean?* An Issue Paper prepared for the 1997 International Oil Spill Conference. American Petroleum Institute, Technical Report IOSC-006, no. 52. http://ioscproceedings.org/toc/iosc/1997/TR6

Ballou, T .G., Hess, S. C., Dodge, R. E., Knap, A. H. and Sleeter, T. D. (1989). Effects of Untreated and Chemically Dispersed Oil on Tropical Marine Communities: A Long Term Field Experiment. In *International Oil Spill Conference Proceedings:* February 1989, Vol. 1989, No. 1, pp. 447-454. doi: http://dx.doi.org/10.7901/2169-3358-1989-1-447.

Cedre (2006.) *Braer* spill incident. Cedre website: 'Database of spill incidents and threats in waters around the world'. Available at: www.cedre.fr/en/spill/braer/braer.php

Efroymson, R. A., Nicolette, J. P. and Suter, G. W. II (2003). *A Framework for Net Environmental Benefit Analysis for Remediation or Restoration of Petroleum-Contaminated Sites*. Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee.

Fingas, M. (ed) (2011). *Oil Spill Science and Technology*. Gulf Professional Publishing, Burlington, MA, USA.

GoMRI (2015). Research programme of the Gulf of Mexico Research Initiative. Available at: http://research.gulfresearchinitiative.org

IPIECA (1994). *Biological impacts of oil pollution: Saltmarshes*. IPIECA Oil Spill Report Series, Volume 6, June 1994.

IPIECA (2000). *Choosing spill response options to minimize damage. Net Environmental Benefit Analysis*. IPIECA Oil Spill Report Series, Volume 10, June 2000.

IPIECA/IMO/IOGP (2012). *Sensitivity mapping for oil spill response*. IPIECA-IOGP Good Practice Guide Series, Oil Spill Response Joint Industry Project (OSR-JIP). IOGP Report 477. http://oilspillresponseproject.org/completed-products

IPIECA-IOGP (2013). *Finding 6: Oil spill risk assessment and response planning for offshore installations*. Finding 6 of the IOGP Global Industry Response Group (GIRG) response to the Deepwater Horizon incident in the Gulf of Mexico in April 2010. Oil Spill Response Joint Industry Project (OSR-JIP). http://oilspillresponseproject.org/completed-products

IPIECA-IOGP (2014). *A guide to oiled shoreline assessment (SCAT) surveys.* IPIECA-IOGP Good Practice Guide Series, Oil Spill Response Joint Industry Project (OSR-JIP). IOGP Report 504. http://oilspillresponseproject.org/completed-products

IPIECA-IOGP (2015). *Impacts of oil spills on marine ecology*. IPIECA-IOGP Good Practice Guide Series, Oil Spill Response Joint Industry Project (OSR-JIP). IOGP Report 525. http://oilspillresponseproject.org/completed-products

IPIECA-IOGP (2015a). *Impacts of oil spills on shorelines*. IPIECA-IOGP Good Practice Guide Series, Oil Spill Response Joint Industry Project (OSR-JIP). IOGP Report 534. http://oilspillresponseproject.org/completed-products

IPIECA-IOGP (2015b). *Economic assessment and compensation for marine oil spills*. IPIECA-IOGP Good Practice Guide Series, Oil Spill Response Joint Industry Project (OSR-JIP). IOGP Report 524. http://oilspillresponseproject.org/completed-products

IPIECA-IOGP (2015c). *Contingency planning for oil spills on water*. IPIECA-IOGP Good Practice Guide Series, Oil Spill Response Joint Industry Project (OSR-JIP). IOGP Report 519. http://oilspillresponseproject.org/completed-products

Lunel, T., Swannell, R., Rusin, J., Bailey, N., Halliwell, C., Davies, L., Sommerville, M., Dobie, A., Mitchel, D., McDonagh, M. and Lee, K. (1996). Monitoring of the effectiveness of response options during the *Sea Empress* incident: a key component of the successful counter-pollution response. In *Spill Science & Technology Bulletin*, Vol. 2, Issues 2–3, pp. 99-112. www.sciencedirect.com/science/article/pii/S1353256196000114

Lunel, T., Rusin, J., Bailey, N., Halliwell, C. and Davies, L. (1997). The net environmental benefit of a successful dispersant operation at the *Sea Empress* incident. In *International Oil Spill Conference Proceedings:* April 1997, Vol. 1997, No. 1, pp. 185-194. doi: http://dx.doi.org/10.7901/2169-3358-1997-1-185

Lunel, T. and Baker, J. M. (1999). Quantification of Net Environmental Benefit for Future Oil Spills. In *International Oil Spill Conference Proceedings:* March 1999, Vol. 1999, No. 1, pp. 619-627. doi: http://dx.doi.org/10.7901/2169-3358-1999-1-619

Michel, J. and Benggio. B. (1999). Guidelines for selecting appropriate clean-up endpoints at oil spills. In *International Oil Spill Conference Proceedings:* March 1999, Vol. 1999, No. 1, pp. 591-595. doi: http://dx.doi.org/10.7901/2169-3358-1999-1-591

Michel, J. and Rutherford, N. (2014). Impacts, recovery rates and treatment options for spilled oil in marshes. In *Marine Pollution Bulletin*, Vol. 82, Issues 1–2, pp. 19-25.

NOAA (2010). *Oil Spills in Mangroves: Planning & Response Considerations.* National Oceanic and Atmospheric Administration
http://response.restoration.noaa.gov/sites/default/files/Oil_Spill_Mangrove.pdf

SEEEC (1998). The environmental impact of the *Sea Empress*. Final Report of the Sea Empress Environmental Evaluation Committee. Her Majesty's Stationery Office, London, UK.

Sell, D., Conway, L., Clark, T., Picken, G. B., Baker, J. M., Dunnet, G. M., McIntyre, A. D. and Clark, R. B. (1995). Scientific criteria to optimize oil spill clean-up. In *International Oil Spill Conference Proceedings:* February-March 1995, Vol. 1995, No. 1, pp. 595-610.
doi: http://dx.doi.org/10.7901/2169-3358-1995-1-595

Sergy, G. A and Owens, E. H. (2007) *Guidelines for Selecting Shoreline Treatment Endpoints for Oil Spill Response*. Emergencies Science and Technology Division, Environment Canada, Ottawa, ON, 30 pp.

Shigenaka, G. (2011) Net Environmental Benefit Analysis. In *Operational Science Advisory Team-2 (OSAT-2)*. National Oceanic and Atmospheric Administration (NOAA).
www.restorethegulf.gov/sites/default/files/documents/pdf/Annex%20M%20NEBA.pdf.

Shigenaka, G. (2014). *Twenty-Five Years after the* Exxon Valdez *Oil Spill: NOAA's Scientific Support, Monitoring, and Research*. National Oceanic and Atmospheric Administration (NOAA), Office of Response and Restoration. 78 pp.
http://response.restoration.noaa.gov/sites/default/files/Exxon_Valdez_25YearsAfter_508_0.pdf.

Southward, E. C. and Southward, A. J. (1978). Recolonization of rocky shores in Cornwall after the use of toxic dispersants to clean up the *Torrey Canyon* spill. In Journal of the Fisheries Research Board of Canada, Vol. 35, No. 5, pp. 682-706.

US EPA (2013). Area Contingency Planning Handbook. Verison 1, March 2013. US Environmental Protection Agency, Washington D.C. www.epa.gov/oem/docs/oil/frp/EPA_ACP_Handbook.pdf

Acknowledgements

The text for this guide was prepared by Rob Holland, Dave Rouse and Rosie Buse of Oil Spill Response Limited.

The authors would like to thank the following for contributing their valuable expertise and advice in developing the content of this document: Richard Santner (BP), Victoria Broje (Shell), Marty Cramer (ConocoPhillips), Tim Lunel (ITOPF), Peter Taylor (Petronia), Peter Collinson (BP), Andrew Tucker (BP), David White (BP) and Garnet Hooper (Jacobs).

The original IPIECA report on NEBA, entitled *Choosing spill response options to minimize damage: Net Environmental Benefit Analysis* (Volume 10 of the IPIECA 'Oil Spill Report Series', written by Jenny Baker and Tim Lunel in 2000), has been drawn upon where appropriate in this document.

This page is intentionally blank

This page is intentionally blank

IPIECA

IPIECA is the global oil and gas industry association for environmental and social issues. It develops, shares and promotes good practices and knowledge to help the industry improve its environmental and social performance; and is the industry's principal channel of communication with the United Nations. Through its member led working groups and executive leadership, IPIECA brings together the collective expertise of oil and gas companies and associations. Its unique position within the industry enables its members to respond effectively to key environmental and social issues.

www.ipieca.org

IOGP

International Association of Oil & Gas Producers

IOGP represents the upstream oil and gas industry before international organizations including the International Maritime Organization, the United Nations Environment Programme (UNEP) Regional Seas Conventions and other groups under the UN umbrella. At the regional level, IOGP is the industry representative to the European Commission and Parliament and the OSPAR Commission for the North East Atlantic. Equally important is IOGP's role in promulgating best practices, particularly in the areas of health, safety, the environment and social responsibility.

www.iogp.org.uk