

A guide to shoreline clean-up techniques

Good practice guidelines for incident management
and emergency response personnel



IPIECA

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

Level 14, City Tower, 40 Basinghall Street, London EC2V 5DE, 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

London office

Level 14, City Tower, 40 Basinghall Street, London EC2V 5DE, United Kingdom
Telephone: +44 (0)20 3763 9700 Facsimile: +44 (0)20 3763 9701
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

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The original IPIECA Report Series will be progressively withdrawn upon publication of the various titles in this new Good Practice Guide Series during 2014–2015.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

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Introduction

This Good Practice Guide is divided into four sections. The first section sets out ten important factors to be considered when contemplating the clean-up of an oiled shoreline. In Section 2, the steps to be taken in managing shoreline clean-up operations are discussed. The third section describes some of the most frequently used clean-up techniques, and sets out the advantages and limitations of each one, as well as the stages in the overall operation when a particular technique is likely to be most useful. The fourth section examines the interaction between stranded oil and different shoreline types, and suggests some possible approaches to addressing the challenges that this interaction can present. A brief summary is provided on page 59, followed by a *References* section and suggestions for further reading. Finally, the two Appendices provide examples of a volunteer registration form and daily worksite sheet, respectively.

Section 1: Guiding principles

Ten key principles drive strategic decisions on shoreline clean-up. Decisions on issues such as which clean-up techniques are best suited to which shoreline type, what equipment can be used, the numbers of personnel that should be deployed and the criteria for terminating operations are all finely balanced. Matrices can be drawn up which match different oils, degree of oiling and shoreline types with optimal clean-up techniques, but other factors can sometimes weigh more heavily and move the balance from a recommended approach to one which better fits the circumstances, perhaps, for example, due to safety concerns. The guiding principles presented below are therefore intended to provide a brief overview of some of the most important factors which influence decisions on shoreline clean-up, although the weight given to each will be determined by the unique circumstances of a specific incident.

Important principles guiding decisions towards successful shoreline clean-up include:

1. recognizing that shoreline clean-up is a local issue calling for local support;
2. minimizing the movement of stranded oil;
3. planning comprehensive contingency arrangements in anticipation of potential incidents;
4. building an organizational structure that provides effective support and strong oversight, to ensure both the safety of personnel working on the shoreline and that clean-up techniques are properly executed;
5. adopting a standardized protocol for reporting shoreline oiling (Shoreline Clean-up Assessment Technique—SCAT);
6. selecting clean-up techniques on the basis of a net environmental benefit assessment (NEBA) taking into account shoreline type, degree of oiling and oil characteristics;
7. agreeing realistic end points, achievable by available clean-up techniques and matched to shoreline 'use' or 'services' provided;
8. working with the weather and tides;
9. minimizing secondary contamination by maintaining separation between hot (dirty) and cold (clean or treated) zones; and
10. managing and minimizing oily waste and, where possible and appropriate, segregating waste streams at the source.

A local issue

Spill statistics, especially for ship-source spills, have shown a welcome decline in recent years but global statistics are of little comfort to the local communities suffering a major spill. These are the communities that feel the brunt of a spill, whether due to the effect on local businesses such as tourism and fisheries, the temporary loss of coastal amenities that are enjoyed by the local population and tourists alike, or simply the disruption caused by the influx of large numbers of personnel and machines necessary to clean the shoreline. Shoreline clean-up is the most visible element of spill response, and is inevitably a focus for media attention. The shoreline is usually accessible by the media and special interest groups, and with the availability of a wide range of communication channels, disquiet in the local community can quickly spread to a much wider audience with unpredictable repercussions.

However, local communities can also be an invaluable resource and their participation in the response is vital. Not only can their representatives advise on local issues and reflect the concerns

and sensitivities that exist, their local knowledge can be indispensable. This may include, for example, a knowledge of the available resources that could be drawn upon to support clean-up operations, shoreline access points, ownership of coastal farmland over which access is required and areas presenting particular hazards to personnel working on the shoreline. Additionally, since prevailing winds and currents tend to drive oil to the same shoreline locations as they do for floating debris, local knowledge of where debris typically accumulates along the shoreline can help to prioritize the shoreline assessment activities.

Minimizing the movement of stranded oil

A balance has to be struck between waiting for all the oil to come ashore to avoid repeatedly cleaning the same areas with each new stranding, and collecting the oil as quickly as possible. In almost all circumstances the balance will fall in favour of rapid collection as the oil reaches the shore, to avoid it becoming buried or refloating and moving elsewhere, including to unoiled areas and areas already cleaned. The circumstances of the incident may, however, dictate otherwise, for example, in the case of a single oil loss from a vessel and depending on the risks of oil movement and burial, it may be beneficial to wait until all the oil has come ashore, not only to avoid repeated cleaning but also to minimize the amount of waste generated. On the other hand, a continuous leak such as from a production or exploration well would call for the regular removal of oil as it reaches the shoreline.

In some situations, however, the remobilization of stranded oil from sensitive shorelines may be a preferred strategy to enable nearshore recovery operations, or to encourage oil to strand on less sensitive shorelines from where it can be more easily removed. This is particularly relevant for wetlands and mud shorelines.

Contingency planning

Regional or area contingency plans consider the risk of spills in terms of potential frequency and likely consequences by first looking at potential spill sources, the most likely spill size and, if they can be foreseen, the types of oil that might be spilled. Oil spill trajectory modelling based on prevailing weather and water currents helps to identify the most vulnerable resources in the path of a spill. Essentially, during the development of a contingency plan, the most appropriate response strategies are addressed in a calm atmosphere without the immediate pressures associated with a spill event. Once the most probable scenarios have been identified, the response options for each scenario can be reviewed and the appropriate levels of manpower, equipment and materials considered together with the structure of the response organization needed to manage the most likely events. Although contingency arrangements will need to be adapted to the particular circumstances of an incident, a number of decisions will have already been made during the planning process. For example, the organizations or agencies from which personnel could be drawn will be known, as will the details of contractors able to provide equipment and personnel to work on the shoreline. Additionally, oily waste issues will have been considered, including identification of suitable locations for temporary storage and available options for final disposal with sufficient capacity to cope with the expected volume of waste.

Regular exercising of contingency plans affords the opportunity for problems to be recognized and rectified. Exercises also allow the individuals involved to develop working relationships and get to know each other's roles within the organizational structure. Further information on contingency planning and oil spill exercises is presented in the respective IPIECA-IOGP Good Practice Guides (IPIECA-IOGP 2015a and 2014a).

Organizational structure

An effective and successful clean-up operation cannot be achieved without efficient management of all aspects of the response. No amount of specialized equipment can compensate for poor organization. Responding to a spill calls for a coherent organizational structure that spans the entire response, combining source control, tracking the spill from the air, on-water operations and shoreline clean-up. Operations onshore depend on an organization that supports the rapid exchange of reliable information between SCAT specialists on the shoreline, the management team and the workforce back on the beach. The system should be able to adapt to a continuously changing situation, responding to feedback from the shoreline and ensuring that all the necessary logistics are in place to supply materials, remove collected waste, and ensure the well-being and motivation of the workforce, while at the same time keeping track of costs and securing sufficient funds to finance the response.

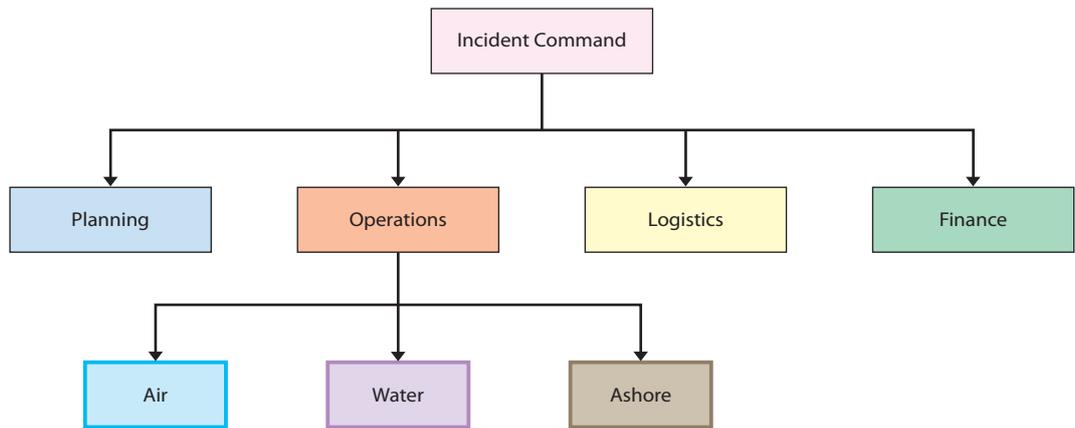
A key feature of effective management is that management capacity should be well matched to the number of people working on the shoreline. Simply increasing personnel numbers working on the shoreline is unlikely to improve outcomes unless properly managed. The initial deployment of personnel and equipment should be closely monitored and escalated or decreased to optimize efficiency and effectiveness. A realistic appraisal of progress and of any adjustments necessary to meet changing conditions is needed, as is the ability to increase the number of personnel if need be, or to scale down the response as work reaches completion. Strong oversight is required to ensure the safety of crews working on the shoreline, and to make certain that recommended clean-up techniques and working practices are being followed, so as to make the most effective use of available resources.

In different countries around the world, spill response management is organized in various ways, but one approach that has been widely adopted is the Incident Command System (ICS) employed by the United States Coast Guard (USCG) and others (see Figure 1 on page 8). One of the major advantages of ICS is that the system provides a template for a number of different organizations to be quickly brought together into a coherent structure where the chain of command, lines of communication, common terminology and individual roles are clearly established.

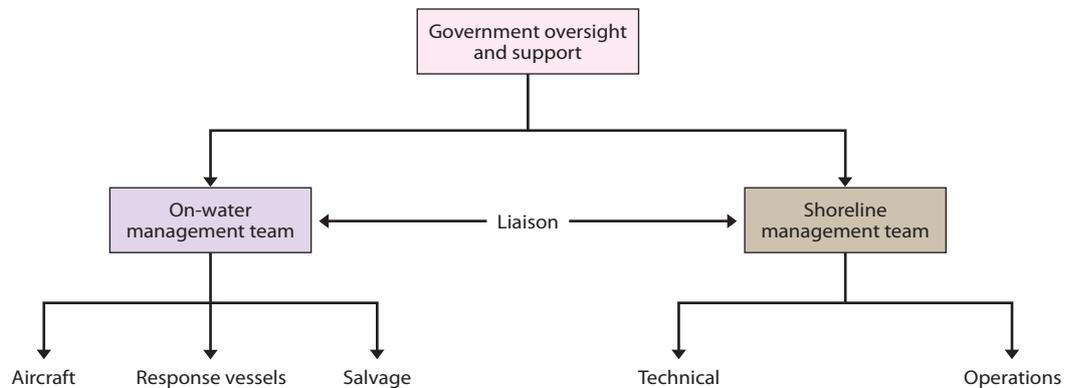
Figure 1b shows a simplified diagram of an alternative organizational structure, variations of which are used in a number of countries. This is often the case where responsibilities are split between responses on the water and on the shoreline. For example, a national navy or coast guard may be responsible for the on-water response whereas shoreline clean-up may be the responsibility of an environmental agency or ministry, or the regional or local authorities. With such a division of responsibilities, close liaison between the organizations accountable for on-water operations and those managing the shoreline clean-up is essential.

Figure 1 Comparison of organizational structures for the management of an oil spill response

(a) Incident Command System



(b) An alternative organizational structure



In the event of a spill, many oil industry personnel who have been trained on ICS will find themselves working alongside authorities using an alternative organizational structure. The opportunity should be taken to conduct oil spill exercises with such authorities to allow industry personnel and government authorities to develop ways of working together and to encourage integration into a single working structure.

Readers may wish to refer to the IPIECA-IOGP Good Practice Guide on incident management (IPIECA-IOGP, 2014b) for further information on this topic.

Shoreline clean-up assessment (SCAT) surveys

Various approaches to carrying out SCAT surveys have been developed but, at their core, they all have the same objective—to provide a protocol for the systematic reporting of shoreline oiling. Without this it is very difficult to allocate priorities to cleaning work since, depending on the observer, one person's 'completely covered in oil' could be another's 'light scattering'. In addition, as the clean-up proceeds, it is important to have standardized references by which to judge progress. The situation on the shoreline will be in constant flux, and it is therefore essential that the results of shoreline surveys are reported as quickly as possible and disseminated to those who will make use of the information in directing operations. A standardized reporting format facilitates the rapid collection of the necessary information.

The IPIECA Good Practice Guide on oiled shoreline assessment surveys (IPIECA-IOGP, 2014c) deals with the subject in detail, and readers may wish to refer to that publication for further information. The terms used throughout the following sections to describe the level and character of shoreline oiling have been taken from the SCAT Good Practice Guide.

Net environmental benefit analysis (NEBA) and the selection of clean-up techniques

A number of factors are drawn together in the assessment of the net environmental benefit of using a particular clean-up technique, including: shoreline type, for example, whether it is mud, sand or rock; how exposed it is; its environmental and social sensitivity and related seasonality; and the amount, persistence, toxicity and rate of natural removal of the spilled oil.

Readers are advised to refer to the IPIECA-IOGP Good Practice Guide on net environmental benefit analysis (IPIECA-IOGP, 2014d) for a full discussion of the methodologies involved in NEBA. In essence, the process leads to an evaluation of available clean-up options to ensure that the selected techniques offer an appreciable environmental and/or economic benefit compared with doing nothing, that is, relying on natural recovery, while at the same time not causing more harm than the oil itself. The process also calls for conflicting factors to be weighed against each other to achieve the best possible compromise. This often involves finding a balance between the conflicting demands for mitigating environmental versus socio-economic impacts. Typical examples include decisions to use aggressive cleaning techniques such as hot water/high pressure washing, or the use of dispersant or other chemical agents nearshore or on the shoreline itself. The trade-off being made is that the risk of localized environmental damage, which may result from the use of such techniques, is offset against the benefit of rapid and effective clean-up.

The assessment itself is usually based on qualitative or semi-quantitative judgment reached by taking all relevant factors into account. The key elements are:

- i) an even-handed review of the ecological importance of the natural resources within the area affected by the spill, and the human uses supported by these resources (also referred to as the environmental and socioeconomic services);
- ii) a full understanding of the fate and effects of the spilled oil together with a clear appreciation of the limitations, advantages and disadvantages of a proposed clean-up technique; and

iii) on the basis of past experience and current knowledge, an assessment of the expected outcome of the proposed clean-up technique compared with the natural processes of oil removal, and consideration of whether any clean-up operation may cause more harm than good.

Although the acronym NEBA is widely used, it may be slightly misleading on two counts. First, net environmental benefit *analysis* suggests a formal quantitative evaluation whereas, more often than not, NEBA involves qualitative judgements in which the different environmental and economic factors to be considered are weighed according to their significance for the affected area; a pragmatic decision should be reached on the basis of balanced argument. In any event, the process should be proportionate to the scale of the impact and preferably, much of the required debate would have taken place during contingency planning, well in advance of any spill. Second, as indicated previously, the *environmental* aspect of the NEBA terminology incorporates the benefit of clean-up to both the environment and the economic use of the affected shoreline. However, given that shoreline clean-up is most often driven by human use, both commercial and amenity, it is important to emphasize that these socio-economic (and political) demands need to be balanced against the environmental impact of the selected clean-up technique.

While it might seem logical that operations to remove oil would reduce environmental damage, a review¹ of post-oiling recovery rates for shoreline types including rocky shores and saltmarshes found that clean-up did not provide any significant benefit to the recovery of organisms living on the affected shorelines. The review suggested that, in some cases, notably sensitive wetlands, the clean-up could slow the rate of recovery.

Realistic and achievable end points

Officials representing communities that have suffered an oil spill frequently require shorelines to be returned to their pre-spill condition and that there should be no trace of oil at the end of the clean-up operation. While on the face of it this might seem a reasonable demand, in the short term it is neither achievable nor, in many cases, necessary. In terms of what is achievable, each of the techniques described in Section 3 is capable of removing a certain amount of the oil, with very few but the most aggressive able to achieve the removal of all traces of oil. The importance placed on the aesthetic appearance, relative to other factors, will determine the required end point and whether the active removal of such traces is necessary. In time, oil residues remaining on exposed surfaces will fade and are slowly removed by natural processes so that, usually within about three seasonal cycles, few traces remain. For oil incorporated into anaerobic sediments, however, the rate of oil removal can be so slow as to be measured in decades.

Shoreline clean-up is often thought of as a three-phase process, with phase one involving the collection of bulk oil, either floating against the shoreline or stranded on it, phase two involving removal or in-situ treatment of shoreline substrates subject to moderate to heavy contamination such as polluted sand or shingle², and phase three involving removal of the remaining residues of

¹ Sell, D. *et al.*, 1995.

² The term 'shingle' is used throughout this document to mean gravel or mixed and coarse sediment shorelines comprising any combination of sand, granules, pebbles and cobbles (see Table 2).

Table 1 *Operational phases of shoreline clean-up*

Phase one	Gross contamination removal—recovery of oil floating against the shoreline and bulk, pooled oil ashore
Phase two	Removal of moderate to heavy contamination—collection of stranded oil and removal or in-situ treatment of oiled substrate
Phase three	Final treatment or polishing—treatment of lightly contaminated sediments and removal of oil residues and stains.

oil to complete the clean-up (final polish)—see Table 1. The first phase is often thought of as the *emergency phase* because of the urgency of collecting oil before it has the chance to move elsewhere, whereas phases two and three are often referred to as the *project phase* when there is usually less time pressure and the opportunity to plan operations more thoroughly.

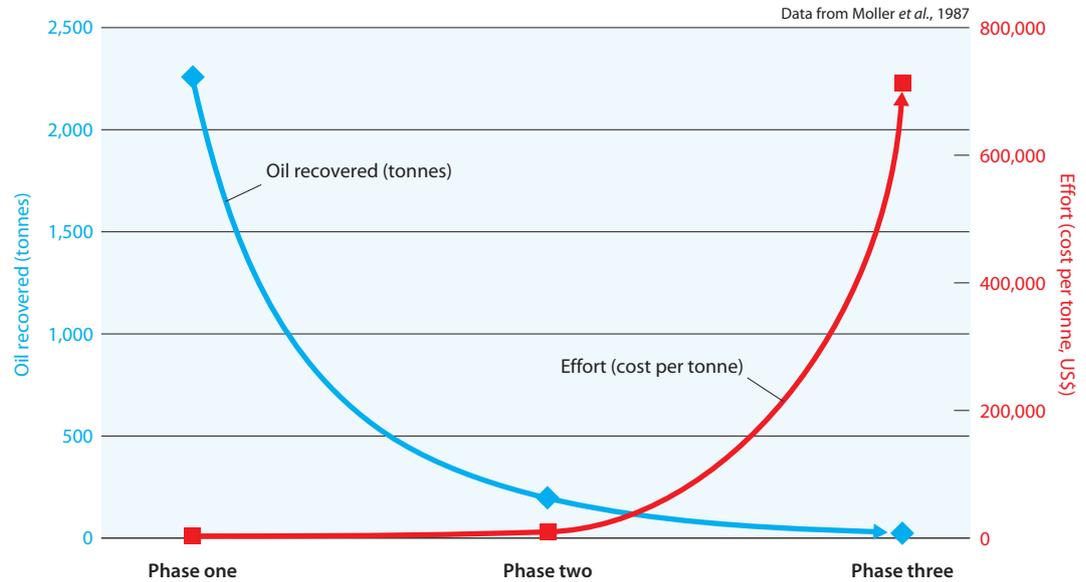
The different public, commercial and environmental ‘uses’ that a particular shoreline segment supports call for different end points to be achieved. For example, an exposed and remote rocky shoreline with difficult access would demand quite a different end point to an amenity beach during or just before the tourist season.

Natural cleaning processes, especially exposure to the full force of the sea, may mean that clean-up beyond removal of mobile oil (phase one) is unnecessary and is potentially a waste of resources. Clearly, in the case of the amenity beach, all three clean-up phases would need to be completed. A key factor in deciding when the operations should be terminated and whether they should proceed through all three phases is the outcome of the NEBA assessment made at each phase.

An interim end point is sometimes appropriate. In temperate climates with winter storms approaching, work might be stopped to allow the opportunity for natural cleaning to take place over the winter with a check made in the spring to see whether any further clean-up is necessary. In tropical climates, the typhoon or hurricane seasons may similarly provide a break point for cleaning operations.

This type of approach is particularly relevant when it is recognized that, as the amount of oil remaining diminishes, the effort required to remove this residue becomes ever greater (see Figure 2 on page 12). Typically, just 10–20% of the overall clean-up effort is expended to remove 90% of recoverable oil whereas the last 10% can involve the remaining 80% of the effort, depending on the end point being sought. At some point, the effort required outweighs the benefit of any further work. The point at which this happens is different for different shoreline types. In general, it is easier to bring sand beaches to a higher standard of cleanliness than shingle or cobble shores. Similarly, different oil types lead to greater or lesser difficulty, with heavy fuel oils generally being more difficult to clean up than spills of crude or lighter oils due to the greater persistence of heavy fuel oil.

Figure 2 Diminishing returns—an example of clean-up costs for a spill in the Far East



In summary, five broad questions can be asked to help decide whether further clean-up is necessary:

1. Is the remaining oil a potential source of harm to environmentally sensitive resources?
2. Would further cleaning do more harm than good?
3. Does the oil interfere with the aesthetic appeal or recreational use of the shoreline?
4. Does the residual level of contamination adversely affect economic resources or disrupt economic activities?
5. Does the effort involved in further cleaning outweigh the environmental or economic benefits that could be delivered?

Weather and tides

The expression, *'Time and tide wait for no man'* is particularly true for work on shorelines. There are clear safety concerns that need to be borne in mind when working on tidal shorelines. Working patterns will also need to be considered, both as an important part of these concerns as well as for practical reasons. Although contracted hours might be based on a normal working day, tides do not follow the same regime. Under certain tidal conditions, some shorelines will be inaccessible and it will be necessary for working hours to be adjusted according to the tides. In some cases stranded oil may be submerged at mid- to high tide levels, making it inaccessible to clean-up crews. In addition, monthly and seasonal tidal variations will need to be taken into account when organizing the temporary storage of waste, usually at the top of a beach, and also when considering current strengths for boom deployment. Storm conditions combined with a high tide can bring water levels to extreme heights, particularly at the equinox in March and September. Oil stranded above normal high water is often released during the equinoxes, so it is advisable to be alert to the potential for oil redistribution during these periods.

If work on the shoreline is called for in conditions of extreme heat or cold, or even heavy rain, work periods will also need to be adjusted to ensure the well-being of the workforce. The appropriate personal protective equipment (PPE) and clothing suited to the prevailing weather should also be made available. The effect of high temperatures on the behaviour of stranded oil also has to be taken into account; this may lead to work being conducted at cooler times of the day. For example, viscous water-in-oil emulsions can break up in the heat and release liquid oil. Semi-solid tar balls can also lose consistency in higher temperatures, impairing the efficiency of beach-cleaning machines that rely on sieving sand to remove tar balls.

Separation of 'hot' (dirty) and 'cold' (clean or treated) zones

The implementation of 'hot', 'warm' and 'cold' contamination zones at each worksite helps to avoid the unnecessary spread of secondary contamination, i.e. contamination of clean areas where decontamination facilities are not provided, most often due to oil being transferred to these areas via the uncontrolled movement of equipment, vehicles and personnel. The number of vehicles moving within the oiled zone should be limited in order to minimize the amount of oil forced into the sediment, and their movement restricted to these 'hot' zones. Such measures and the restriction of vehicles carrying oily waste from entering the 'cold' zones will help to avoid the spread of oil onto roads and to minimize the amount of waste material that is generated.

Decontamination stations can be set up for personnel leaving the oiled section of the beach, and may also be required when moving oiled equipment and machinery from one worksite to another or removing it at the close of operations. Arrangements for controlling the run-off from these 'wash-down' areas will also need to be carefully considered to avoid the spread of contamination.

The designation of temporary waste storage sites in the planning process should include surveys of prospective sites, with a clear notion of the mechanisms to be put in place to avoid these also becoming sources of secondary contamination. Apart from physical controls, such mechanisms might incorporate the appointment of operations personnel specifically to implement and enforce these arrangements.

Waste management, minimization and segregation

Waste management, transport and disposal often constitute the largest component of the overall cost of responding to a major incident. An analysis of the amounts of waste being generated is also a useful indicator of how well the operation is being conducted. Following a major spill, a massive quantity of waste, often as much as ten times the volume of oil spilled, is generated in a very short time. This will almost certainly overwhelm the capacity of existing disposal routes since they will be geared only for the much smaller amounts of waste that are typically generated by routine local industrial and municipal activities. In practice, the number of workable disposal options is likely to be limited and, in some jurisdictions, waste with relatively high oil content may be treated as a hazardous material calling for more specialized treatment. As a result, waste disposal can become a bottleneck in the clean-up operation, sometimes delaying work on the shoreline until suitable options for storing and disposing of collected waste can be arranged. One of the most important elements of contingency planning is the identification of viable waste

disposal routes or, as a minimum, temporary storage sites. In some situations, the excessive removal of beach material can lead to destabilization of the shoreline and subsequent enhanced levels of erosion. In recognition of these difficulties, attention to waste generation and minimization is strongly advocated throughout this Good Practice Guide.

As previously noted, one way to achieve waste minimization is to avoid the use of heavy equipment on shorelines and to rely, as far as possible, on manual collection whenever practical. On sand beaches, mechanical methods typically generate five times as much waste for the same amount of oil collected by manual methods. Put another way, the oil content of manually collected contaminated sand is, on average, 5–10% oil while for mechanically collected waste the oil content is only 1–2%. It is accepted, however, that it may not be practical to consider manual clean-up for long segments of heavily oiled beaches. The amount of waste generated can also be significantly reduced by the use of techniques that avoid the removal of shoreline substrates, such as surf washing or tilling with a harrow or plough. Waste generation is a crucial factor in the application of NEBA in deciding on the most suitable clean-up techniques.

Another frequently offered recommendation is that responders should ensure that waste is segregated at the source into different waste streams so that different waste options can be adopted for each stream. For example, liquid waste may follow one route, highly contaminated oily sand another, and other oily debris, including oiled PPE, might follow a third route. This waste segregation has the benefit of reducing the amount of material that may need to be disposed of as hazardous waste and easing the load on facilities of restricted capacity. However, there is no benefit in separating waste into different streams if there is only one disposal route and if all the waste ends up in the same place. Even in this latter situation, there may be some treatment options worth considering, for example, avoiding the unnecessary transport of excess water by decanting on site or compressing sorbent materials prior to transport so that the bulk volume is reduced. Depending on local regulations, it may be possible to allow the water released to return to the spill site, or arrangements may be required for its subsequent treatment.

For further guidance on this topic see the IPIECA-IOGP Good Practice Guide on oil spill waste minimization and management (IPIECA-IOGP, 2014e).

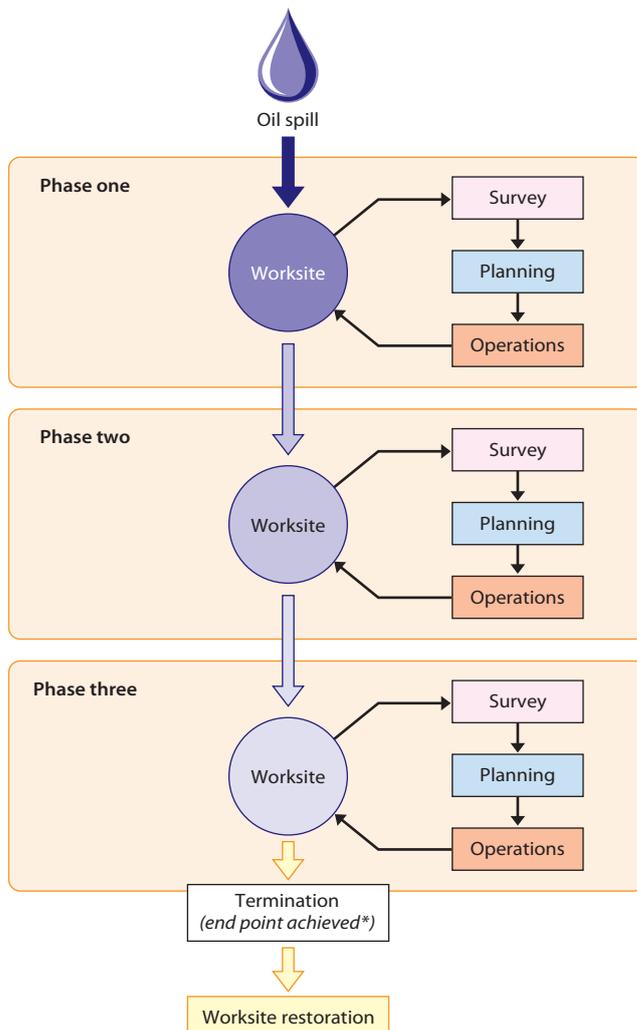
Section 2: Steps in the management of shoreline clean-up

Although clean-up operations can be considered in terms of the three phases described on pages 10–11, the following four steps in the management of shoreline clean-up can be recognized:

- **surveillance and monitoring:** evaluation of the scale of operations required;
- **planning:** setting the parameters of the operations including establishing end-point criteria;
- **operations:** implementing clean-up operations; and
- **termination:** bringing operations to a close at the agreed end points.

In the simplest terms: the *surveillance and monitoring* function identifies what work needs to be carried out; technical advice on how best to conduct that work informs decisions taken at the *planning* step; and the *operational* function implements that advice to get the work done. As the work proceeds, each step forms part of a continuous cycle: evaluating the progress made; adjusting the technical advice in recognition of the changing situation; and modifying operational procedures accordingly until the agreed end points have been reached and operations are brought to a close (Figure 3).

Figure 3 Shoreline clean-up management cycle



* Depending on the agreed end point, operations may be terminated on completion of phases one, two or three

Surveillance and monitoring

Key elements of surveillance and monitoring include: aerial surveys; shoreline survey and monitoring (SCAT) teams; reporting protocols.

Unless the source and extent of pollution is immediately obvious, for example where a spill is contained within a port, one of the first response actions following a spill is to conduct an aerial survey. Its purpose is to gather information on the nature of the incident, the extent of the pollution and the likely immediate consequences. Aerial surveillance provides a rapid initial assessment of the probable scope and scale of the required response.

Once oil reaches the shoreline, helicopters provide the most flexible platform for observations, having better manoeuvrability than fixed-wing aircraft and, depending on local regulations, offering the possibility of landing on the shoreline to make detailed inspections. These initial surveys provide information on the distribution of oil along the shoreline, and on which areas have been most heavily impacted. They also enable the identification of environmental resources already affected and those under threat, as well as potential access routes to affected shorelines. These data are used to inform more detailed surveys (i.e. SCAT) to be undertaken on foot or by boat. It is essential to 'ground truth' any observations made from the air, i.e. to visually verify the results of those surveys by carrying out subsequent surveys on the ground. Some features, for example mineral deposits, algae and peat outcrops, can easily be mistaken for oil because of their appearance when viewed from the air. Most importantly, it is not possible to get a reliable estimate of the thickness of stranded oil from aerial observations. In addition, on sand beaches, stranded oil may be covered by a layer of windblown sand or by sand accreted on subsequent tides. On shingle and cobble beaches, the oil is likely to have penetrated into the substrate, and without surveys on the ground it is impossible to know how far this penetration extends. Similarly, the depth of oil pooled on rocky shores can only be determined by close inspection.

The requirement to keep one or more helicopters on-site once surveys on the ground are under way and clean-up operations have started depends on the circumstances of the incident. If the geographical extent of pollution and distribution of stranded oil is likely to change over time, due to more oil coming ashore or mobile oil moving along the shoreline, helicopters may continue to be required. Aerial transport of shoreline survey and monitoring (SCAT) teams to more remote locations that are inaccessible by road vehicles may also need to be considered.

The composition of the SCAT teams are important. Typically such groups would be led by a technical specialist well versed in shoreline clean-up, coastal geology and survey protocols, and also include representatives of the jurisdictional authorities and affected communities. Having taken all the relevant factors into account, final decisions on how best to respond will be taken by the spill management team, but the SCAT team should nevertheless be sufficiently competent to make reliable operational recommendations so that clean-up operations can begin as quickly as possible. To a large extent the observations reported by these teams determine the course of the shoreline response, and the entire response organization relies heavily on their recommendations.

In some response organizations the responsibility of the survey team is restricted to reporting the distribution of oil and levels of oiling, and on the basis of this report a second team is deployed to propose optimum clean-up techniques. The disadvantage of this approach in a situation that is in constant flux is that it introduces delays at each stage, and by the time the second group have made their recommendations and the required personnel and equipment are deployed, the situation may have changed considerably.

The number of SCAT team members should be limited. If a group becomes too large, it will not only face challenges with regard to transport logistics but will also find it increasingly difficult to reach a consensus. However, in an incident covering a large geographical area, multiple SCAT teams may need to be deployed. To ensure consistency between teams and between consecutive surveys, the importance of standardized reporting protocols cannot be overemphasized. Standardized descriptions of shoreline characteristics follow the widely established classification system known as the Environmental Sensitivity Index (ESI), which is based on vulnerability to oil pollution, with values ranging from 1–10 where 1 is robust and resilient and 10 represents the most vulnerable (Figure 4).

Figure 4 *The Environmental Sensitivity Index*



Standardized shoreline descriptions also include the average substrate dimension (grain size) of the affected shoreline (Table 2).

Table 2 *Shoreline descriptors*

Description	Grain size (mm)
Mud/silt/clay	0.00024–0.625
Sand	0.625–2.0
Pebbles/granules (gravel)	2.0–64
Cobbles	64–256
Boulders	>256

Source: adapted from MCA, 2007

Terms such 'light', 'moderate' and 'heavy' can be used to categorize the initial surface oil cover (factoring the oil's distribution and the width of oiling across the shore) and the same terms can also be used by factoring this initial categorization of surface oil with average oil thickness to generate an overall surface oil categorization. This is a very useful metric for the management team, when tracking shoreline oiling conditions and treatment progress on a shoreline segment-by-segment basis. The use of standard terms and definitions is described in the various SCAT guides and manuals cited in the *References* and *Further reading* sections of this guide, and are summarized in Table 3, below.

Table 3 Standard terminology for oil location, distribution, thickness and character

Location on shoreline	
Lower Intertidal Zone	Lower third of tidal range
Mid Intertidal Zone	Middle one-third
Upper intertidal Zone	Upper one-third
Supratidal Zone (Splash Zone)	Above high water mark
Distribution	
Trace	<1%
Sporadic	1–10%
Patchy	10–50%
Broken	50–90%
Continuous	90–100%
Thickness	
Thick oil	>10 mm
Cover	1–10 mm
Coat	0.1–1 mm
Stain	<0.1 mm
Film	Iridescent sheen
Stranded oil characteristics	
Fresh	Un-weathered oil
Mousse	Water-in-oil emulsion
Tar balls	Discrete pieces (balls) of weathered oil generally, dimension <100 mm
Tar patties	Weathered oil, dimension >100 mm
Tar	Highly weathered 'coat' or 'cover'
Surface oil residue	Mobile oil and sediment mixtures on surface or within interstices
Asphalt pavement	Stable mixture oil and sediment (generally shingle)
No oil observed	No visible oil

Planning

Key planning elements include: the use of SCAT data and sensitivity maps; setting priorities; matching clean-up techniques to shoreline types and degree of pollution; segmentation and end point selection.

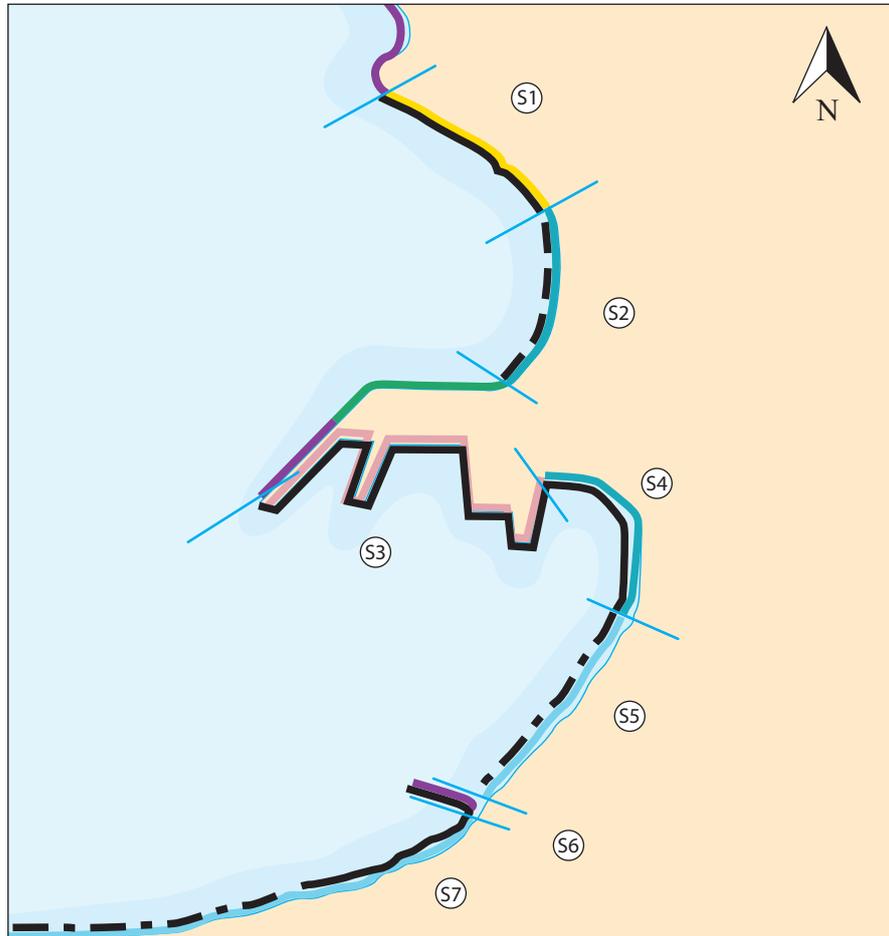
One of the products of the contingency planning process in locations where detailed response arrangements have been put in place is likely to be sensitivity maps, which highlight, among other things, areas of particular environmental vulnerability or socio-economic importance. The information collated and presented in sensitivity maps, together with the information from the initial SCAT surveys on the levels of oiling, oil distribution and characteristics, provide the basis for setting the priorities for shoreline clean-up. Accumulations of fresh oil which may mobilize and move to previously unoiled areas or to areas of greater vulnerability are usually the priority target. Once the risk of further movement of the oil has passed, the ranking of areas for priority clean-up operations is based on a balance between those most heavily polluted and an area's importance or vulnerability as indicated by sensitivity maps. Sensitivity mapping for oil spill response is the subject of a Good Practice Guide of the same title (IPIECA-IMO-IOPG, 2012).

By maintaining the same composition of the SCAT team throughout the response, the same people that recommended the use of a particular clean-up technique are able to monitor its implementation and, if necessary, adapt their recommendations accordingly. SCAT team members will then be well-placed to judge whether the desired end point has been reached, as they will have a clear appreciation of the condition of the shoreline at the start of the operation and the level of cleanliness that can realistically be achieved by the end of it.

Typical applications for individual clean-up techniques, their suitability for use on particular shoreline types and an analysis of when each technique might be used to best effect during the response operation, are discussed in more detail in Section 3. In order to manage operations effectively, the affected shoreline is divided into workable segments within which the shoreline type or level of oiling is more or less uniform and the boundaries are easily identifiable. Segment boundaries are usually identified by a change in shoreline type but may also rely on a natural feature such as a river or stream, or a specific landmark such as a conspicuous building or access point. Segment boundaries may also be defined by a significant change in oil conditions (e.g. from moderate oiling to no oiling) The purpose of dividing the shoreline into segments is to facilitate the management of clean-up operations by allocating worksites according to shoreline type or oiling conditions, matched with clean-up techniques, and to assign specific end points to each segment (see Figure 5 on page 20).

It is important that the end points for clean-up phases two or three are determined for each shoreline segment at the outset of shoreline operations when planning the response, taking into account the outcome of NEBA assessments. Since different clean-up techniques achieve different end points, the choice of end point strongly influences the clean-up technique to be used on each shoreline segment. Not only do the assigned end points provide clean-up teams with a clear idea of the level of cleanliness that they are aiming to achieve, they also help to moderate expectations of what the clean-up operations can accomplish.

Figure 5 Example segmentation of an oiled shoreline



Segment	ESI (see Figure 4)	Oiling (see Table 3)
S1	8A Sheltered rocky shore	Heavy, continuous, thick, without emulsion (mousse)
S2	3A Fine to medium-grained sand beach	Moderate, broken, thick, mousse
S3	8B Sheltered, solid man-made structures	Heavy, continuous, cover, mousse
S4	3A Fine to medium-grained sand beach	Heavy, continuous, thick, mousse
S5	4 Coarse-grained sand beach	Moderate, patchy, cover, mousse
S6	1B Exposed solid man-made structure	Heavy, continuous, cover, mousse
S7	4 Coarse-grained sand beach	Heavy continuous thick mousse in north of segment reducing to moderate patchy cover in south

Consistent descriptors must be used to ensure a clear understanding of when the end point has been reached. These descriptions are the same as those used to express the level of contamination during the initial SCAT surveys but with emphasis on the use of the semi-quantitative criteria for oil distribution as illustrated in Table 4. Additional descriptions are sometimes used, particularly for the end point for recreational sand beaches, such as, *'no buried oil, no greasy texture, no sheen and no oily smell'*. Iridescent, silver or colourless oil films or sheens floating at the water's edge are commonly associated with oiled shorelines but represent very small amounts of oil due their extremely low film thickness. For weathered stains or films on amenity rocky shores *'oil that does not rub off on clothing'* might also be considered as a test for a possible end point.

Table 4 Illustrative examples of possible end points

Shoreline type	Example proposed end point
Concrete sea defences	Patchy oil cover to continuous coat. No mobile oil released during natural flushing (some sheening acceptable)
River bank vegetation	Patchy oil cover—no mobile oil released during natural flushing (sheening acceptable)
Mudflats	Sporadic surface oil residue
Recreational sand beach	No visible oil, no buried oil, no greasy texture, no sheen and no oily smell
Publically accessible rocky cove and cobble beach	Patchy tar coat for rock outcrops (not to rub off on clothing); sporadic surface oil residue for cobbles (oil in interstices)—warning signs to be erected.

When taken together with the terminology set out in Table 3 (page 18), the end points suggested above are semi-quantitative observations that can be easily interpreted in practical terms. On occasion, an end point may be proposed that involves proceeding with the clean-up until oil concentrations in the beach sediment decline to a specified level, and some local regulations may require that such criteria are met before reopening a beach for bathing or recreational use (cf. Blue Flag criteria below). However, there are considerable difficulties with this approach, not least that of estimating when a specified oil concentration level has been achieved in practice during clean-up operations to address environmental impacts or impairment of amenity use of the shoreline. Furthermore, because of the extreme variation in the distribution of oil through the sediment, it is particularly difficult to take representative samples, and the approach is open to unintentional bias through the selection of samples of more heavily contaminated sediment.

For bathing beaches, the Blue Flag criteria are widely accepted internationally. The Blue Flag is a voluntary label awarded to more than 3,850 beaches and marinas in 48 countries across Europe, South Africa, Morocco, Tunisia, New Zealand, Brazil, Canada and the Caribbean. The required level of cleanliness is measured against a range of different parameters which, for oil pollution, are:

1. There must be no oil film visible on the surface of the water and no odour detected. On land the beach must be monitored for oil, and emergency plans should include the required action to be taken in case of such pollution.
2. There has to be an absence of floatables such as tarry residues, wood, plastic articles, bottles, containers, glass or any other substance.

In Europe, bathing beaches are also subject to the provisions of the European Community Bathing Waters Directive (2006/7/EC) which is primarily concerned with routine monitoring of potential pollutants including oil.

Operations

Key operational elements include: worksite delineation; risk assessment and management; work programme; volunteer management; reporting and briefing schedules.

With priorities established and segments identified, worksites within each segment can be set up. A worksite might comprise the entire segment, or the segment may be further subdivided according to the clean-up technique to be applied, the access required for equipment and the nature of the group working on the shoreline. Individual worksites tend to be allocated to a single organization or agency, a team from within that organization or agency, or an individual contractor, so that the scope of work is clearly defined both geographically and in terms of the end point to be delivered. For example, a segment may include a length of shoreline comprised of a sand beach interspersed by rock-armour groynes; the manual cleaning of the sand beach might constitute one worksite and the groynes, which are to be cleaned using high-pressure washing, constitute another.

Before work can begin, a risk assessment should be conducted for each worksite. This should identify the particular hazards associated with the location (such as strong waves, rock falls, slippery rock surfaces, the effects of heat or cold), together with the types of equipment to be used or likely to be moving around on the shoreline, and the types of materials to be used, especially if these include chemicals. Such risks can be managed through daily safety briefings to ensure that personnel are aware of the hazards associated with the environment in which they are working. Examples of ways to manage risks include: ensuring that workers take regular rest periods; taping off areas to segregate vehicular traffic from manual clean-up crews; ensuring that the correct PPE is worn; and briefing workers on the use of each specific type of chemical that may be utilized. It is important to ensure that personnel do not carry oil into clean zones (e.g. rest areas) as this would present the risk of skin contact with the oil or of the oil being ingested with food and drink. Decontamination zones should be arranged at the worksite access points to allow workers to remove contaminated PPE before entering the clean zones. Further advice on oil spill responder health and safety can be found in the IPIECA-IOGP Good Practice Guide on this topic (IPIECA-IOGP, 2012).

For each clean-up technique there is an optimum team size, and worksites can be subdivided accordingly, for example to match the anticipated work rate of the team. This tactic promotes a methodical approach so that a shoreline is cleaned along its length at a rate of so many metres per day, thereby allowing progress to be easily monitored, and facilitating planning and logistics for the following days. It avoids the random movement of workers over the shoreline and the risk of secondary pollution resulting from oil being walked into clean areas. In addition it helps to ensure that cleaning is consistent along the length of shoreline and that no areas are missed.

The example in Box 1 illustrates the use of simple estimates in initial planning. For example, if only front-end loaders (FELs) are utilized and each has a capacity of 2 m³, 150 m³ of oily waste

Box 1 *Example of initial planning considerations with regard to the optimum size of a clean-up workforce*

In the initial planning of the size of the workforce, the rules of thumb described in Section 1 can be drawn upon. By way of illustration, a sand beach 2 kilometres long has been identified as a priority clean-up site and the SCAT team reports stranded fresh oil, with patchy cover over a band averaging 5 metres wide. This leads to the following estimate the amount of oil present:

$$2,000 \text{ m} \times 5 \text{ m} \times \frac{5}{1000} \text{ m (cover = 1–10 mm thickness)} \times 30\% \text{ (patchy = 10–50\%)}$$

or $\sim 15 \text{ m}^3$ of oil.

From experience it has been found that, over the duration of an incident, manual recovery leads to a concentration of 5–10% oil in collected waste. However, in the early stages of a clean-up operation (as in the scenario above) the selectivity of manual recovery should result in oil concentrations at the upper end of this range or higher. Together, the oil and sand might then amount to some 150 m^3 oily waste material to be collected. For planning purposes, given the expectation that each person could collect some $1\text{--}2 \text{ m}^3$ per day, this represents some 75–150 man days. Five teams of ten with two front-end loaders (to transport collected material off the beach) should be sufficient to collect this material in two to three days, depending upon the distribution of oil, the characteristics of the beach and the distance to temporary storage.

represents more than 75 (say 80) FEL movements. With two machines over two days, each machine must make 20 movements per day. In an eight-hour day, that equates to a movement every 24 minutes or so. Depending on the configuration of the worksite, such an estimate can assist in deciding on the appropriate number of machines. Theoretically, 100 clean-up workers deployed in 10 teams would be able to clear the beach more quickly, but (a) the coordination of 10 teams is more difficult than five, (b) more front-end loaders would be required and (c) the size of the working space would also need to be considered—in this case each of the 100 workers would be occupying a stretch of sand beach just 20 metres long. (This working space requirement is a particularly important consideration for mechanical collection with heavy machinery and also where high-pressure washing is to be used.)

The optimum number of workers in a manual clean-up team is usually found to be about 10, headed up by a team leader. This size of team can be replicated a number of times with team leaders reporting to a worksite supervisor or beachmaster. As shoreline operations progress and the tasks become more routine, the number of workers each team leader can manage effectively may increase to a worker:team-leader ratio higher than the initial planning levels of 10:1. For high-pressure washing, smaller teams comprising two or three personnel are required to operate the equipment, with the work of each team coordinated by a worksite supervisor. As for manual clean-up, it is useful to delineate the working area for each team to promote a methodical approach.

In general, it is more efficient to start with a smaller number of teams, properly set up the worksite with logistics support in place, and monitor the progress of the deployed teams. A reassessment of what further work is required can then be made and a decision taken on whether changes in the numbers of personnel are merited, either up or down.

Whether professionally employed clean-up workers or volunteers are deployed, the same considerations apply, although the productivity of volunteers is likely to be lower due to

inexperience and lack of training. Professional clean-up workers are generally easier to manage because they are more disciplined, follow instructions and remain committed throughout the response; volunteers, on the other hand, do not have the same incentive and may try to follow their own imperatives. Given these and other issues, such as the need to provide transport, accommodation, food and additional emergency medical cover, management teams may prefer not to use volunteers, and avoid the potential liability should a volunteer become injured while working on the spill. Nevertheless, the extensive media coverage that accompanies any major spill often attracts large numbers of volunteers into the affected area. Consequently, political pressures are likely to result in a need for volunteers to be integrated into the response effort. Careful management of these issues is needed so that the well-meaning intentions of the volunteers are put to good use and that their inclusion in the response does not disrupt the clean-up operation.

It is therefore essential that the volunteer contribution is controlled from the start by managing the influx of volunteers, which can be best achieved by requiring volunteers to register with the response organization (see the example volunteer registration form in Appendix 1 on page 63). Registration also offers the opportunity to assess whether volunteers have any particular skills that can be utilized, such as medical, veterinary or logistics expertise, or whether basic training is required. Unskilled volunteers will need operational and safety training so that they can be used effectively and are aware of the safety issues involved in working on the shoreline. Ideally, unskilled volunteers would not be put to work until phase two of the clean-up operation, after bulk oil has been removed. Volunteers may also be used in many other positions, such as logistics support for volunteers, arranging food and accommodation or, if suitably skilled, assisting with administrative tasks within the response organization.

A clear chain of command is of paramount importance for the proper supervision of all personnel working on the shoreline, particularly in the case of volunteers, to avoid conflicting instructions and any ambiguity about who is in charge of assigning tasks. Worksite supervisors should make sure that volunteers remain motivated and focused on allotted tasks, and should ensure their safety, whether they operate as a separate workforce or within teams of professional workers. Daily records of the worksites attended by each individual and of the work undertaken should be maintained.

Professional workers and volunteers alike should be required to attend briefings at the beginning and end of each working day. The morning briefings include a site-specific safety briefing, details of procedures to be followed in case of an accident, an overview of the work to be undertaken during the day and individually allotted tasks within the worksite. The evening meeting reviews the day's progress, allows any problems that have arisen to be discussed and suggestions for improvements to working practices to be considered. The site supervisor can then report progress and any logistics issues to the management team so that personnel, equipment, materials, evacuation of waste and logistics support can be organized for the following days (see Appendix 2 on page 64).

Termination

Key elements include: closing worksites; restoration.

In order for worksites to be closed there should be consensus that the agreed end points have been reached so that cleaning operations can cease. The final phase of terminating shoreline clean-up is the restoration of worksites. Each site is inspected to ensure that any rubbish which accumulated during the work, such as food wrappers, discarded PPE, plastic bags, etc., are collected and disposed of appropriately and that, as far as possible, temporary storage sites and access points are returned to a pre-spill state. This may mean levelling, re-seeding or replanting where worksite traffic has impacted vegetation, reinstating habitats where access roads have been constructed or undertaking remedial works to the local road network to repair any damage caused by heavy vehicles.

Section 3: Shoreline clean-up techniques

Defensive/passive clean-up techniques

Debris removal

One of the most effective ways to minimize both the effort required to clean a shoreline and the amount of oily waste for disposal is to remove debris from the shoreline or out of the path of the spill before the oil arrives and so avoid the debris becoming contaminated. This may be general flotsam and jetsam that has accumulated in natural collection points, seaweed thrown up by winter storms, or even tree trunks. However, in some situations large natural debris stabilizes the shoreline and its large-scale removal could lead to erosion. Furthermore, stranded seaweed provides a valuable source of nutrients to littoral ecosystems. To take account of both these concerns, an assessment of net environmental benefit should be conducted to determine whether, on balance, removal would be the best option.

The areas where oil is most likely to strand are usually the same natural collection points where debris accumulates. These should be highlighted as priority areas for pre-stranding debris removal (also referred to as pre-impact debris removal). Aerial observations of the movement of oil and trajectory modelling can also provide some forewarning of where there is an imminent threat of oil stranding. Given enough time, clearing beach debris prior to it becoming oiled may also allow the collected waste to be disposed of at non-hazardous waste processing facilities, depending on local regulations.

Below: shoreline before and after pre-impact debris removal



Source: ITOFF



Source: ITOFF

Passive cleaning—‘natural cleaning’

Although the term ‘passive cleaning’ is sometimes used to describe placement of sorbent arrays to collect oil leaching from shorelines, the most commonly used passive cleaning technique is ‘natural cleaning’. Once mobile oil has either been recovered or has remobilized elsewhere, the primary processes that lead to the natural removal of oil remaining on the shoreline are biodegradation, photo-oxidation, abrasion, oil-mineral aggregation (also referred to as clay-oil flocculation) and dispersion. Biodegradation and photo-oxidation usually proceed relatively slowly in terms of removal of oil from shorelines, and the most significant short-term processes are abrasion, the formation of oil/mineral aggregates (OMAs) and their dispersion through the water column. Abrasion is the mechanical scraping of a surface by pebbles and sand particles carried by waves breaking on the shoreline. OMAs are formed by the interaction of dispersed oil droplets and small mineral particulates to form neutrally buoyant agglomerates which disperse over a wide area and are eventually either accommodated within the sediment and/or broken down through biodegradation.

Typical applications

- Exposed rocky headlands, and shorelines exposed to wave action but where access is difficult or dangerous or where amenity, recreational or aesthetic value is not of primary importance.
- Wetlands where an assessment of the risks to the habitat from clean-up operations (for example damage to plant roots and compression of fragile substrate by trampling) points to a lower risk of damage if the oil is left for removal by natural cleaning processes and degradation.

Method outline

- Establish transects along the shorelines that are periodically monitored to assess the rate of natural oil removal.
- For rocky exposed shorelines, monitor the effect of wind, waves and weather.
- For wetlands, monitor the impact of oil and subsequent recovery in case intervention is called for, e.g. if the seasonal arrival of birds or other animals is anticipated.

Timing

Passive or natural cleaning is typically applicable to lightly oiled shorelines or during phases two and three of the clean-up operation (see Table 1).

On rocky shores a black residual coating of oil will weather and degrade naturally over time, fading to a stain, and over two or three seasonal cycles will become less and less visible. In wetlands, depending on the characteristics of the oil, it may become incorporated into the sediment and degrade only very slowly.

Advantages and disadvantages

- ✓ Relies on natural cleaning processes.
- ✓ Very low labour and equipment requirements.
- ✓ Low biological impact on rocky shores whereas impact variable for wetlands.
- ✗ Requires removal of bulk mobile oil or risks its release and movement elsewhere.
- ✗ Potential for residual oil to create chronic biological impacts.

CASE STUDY 1: Example of defensive techniques to minimize damage from an oil release

Sergo Zakariadze, San Juan, Puerto Rico, 1999

In November 1999 the cement carrier *Sergo Zakariadze* stranded at the foot of the historic fort, El Morro, at the entrance to San Juan harbour. Spill contingency arrangements were put in place while salvage operations were conducted, which included an example of a defensive technique that involved wrapping the target in polythene sheeting or geotextile materials. This approach was used to protect another historic fort, El Cañuelo, part of a UNESCO recognized cultural heritage site, which was at risk from a spill of bunker fuel from the casualty stranded directly up wind. If oil had been lost from the vessel, windblown oil, thrown up by waves breaking on the adjacent shoreline, could have led to severe staining of the weathered sandstone walls of the fort. Experience from a similar previous incident had shown that removal of the oil stain would have called for aggressive cleaning techniques, risking damage to the fabric of the historic monument. Polythene sheeting was laid in vertical strips around the sections of the building facing the sea and held in place with sand bags, top and bottom.



Left: one of the forts of Old San Juan, a National Historic Site overseen by the US National Parks Service, part of the US Department of the Interior.

Source: ITOPF

Bioremediation

All shorelines possess naturally occurring oil-degrading microorganisms and these play a significant role in the longer-term removal of oil. The rate of natural biodegradation, whereby oil is ultimately converted to carbon dioxide and water, can vary from days to years and depends upon various factors including the:

- type and quantity of oil;
- shoreline type;
- availability of nutrients and oxygen;
- degree of water flushing through tidal or wave action; and
- climate and seasonal weather factors.

Bioremediation is not strictly a passive technique, but is introduced here because, in principle, it is an extension of natural cleaning through the enhancement of natural biodegradation.

Nutrients including nitrogen, phosphate, and iron are essential to any biological process and crude oils are naturally deficient in these major nutrients. Furthermore many, though not all, marine ecosystems are naturally nutrient-poor. Thus, when an oil spill results in a sudden increase in available food (oil hydrocarbons), there may not be enough nutrients in the water to support microbial growth. Nutrient addition ('biostimulation') to relieve this limitation may enhance biodegradation and various strategies (such as granular slow-release products) have been used on cobble and boulder shorelines to provide additional nutrients in a suitable form. Although bioremediation may accelerate the process, it is unlikely to reach the same pace as physical clean-up methods.

Microbes that can degrade oil constituents are ubiquitous and there is little convincing evidence that bioaugmentation (addition of more microbes) significantly enhances either the rate or the extent of oil biodegradation on marine shorelines.

The indigenous community of microorganisms will be adapted to the specific shoreline locality. It is the larger, more complex oil molecules that are most resistant to microbial attack, and which are likely to remain for the longest periods, though mainly as biologically inert residues.

Taking into account all the factors summarized above, it is clear that bioremediation is rarely likely to provide a practicable technique for shoreline clean-up of either bulk or moderate oiling. It is likely to be limited to clean-up phase three, if considered.

Advantages and disadvantages

- ✓ Under controlled conditions may increase the rate of biodegradation on cobble and boulder shorelines, where nutrients are limiting.
- ✓ Low environmental impact compared to other intervention techniques for clean-up phases two and three.
- ✗ Requires slow release mechanism and risk of dilution on tidal shores.
- ✗ Remains a relatively slow oil removal process.

Sorbents used in passive mode

Sorbents are either man-made or natural materials that preferentially soak-up oil rather than water. More information on sorbent types is provided under the section on the recovery of floating oil (pages 31–32).

Typical applications

- Arrays of sorbents can be used to recover oil leaching from riprap or other sea defences, or along the sea margin of mangroves and temperate wetlands.
- Sorbent nets are used to recover oil released from a number of different shoreline types ranging from coarse sand beaches to rocky shorelines.

Method outline

An array of sorbent filaments (pom poms) is tied at intervals along a rope which is anchored so that it can move freely with the tidal rise and fall, and capture oil released through the tidal cycle or by wind-driven water movement. The application works better with viscous oil, though sorbent booms can replace pom poms for lighter oils. To remain effective, sorbent materials must be changed once they become saturated with oil. Fixings need to be checked regularly to ensure that they remain secure and that net mops have not become buried by beach material.

Timing

The technique is used to recover relatively moderate volumes of mobile oil (clean-up phases two and three) and oil released from flushing or surf washing operations (see later in this section).

Suggested end point

The end point is reached when the release of oil from the shoreline subsides. If further cleaning of the shoreline is called for, alternative active techniques will need to be considered.

Advantages and disadvantages

- ✓ Relies on natural water movement.
- ✓ Low labour requirement—sorbent materials need to be exchanged when saturated.
- ✓ Low biological impact.
- ✗ End point leaves surface oil residue, cover or coat and, depending on location, further treatment may be required or the oil may be left for natural cleaning.
- ✗ Sorbents used in a passive mode do not retain low viscosity oils very well.
- ✗ Roped arrays of pom-poms deployed off wetlands can be difficult to recover if left in place for too long, as they can become entangled with vegetation.
- ✗ Spent sorbent requires proper disposal.

Active clean-up techniques

Recovery of floating oil

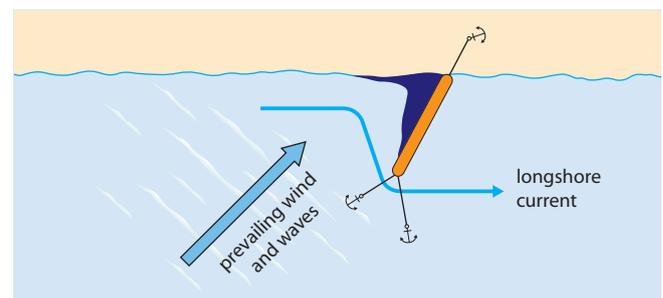
Oil stranded on shorelines can become mobile and re-float with changing tides and weather. Consideration should be given to techniques to recover such mobile oil, which is most prevalent at clean-up phases two and three.

Typical applications

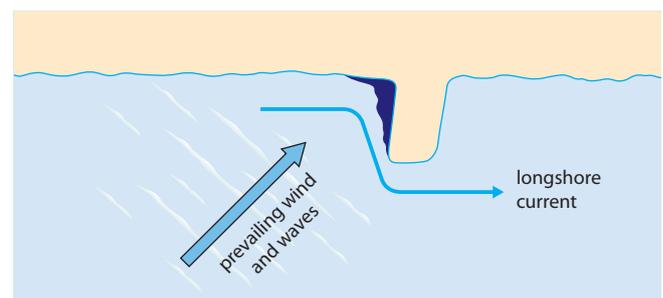
- Floating oil pressed against the shoreline by the wind or contained within a shoreline boom.
- Collection points where oil accumulates, which provide an opportunity to recover free oil using a variety of methods, for example:
 - collection points—longshore drift: classically this refers to the transport of sediment along the coast due to waves breaking obliquely on the shoreline, but a similar transport of sediment can also be caused by a longshore current. Prevailing onshore winds generate wind-driven surface currents towards the shore, but because the wind direction is rarely exactly at right angles to the coast the water is deflected along the shoreline. Spilled oil follows the longshore current, accumulating in natural collection points, where flotsam and jetsam also pile up. In the absence of natural collection points, a collection point can be created either by placing a boom projecting into the sea at an acute angle to the longshore current, or by taking beach material and building a temporary, solid promontory (Figure 6). The technique is restricted to conditions of light breezes and slight seas (i.e. wave heights between 0.5 and 1.25 metres high) since, in stronger winds and sea conditions, breaking waves are likely to interfere with the recovery of oil from collection points and may lead to booms becoming damaged.
 - collection points—beach weirs: these can be utilized on sand or shingle beaches in non-tidal waters, or where the tidal range is low and the area is subject to either prevailing onshore winds or diurnal, onshore/offshore winds. A trench is dug at the top of the beach, level with the high water mark, and when the water level rises, induced by the onshore wind, oil floating at the water's edge flows over into trench from where it can be pumped to storage. On some lower energy beaches with small tidal range it may be possible to extend the trenches into the mid-intertidal zone. It should be noted that man-made alterations to the geomorphology of the beach may have a short-term impact on active shorelines, and the net environmental benefit of such disruption needs to be fully assessed.

Figure 6 Creation of collection points on shorelines subject to longshore drift

(a) Positioning of an anchored boom



(b) Construction of a temporary solid promontory



Method outline

- Pumps: in calm waters with vehicular access to the shoreline, such as within a port or harbour, oil can be pumped directly from the containment area to temporary storage tanks or into a road tanker, vacuum truck or slurry tanker. The type of pump selected will depend on the viscosity of the oil, with positive displacement pumps required to transfer the more viscous and emulsified oils. Many vacuum and slurry tankers have a fully opening rear door to allow the discharge of highly viscous oils; if the oil is to be transferred directly to a road tanker which has no rear door, careful attention needs to be given to ensuring that the loaded oil is not too viscous to be discharged easily. Some slurry tankers rely on centrifugal pumps to fill the tank, and it important to note that these do not function well with viscous or emulsified oils. Vacuum trucks range in power, from those used to empty septic tanks to industrial vacuum vehicles that have a suction power an order of magnitude greater.

Oils with high pour points (i.e. a pour point higher than ambient or seawater temperatures) and which are therefore in a semi-solid state, or oils that are very highly emulsified and cannot be pumped, can sometimes be recovered with an excavator bucket provided there is adequate access for such machinery. Emulsified oils may stick to the inside of the bucket making it difficult to empty.

In all cases, oil transferred directly from the water surface is likely to be associated with some free water which, after being allowed to settle in the receiving tank, can be decanted. Depending on local regulations it may be possible to return the decanted water back to the sea or it may require separate treatment prior to return to the environment.

- Skimmers: in slight seas wave motion makes it difficult to pump oil directly into an open hose, though floating attachments can improve recovery. With sufficient water depth, smaller or medium-sized skimmers of various designs can be used at the water's edge to recover oil and pump it ashore. (See the Good Practice Guide on at-sea containment and recovery (IPIECA-IOGP, 2015b)). Rope mop skimmers are not restricted by water depth and can be used even in shallow waters provided an arrangement to fix the rope mop and associated pulley system can be devised.
- Manual scooping from boats: in calm to slight seas, shallow-draft boats can be used for collecting oil if access to the shoreline is difficult by land. The oil can be manually scooped from the water surface into 200-litre drums or, for viscous oils, into 1 m³ 'big bags' or 'jumbo bags'. Scoops used to collect more viscous oils can be made from a mesh or perforated metal to allow water to drain while retaining the oil (see photograph below).

Collection of oil from the water surface using scoops



Source: ITOPE

- Sorbents: if no vehicular access is available it may still be possible to collect floating oil from the shore using sorbents; these may include proprietary materials as well as naturally-occurring materials such as bagasse (fibrous waste from sugar cane processing) and straw. It should be noted however, that dried vegetation, such as straw, does not make particularly good sorbent material as it quickly becomes waterlogged and therefore needs to be collected very soon after it has been applied. Oil-soaked sorbents can be bagged and carried to a temporary storage area. In general, the large-scale use of sorbents on shorelines is not advocated since it adds to the quantities of waste for both transportation and disposal. However, where no other methods of collecting free-floating oil are viable, it is one possible solution.

Timing

The technique is used to recover mobile oil in the first phase of the response.

Suggested end point

The end point is reached when no significant quantities of floating oil remain, i.e. no recoverable oil.

Advantages and disadvantages

- ✓ Removal of bulk floating oil.
- ✓ Low biological impact.
- ✗ End point leaves surface oil residues, cover or coat and, depending on location, further treatment may be required or the oil may need to be left for natural cleaning.
- ✗ Use of sorbents for bulk oil collection adds to volumes of waste for transport and disposal.

Trenching

Typical application

- Mobile oil stranded on shallow sloping beaches on tidal shorelines.

Method outline

- Trenches dug by an excavator across the beach slope, parallel to the water's edge, can provide collection points for the recovery of fluid oil. Oil lying on the surface is encouraged to flow into the trench either manually with a squeegee (a smooth, flexible rubber blade attached to a broom handle) or by flushing the oil down the beach with volumes of water at low pressure. Once contained within the trench, the oil (and water) can be pumped into slurry tankers or temporary storage tanks or recovered by vacuum trucks. As far as possible the quantity of water recovered with the oil should be minimized, for example, by the use of skimming heads.
- Although trenching has been used successfully on tidal hard-packed sand and shingle beaches, the trenches tend to get filled in with each tide and may need to be reopened at the subsequent low tide.

Use of a trench to recover oil



Source: ITOPE

Timing

The technique is used to recover fluid stranded oil in the first phase of the response.

Suggested end point

As time goes on this technique will produce less and less recoverable oil. The end point is reached when the quantities of fluid oil recovered are no longer significant, i.e. no recoverable oil.

Advantages and disadvantages

- ✓ Removal of stranded fluid oil.
- ✓ Low biological impact.
- ✗ End point leaves oil contaminated beach substrate (surface oil residues) and, depending on location, further treatment may be required or the oil may need to be left for natural cleaning.
- ✗ If trenches are not lined, oil can penetrate into the walls and create a subsurface oiling issue.
- ✗ Without careful marking and recording of the location, trenches can be difficult to find subsequently. If not found and cleaned, trenches can become a sporadic and unpredictable source of oil contamination for some time after the spill.

Manual recovery of stranded oil**Typical application**

- Non-fluid stranded oil and oiled beach materials (sand and shingle) on any shoreline accessible on foot.

Method outline

- Stranded oil and contaminated substrates can be removed with a variety of implements depending on the type of shoreline and texture of the material to be recovered. Suitable implements range from trowels, scrapers, rakes and shovels to rags and sorbents. Recovered oil is usually placed in heavy-duty plastic bags (e.g. > 400 gauge/100 µm thick), rubble and fertilizer bags, or woven polypropylene sacks such as those used for packaging sugar and rice. Lighter-gauge plastic bags deteriorate quickly in sunlight and risk becoming a secondary source of pollution. Suitable bags are those with a nominal capacity of 25 kg, and should be filled no more than about $\frac{3}{4}$ full, or approximately 15 kg in weight, for ease of handling and to avoid spillage.
- If the shoreline supports machinery, collected waste can be put straight into the bucket of a front-end loader for transfer to a staging area.
- On sand beaches in the earlier stages of the clean-up when the gross contamination is being removed, shovels will be the tool of choice; as the operation nears its end, rakes are preferred.
- In contrast, on rocky and cobble shores where there is no vehicular access and no possibility of high-pressure washing, wiping by hand and the use of hand trowels may be the only possible means of cleaning. The method is highly labour-intensive and slow but may be appropriate in some circumstances, especially where labour is plentiful.
- If oil is to be collected manually from sensitive wetlands, whether temperate or tropical, or from saltmarshes or mangroves, careful consideration of the merits of physical intervention are required. If a decision is made to remove the oil, close supervision of the workforce and precautions such as the use of duckboards are called for to avoid damaging the vegetation by excessive trampling.

- Oily waste should be consolidated at a staging area, higher up the shoreline and well above the high-water mark to avoid the bags being washed away before they can be collected. The collected material might be loose, bagged, placed in bulk bags (~1 m³ capacity, also known as 'jumbo bags', 'ton bags', 'super sacks' or 'big bags') or loaded into skips or dumpsters. In all cases, however, the staging area should be prepared with polythene sheeting or a bund so that the oil can be contained if the collected material is spilled or if bags or other containers should leak. Where possible, the location should also be selected so that it is accessible to road vehicles to allow the waste to be picked up and transported for disposal or taken to temporary storage.
- A variety of situations may preclude vehicular access to recover waste from staging areas, including, for example, oil collected in rocky coves, below cliffs or along sensitive shorelines such as sand dunes where vehicle traffic is prohibited; in such cases, alternative means of transferring the bagged waste will be required. Solutions to this challenge include: human chains; use of all-terrain vehicles (ATVs) to transfer the material along the shoreline to an access point; cranes; and zip wires or aerial ropeways. Helicopters have also been used but, given the cost, this solution will need to be evaluated carefully. To make optimum use of any of these resources, the chosen operation will need to be extremely well coordinated. In certain circumstances, such as in remote collection areas with long transit distances, direct transport by helicopter to a disposal facility or temporary storage area might well offer the most cost-effective solution when compared, for example, with evacuating the waste by boat; the latter would probably involve repeated handling of the waste, for example, loading the vessel at the shoreline before sailing to a dock where the waste is offloaded and then reloaded onto trucks for onward transport.

Timing

The technique is used to recover stranded oil and contaminated sediments through all three phases of the response, and is sometimes even used to recover floating oil. As the predetermined end point is approached, further treatment such as sieving or harrowing may be necessary for high amenity beaches, but in many cases manual clean-up can achieve a satisfactory end point.

Suggested end point

Depending on the season, the likelihood of natural cleaning and the services provided by the shoreline, end points might vary from the removal of gross contamination, or removal of light to moderate surface oil residue, to no visible oil, no buried oil, no sheen, no greasy texture and no oily smell.

Advantages and disadvantages

- ✓ Removal of stranded oil from all types of shoreline as well as contaminated sediments from sand and shingle shorelines.
- ✓ Highly selective, leading to a high oil content in oily waste with relatively small amounts of clean substrate, thereby minimizing the amount of waste for transport and disposal.
- ✓ Can achieve a range of end points including those for amenity use.
- ✓ Low biological impact.
- ✗ Labour-intensive and slow; as an indication, one person can typically collect 1–2 m³ of oiled sand per day.
- ✗ A large workforce needs to be well organized with a high level of supervision to maintain focus, ensure selective recovery of oil (thereby minimizing amounts of waste generated) and to avoid secondary pollution.
- ✗ The coordination of large numbers of volunteers in this role calls for significant management effort.

Mechanical recovery of stranded oil

Typical application

- Non-fluid stranded oil and heavily oiled beach sediments on sand and shingle shorelines accessible by heavy machinery.
- The oil or contaminated sediment to be recovered needs to be of a consistency sufficient to allow concentration into cohesive piles or mounds which retain their structure long enough for subsequent collection by front-end loaders or excavators.
- The technique generates large quantities of lightly oiled waste, and is generally only applicable to high amenity shorelines immediately prior to, or during, the tourist season when the need to respond as quickly as possible may override environmental and waste minimization concerns.

Method outline

- Excavators, road graders, and tracked and wheeled loaders (also known as front-end loaders or payloaders) have all been used in the recovery of oil and oily sediments from shorelines.
- Graders can be used on hard-packed, fine-grain sand beaches where oil penetration is likely to be limited. By setting the grader blade to skim just below the surface of the beach, oil and sand can be concentrated in rows for collection with front-end loaders (see the *Alvenus* case study on page 38).
- Loader buckets can be used to concentrate oil and oily sediments, and collect oil and sediments directly. However, the depth to which the bucket digs into the beach cannot be controlled to the same extent as a grader, and much more clean substrate will be mixed with the oil, resulting in considerable quantities of clean sediment being collected with the contaminated material.
- The ability of the shoreline to support heavy vehicular traffic depends on the type of substrate and whether it's wet or dry, and on the shoreline gradient. Dry soft sand, impassable by wheeled vehicles, may be passable by tracked vehicles but the amount of oil mixed into clean substrate is likely to be greater if tracked vehicles are used.
- For the reasons outlined above, the use of bulldozers is not usually recommended for mechanical collection due to the likelihood of excessive mixing of clean and contaminated sediments.

Timing

Recovery of stranded oil and contaminated sediments is carried out from early in the response, through phase one to phase two.

Suggested end point

Light to moderate contamination. In cases of greater oil penetration, it may not be possible to achieve a better end point than moderate contamination. Alternative techniques may be needed to achieve a higher level of cleaning such as surf washing or, for sandy shores, ploughing/harrowing.

Advantages and disadvantages

- ✓ Removal of stranded oil and contaminated sediments from sand and shingle shorelines.
- ✓ Rapid removal of large volumes of stranded oil and contaminated sediments.
- ✓ Low labour requirement.
- ✓ Low to moderate biological impact; some loss of infauna.
- ✗ Potential for production of excessively large quantities of waste with typically low but variable oil content;

- ✗ Movement of heavy machinery over oiled shorelines mixes the oil further into the substrate; some shorelines, such as soft coarse sands, do not support heavy machinery which risks sinking and becoming stuck once loaded.
- ✗ Potential risk of heavy machinery damaging habitats such as dunes, together with the risk that excessive removal of substrate can create adverse geomorphological changes to shoreline profiles and/or erosion.
- ✗ It is strongly recommended that heavy machinery is not used on sensitive shorelines such as saltmarshes due to the risk of causing long-term damage to the habitat.

Surf washing

Typical application

- Sand, shingle, pebble and cobble shorelines accessible to heavy machinery and exposed to breaking waves with moderate to light levels of contamination but not significant quantities of stranded oil.
- Separation of bulk oil from sediments where it is buried or intimately mixed into the sediment.

Method outline

- Equipment such as front-end loaders, excavators or bulldozers is used to move oiled beach material into the high-energy surf zone.
- In the absence of machinery, the material can be moved towards the surf zone manually, observing sensible precautions when working on a dynamic shoreline.
- The material is agitated and cleaned by wave energy, relying on the natural processes of abrasion, oil/mineral aggregates and dispersion. Some evaporation may also occur with lighter and less-emulsified products and is clearly apparent from the oily smell during the operation.
- In conditions where there is a likelihood of significant quantities of free oil being released using this technique, the use of sorbents is recommended to collect the oil—sorbent nets for viscous oils and proprietary sorbent mats or booms for lighter oils. Oil stranding on the beach surface can be recovered manually (see the *TK Bremen* case study on page 39).
- In most cases, wave energy will redistribute the beach substrate back up the beach over time but larger cobbles may need to be replaced to maintain the beach profile.

Timing

The technique is used during phases two and three, after removal of bulk stranded oil but before undertaking any final clean-up of adjacent high amenity areas, as the oil and sheens released may re-contaminate these areas. Alternatively, the use of the technique should be restricted to wind and tide conditions that would carry any released oil away from sensitive shorelines.

Suggested end point

To reach a final end point acceptable for high amenity shorelines, repeated treatment or ploughing/harrowing might be required, as well as reinstatement of the beach profile. For shorelines where natural cleaning can be allowed to proceed more slowly, the beach material is left in the surf zone and, over time, will become redistributed through the action of waves and tides according to grain size to reform the natural beach profile. Any residual stains or films will weather and degrade naturally.

Advantages and disadvantages

- ✓ Relies on natural cleaning processes.
- ✓ Low labour requirement.
- ✓ Method for treating buried oil.
- ✓ Minimizes the amounts of oily waste for evacuation and disposal.
- ✗ Potential release of oil and sheens.
- ✗ Temporary disruption of beach profile.
- ✗ Potential for low levels of infauna loss.

CASE STUDY 2: Example of mechanical clean-up using graders and dump trucks on a hard-packed sand beach**Alvenus, Louisiana, USA, 1984**

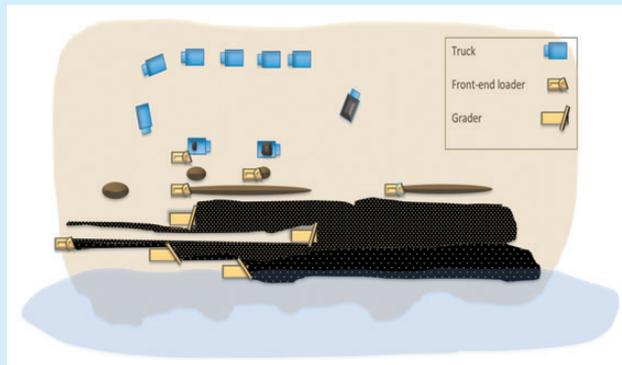
In July 1984, the tanker *Alvenus* grounded in the Calcasieu River and spilled approximately 8,500 tonnes³ of viscous Merey and Pilon crudes. Most of the oil stranded along some six miles of the Galveston seawall and along 13 miles of Galveston West Beach, a hard-packed sand beach where, because of the scale of shoreline contamination and the touristic importance of the location at that time of year, a massive mechanical clean-up operation was undertaken. At its peak approximately 50 graders and 100 dump trucks,³ each with a capacity of 25 cubic yards, were engaged in the operation which resulted in some 100,000 cubic yards⁴ (~76,500 m³) of sand being removed from the shoreline.

Working from the top and the bottom of the beach, the graders were used to draw the contaminated sediment into rows parallel to the water's edge. The rows of oily sand were then worked into piles by front-end loaders before being loaded onto trucks.

Despite the large quantity of sediment removed, the quantity of waste generated in the Galveston beach clean-up did not greatly exceed the amount of waste that, as a rule of thumb for shoreline clean-up, is often as much as ten times the amount of oil spilled. In addition, because significant sand movement occurs annually along this coastline, it was judged that there was no need for sand replenishment.

Right: schematic of the mechanical clean-up of the Galveston shoreline.

Below: Galveston West Beach, and one of 50 graders engaged in the shoreline clean-up operation.



³ Alejandro and Buri, 1987 ⁴ NOAA Incident News website: <http://incidentnews.noaa.gov/incident/6267>

CASE STUDY 3: Example of surf washing used to clean several thousand metres of oiled sandy beach

TK Bremen, Brittany, France, 2011

In December 2011, the cargo ship *TK Bremen* grounded during a storm on a sandy beach spilling IFO 120 and diesel oil onto the shoreline. The grounding location was close to protected dunes and an ecologically sensitive estuary, which supports an important oyster fishery. The bulk of the stranded oil was removed from the beach during the first few days by manual and mechanical means, but considerable quantities of buried oil and oil-impregnated sand remained at the mouth of the estuary. The environmental and socio-economic sensitivities of the surrounding area meant that any further clean-up operations had to carefully consider sea state, wind and tides, in order to prevent further contamination of these shorelines. Natural cleaning was discounted due to the potential for oil being released on rising spring tides, particularly in rough winter seas, and entering the estuary. The large volume of sand to be treated meant that ex-situ cleaning was also not practicable.



Source: ITOPF



Source: ITOPF

Surf washing was therefore used to clean several thousand cubic metres of oiled sand, in just a few days. Commonly conducted on a rising tide, this technique can also be used at ebb tide to enable better recovery of the released oil. The most appropriate site for surf washing was selected at a distance from the original location of the oily sand, to ensure that released oil was carried away from the estuary, and that the cleaned sand stayed within the beach's sediment system. Oil was recovered from the water immediately downstream of the surf washing point by fine mesh nets, attached at intervals to ropes, parallel to the water line and offset in the direction of the drift, anchored using 1 m³ 'big bags' filled with sand and buried in the beach. As the tide went out, the surf washing point was shifted down shore and in the direction of the drift. To ensure that any remobilized oil/sheen was not carried towards the mouth of the estuary, the operation could only be implemented in periods of moderate to strong wave action and north to north-westerly winds, and during the first three or four hours of the ebb tide.

Due to the fluidity of the oil, the nets did not collect all the pollutant released: some of it escaped in the form of sheen, which ultimately dissipated at sea. On the sea surface, beyond the surf zone, two small boats equipped with scoop nets and sorbent booms for trawling recovered any floating oil. Subsequent tidal cycles finalized the clean-up and gradually redistributed the shifted sediment.

Flushing/flooding

Typical application

- Sand or shingle beaches with buried oil where surf washing is not viable.
- Rock boulder shores and sea defences where oil is trapped within cavities.
- Oil trapped under wharves.
- In conjunction with high pressure washing to carry run-off to collection points.
- Sensitive shorelines such as saltmarshes and mangrove stands.

Method outline

- The technique uses high volumes of seawater at low to moderate pressure to dislodge and remobilize stranded, trapped or buried oil and channel it to collection points.
- Portable self-priming centrifugal pumps (30 to 60 m³/h) can be used to supply seawater to fire hoses or flushing lances (hand-held lengths of rigid pipe) directed into the beach to agitate the substrate and release trapped oil. Proprietary flushing lances exist that introduce air into the water flow through a venturi arrangement that is intended to provide both additional agitation and flotation to bring the oil to the surface.
- The oil released can be floated down to collection points by flooding the section of the shoreline being treated with water pumped through perforated pipes laid along the top of the beach.
- It may also be possible to use high volumes of water at low pressure to flush fluid stranded oil from sensitive shorelines such as saltmarshes and mangroves, and so avoid the levels of physical intervention and risk of damage associated with manual removal.

Timing

Flushing is generally applicable for use during phase two of the response. It should be undertaken prior to final clean-up of adjacent shorelines; if the remobilized oil is not recovered it presents a risk of contamination to surrounding areas.

Suggested end point

The end point is reached when no more oil can be released by flushing, i.e. no recoverable oil. Depending on the shoreline type the result may range from a greasy texture for sand beaches to a relatively heavy coating for viscous oils attached to rocks or sea defences, where only mobile oil has been removed by this technique.

Advantages and disadvantages

- ✓ Removal of buried and trapped oil.
- ✓ Removal of mobile oil from sensitive shorelines.
- ✓ Minimal disruption of beach profile (see also 'surf washing' on page 37).
- ✓ Low biological impact.
- ✗ Moderate to high labour requirement.
- ✗ Restricted area treated by a single flushing lance results in slow progress.
- ✗ Heavy coating of oil remains for some shoreline types, e.g. rocks and sea defences.

Use of concrete ('cement') mixers

Typical application

- Sheltered pebble/cobble beaches where significant amounts of oil remain trapped but where shoreline is low-energy (not suitable for surf washing) or non-tidal.
- Higher energy pebble/cobble shorelines where, if surf washing were to be used, there is a significant risk that the oil released could contaminate adjacent sensitive resources, such as mariculture, sea water intakes or recreational beaches.

Method outline

- The drum of a concrete mixer truck is part loaded with contaminated pebbles/cobbles. (To avoid damage to the drum and mixer elements, stones should not exceed 150 mm in diameter). A typical mixer truck has a capacity of 5–6 m³. Large debris, e.g. driftwood, should be removed prior to loading.
- A solvent, such as a shoreline cleaner (see *Use of chemical cleaning agents* on page 44) or odourless kerosene is added at 1–2%, i.e. a ratio of solvent to contaminated pebbles between 1:50 and 1:100 depending on the degree of contamination. The solvent and oiled pebbles are mixed thoroughly by rapid rotation of the drum for a period of about five minutes.
- The speed of rotation is slowed to allow the concrete mixer to be filled to capacity with water, and the contents of the drum mixed for a further 30–60 minutes depending on the average size of the pebbles; smaller aggregates will need longer than large ones.
- Oily wash water is decanted into a temporary storage tank to allow separation of the oil, and the pebbles are discharged ready for transport back to the source shoreline.
- Oil separating from the wash water can be recovered with sorbents or a small skimmer, and efforts should be made to recycle as much of the wash water as possible. Spent wash water will require separate disposal arrangements according to local regulations.
- A cleaning station set up with several concrete mixers working in parallel can optimize logistics and take advantage of the benefits of scale by working with associated equipment such as loaders, pumps and tanks.
- The process produces stones that are still slightly contaminated with a greasy film. These can be placed at the water's edge for final rinsing. During periods of heavy weather these pebbles will be redistributed and any residual films removed.

Timing

This is a final clean-up technique used during phase three of the clean-up operation, and requires the removal of bulk oil prior to its use.

Suggested end point

The process leaves a greasy film removed through natural cleaning at the water's edge.

Advantages and disadvantages

- ✓ Depending on the size of the concrete mixer, can achieve a batch treatment rate of 5–6 tonnes/hour.
- ✓ Allows cleaned material to be returned to source shoreline.
- ✓ Equipment is mobile and a washing station can be set up with several machines working in parallel.

- ✗ Moderate labour but high equipment requirement.
- ✗ Relatively slow and consequently costly.
- ✗ Requires double handling and transport of material from shoreline to washing station and back again.
- ✗ Fine particles of sand and grit accumulate within mixer drum and may need separate disposal arrangements.
- ✗ High volumes of wash water may need further treatment and separate disposal arrangements according to local regulations.

In-situ washing

Typical application

- Shorelines comprising small boulders and cobbles accessible to machinery and where significant amounts of oil and oily debris remain trapped.
- Areas where relocation of the contaminated material into the surf zone is not possible or where the shoreline is non-tidal.
- Higher energy shorelines where, if surf washing or flushing were to be used, there is a significant risk that the oil released could contaminate adjacent economically or environmentally sensitive resources.
- This technique provides a very limited treatment rate in terms of tonnes of oiled substrate treated per day, and is therefore likely to be restricted to short sections of shoreline or coves where environmental or economic concerns are particularly high.

Method outline

- Two methods:
 1. An excavator is required to move the material to a suitably strong and watertight tank, such as a sectional tank (Braithwaite tank), a skip placed on a flat surface, or any other container available locally that could be adapted for the purpose. The excavator bucket is used to agitate the material in the tank with surface cleaners or odourless kerosene and seawater in much the same way as with the concrete mixer described above. Oil released can be collected both from the surface of the washing tank and from oily water pumped into temporary storage tanks where the oil is allowed to separate.
 2. The excavator is used to load material onto a heavy-duty grill with an appropriate mesh size to retain the material to be cleaned above the tank. The material is then cleaned with high-pressure washers and the wash water collected in the tank from where it can be pumped to temporary storage tanks for oil separation and recovery. This method can also be used to clean the individual elements of sea defences, e.g. Tetrapods, Dolos, Xblocs, etc., if the defences are dismantled for cleaning.
- The cleaned material is placed in the surf zone for final cleaning.

Timing

This is a clean-up technique used during phases two and three after mobile, free oil has been recovered but heavily contaminated substrate remains.

Suggested end point

Removal of gross oil contamination, and end point to suit shoreline use.

Advantages and disadvantages

- ✓ Removes gross contamination from cobbles, boulders and sea defence elements, and with high pressure washing can achieve a high degree of cleaning.
- ✓ Avoids transfer of oiled material from the shoreline.
- ✗ Very limited batch treatment rate with relatively high equipment demands.
- ✗ Wash water may need further treatment and separate disposal arrangements according to local regulations.

High-pressure washing**Typical application**

- Boulders and bedrock where a coating remains that is not exposed to sufficient wave action and has therefore become, or is likely to become, weathered and hardened.
- Manmade structures.
- Rocky foreshores with easy public access; high amenity shorelines.

Method outline

- Proprietary pressure washers offer systems with either hot or cold water at high pressure, but the more resistant the oil residue, the higher the temperature required to remove it. For hot water washers it is recommended that the temperature is set to no higher than 95°C, as vapour under pressure is not as efficient as water. Operating pressures may vary from 50 to 150 bar with a water flow rate in the range 10–20 litres/minute. A test area should be selected to optimize the efficiency of the technique using a range of pressures and temperatures.
- While some systems are designed for use with seawater, most rely on a freshwater supply which needs to be portable to allow it to be moved with the work area as the operation progresses. Seawater systems can be supplied by submersible pumps fitted with gross filters to avoid ingress of shells and algae, etc., with the seawater then being passed to a settling tank before entering the high-pressure pumps.
- With a team of two people per washer (one operating the lance, the other monitoring effluents and maintenance issues) an average of 1–3 m²/hour can typically be cleaned depending on the skill of the operator, ease of access and the level of contamination.
- Cleaning from the top of the shoreline allows effluents to flow over areas not yet cleaned. Depending on the shoreline type and configuration, effluents can be contained in trenches or rock pools, or at the water's edge with sorbent booms.
- Where effluents cannot be contained, such as on flat rocky platforms, a supplementary water flow, or flooding, can be used to direct effluents to a collection point. When cleaning rocks at the margins of a sand or shingle beach, geotextiles or plastic sheeting can be used to prevent effluents from penetrating the substrate. Sorbents placed at the base of the rocks being cleaned are used to recover as much oil as possible as the effluents pass through them.
- At high operating pressures, the spattering of surfaces adjacent to the work area can be a problem. Areas which may already have been cleaned or which have not been oiled need to be protected.

Timing

This is a final (phase three) clean-up technique. To avoid re-oiling of cleaned surfaces, it should not be commenced until all mobile oil has been recovered. It is usually restricted to high amenity areas or where natural cleaning is unlikely to be effective or sufficient, such as in ports and harbours.

Suggested end point

Thin residual stains or films may remain, which are best left to weather and degrade naturally. Repeated treatment or use in conjunction with chemical cleaning agents may be necessary if the removal of traces of oil is required, such as when cleaning promenades and marinas.

Advantages and disadvantages

- ✓ Can achieve a high degree of cleanliness.
- ✓ Equipment is relatively easily sourced and mobile.
- ✓ Moderate labour requirement.
- ✗ Biologically destructive.
- ✗ High levels of 'spatter' present the risk of contamination of areas adjacent to the work area.
- ✗ Potential damage to the surface of concrete, soft rock (e.g. sandstone) and jointing materials in concrete structures.
- ✗ Relatively slow and consequently costly.

Use of chemical cleaning agents**Typical application**

- Usually in conjunction with moderate to high pressure washing where supported by NEBA and permitted by national regulations. Typically used for cleaning:
 - boulder and bedrock areas;
 - manmade structures; and
 - rocky foreshores with easy public access; high amenity shorelines.
- Use of chemicals on shingle/cobble shorelines is not recommended since oil/chemical mixtures tend to penetrate deeper into the shingle where tidal flushing is likely to be less effective.

Method outline

- Two chemical categories:
 1. Surface cleaning agents are applied to the surface to be cleaned according to the manufacturer's instructions. The combined solvent-surfactant action of the surface cleaners reduces the viscosity of the oil and alters its surface tension to facilitate lifting the oil from the surface being cleaned. Crucially, unlike dispersant use (see below), the intention is not to disperse the released oil but to collect it, either directly using sorbents, or by flushing it to a collection point for recovery by sorbents, pumps or skimmers.
 2. Where permitted, dispersants are applied to the oily surface and mixed into the oil with vigorous brushing. The oil/dispersant mixture is then flushed off. For planning purposes, an oil to dispersant ratio of 20:1 is used. An estimate is made of the average quantity of oil per unit area, based on the oil thickness, and the appropriate application rate for the area to be treated is determined. By way of illustration, an oil layer 2 mm thick represents 2 litres of oil/m², calling for $\frac{2}{20}$ litres of dispersant, or 1 litre of dispersant for each 10 m² of oiled surface.

- The use of dispersant may be more highly prescribed than surface cleaners because the oil released by surface cleaners is recovered, whereas dispersants are intended to promote the dispersion of oil into nearshore waters. For that reason their use should be restricted to areas where there is adequate water movement to bring about the rapid dilution of the dispersed oil.

Timing

This is a final clean-up technique, typically used during phase three of the clean-up operation and in high-amenity areas.

Suggested end point

Minimal traces of oil stain or film. A repeat application may be necessary for particularly resilient stains.

Advantages and disadvantages

- ✓ Can achieve a high degree of cleanliness.
- ✗ If the use of chemicals on shorelines is permitted, only those products approved for that purpose under national regulations should be used and only at recommended dose rates.
- ✗ Moderate to high labour requirement.
- ✗ Requires close supervision to ensure proper application of chemicals and the correct use of PPE.
- ✗ Potential for localized biological impact.
- ✗ Oil released by surface cleaning agents needs to be recovered.
- ✗ Dispersants require sufficient water movement to allow the rapid dilution of dispersed oil.
- ✗ Not suitable for large-scale treatment.
- ✗ Not suitable for shingle/cobble shorelines.
- ✗ Relatively costly.

Use of particulate sorbent as a masking agent

Typical application

- Rocky shores with limited access.
- Seal, penguin or otter haul-outs.
- Marsh vegetation to protect wildlife.

Method outline

- Particulate mineral (vermiculite) or organic (peat, bark, straw, etc.) sorbents are broadcast onto the affected shoreline.
- Mineral sorbents tend to be used exclusively on rocky shorelines, whereas organic sorbents can be used on both rocks and marshes.
- On rocky shores, and on marshes where accessible, the sorbent may be worked into heavier accumulations of oil and the oil/sorbent mixture recovered manually.
- More often, however, once applied, the oil and sorbents are left to degrade naturally. While the mineral sorbents themselves will not degrade, they are removed naturally over time and distributed over a wide area.
- If the sorbents are washed off prematurely leaving oily surfaces that are still tacky, repeat applications may be required.

Timing

This technique is applicable for use during phases two to three of the clean-up operation. After removal of mobile oil, particulate sorbents are used to mask the covering of oil on rocks and marsh vegetation to protect wildlife.

Suggested end point

When used to protect wildlife, no further treatment is foreseen and the oil is usually left to degrade naturally.

Advantages and disadvantages

- ✓ Provides a means of masking oil while still tacky and transferable, until the oil weathers and natural cleaning processes lead to its removal and degradation.
- ✓ Minimizes contact between the oil and wildlife (birds and mammals).
- ✗ Potential localized biological impact for fauna other than target groups.
- ✗ Sorbent/oil mixture is largely unrecoverable, so this is usually unsuitable as an effective clean-up technique.

Sieving**Typical application**

- Dry sand, amenity beaches contaminated with tar balls or pellets of weathered oil, and sand remaining after manual clean-up.

Method outline

- In principle, contaminated sand is placed on a fine-mesh screen with a hole size that allows the dry clean sand to drop through as the screen is shaken or vibrated but retains tar balls and oily pellets.
- The scale of the operation ranges from small, hand-held garden sieves through static sieves of 1–2 metres and vibrating screens of table-top dimensions, to commercial-scale units used in the mineral processing industry. While static sieves and medium-sized vibrating screens can be loaded by hand, larger industrial units require heavy machinery to move the sand for treatment, load the screen and return the clean product.
- At the smallest scale, the use of garden sieves is highly labour-intensive and would probably prompt a decision to terminate operations on the basis of a determination of whether that level of effort could be justified.

Timing

This is a final (phase three) clean-up technique for recreational amenity beaches.

Suggested end point

The target end point is no visible tar balls or pellets of weathered oil and sand.

Advantages and disadvantages

- ✓ Can achieve a high degree of cleanliness.
- ✓ Most equipment is relatively mobile.
- ✓ Reduces the amount of waste for disposal.
- ✓ Minimal biological impact.
- ✗ Large-scale sieving operations require the transfer of material to the sieve location and the return of clean product to the beach.
- ✗ Very small-scale operations are highly labour-intensive.

Beach-cleaning machinery**Typical application**

- Sand amenity beaches contaminated with tar balls or the residue from manual clean-up, or pellets of weathered oil and sand. The technique requires that shorelines are accessible by vehicles including tractors and trailers.

Method outline

- Beach-cleaning machines are primarily used for the collection of flotsam and jetsam and litter left by beach users on recreational beaches. The main approaches used in their design are a rotating rake system, a sieve system or a combination of these two. For rake systems, sprung tines are mounted across a rotating belt. The collected material is lifted by the tines and dropped into a hopper. In the sieve system, sand is removed from the beach surface to a predetermined depth and conveyed up to a vibrating screen. The clean sand drops through the screen back onto the beach and the oily debris is transferred to a collection hopper. Available machines include pedestrian controlled devices about the size of a lawnmower, those towed behind a tractor, and self-propelled machinery.
- Another design which operates best on wet, hard-packed sand is an oleophilic drum which picks up oil as it is rolled along the beach. The oil is then scraped from the drum and transferred to a storage compartment.



Source: ITOPF

A tractor-towed beach-cleaning machine

Timing

This is a final (phase three) clean-up technique for recreational amenity sand beaches.

Suggested end point

No visible tar balls or pellets of weathered oil and sand.

Advantages and disadvantages

- ✓ Can achieve a high degree of cleanliness.
- ✓ Mobile equipment.
- ✓ Very low labour requirement.
- ✓ Minimizes the amount of waste for disposal.
- ✓ Large areas of shoreline can be treated relatively quickly.
- ✓ Minimal biological impact.
- ✗ Low availability of beach-cleaning machines outside major beach resorts.
- ✗ Tar balls may fragment during processing (particularly in warmer weather) resulting in small tar balls falling back onto the beach.

Harrowing/ploughing**Typical application**

- Tidal shorelines of sand or fine shingle with trafficability sufficient to support tractors using ploughs or harrows.

Method outline

- A variety of clean-up techniques can leave sand and shingle shorelines with low levels of contamination but with a residual greasy texture and oily smell. The use of agricultural equipment, e.g. ploughs and harrows, to turn over and aerate the beach material usually leads to the rapid removal of residual nuisance levels of contamination.
- The action of the cultivation equipment is equivalent to surf washing but without the wholesale movement of substrate to the surf zone. It brings the oiled beach material to the surface, promoting biodegradation and the dispersion of oil mineral aggregates.
- Repeated 'cultivation' of the beach over consecutive tidal cycles may be required to obtain the required end point.

Timing

This is a final (phase three) clean-up technique used to enhance natural cleaning.

Suggested end point

No visible oil, no buried oil, no sheen, no greasy texture and no oily smell.

Advantages and disadvantages

- ✓ Can achieve a high degree of cleanliness by enhancing natural processes.
- ✓ Required equipment is widely available.
- ✓ Low labour requirement.
- ✗ Potential for infauna loss.



Source: ITOPE

Ploughing an oiled shoreline

Sand replenishment

Typical application

- Sand and shingle shorelines accessible to the public at the height of, or immediately prior to, the tourist season where the loss of recreational services has the potential for significant economic consequences. Replacement material must be closely matched to that which was removed, both in terms of its mineral composition and grain size. If different from the original, it is likely to respond differently to the hydraulic conditions, possibly resulting in the new material being quickly washed away. A further consideration is the likelihood of natural replenishment. Most sand beaches are in a constant cycle of accretion and erosion, and with strong wind conditions or combined wind and tidal surges beach profiles can change dramatically in a 24-hour period. Such changes can sometimes be measured in terms of metres of sand depth lost or gained.
- The technique might also be considered for other shorelines where significant amounts of material have been removed as a result of clean-up operations and where the source of natural replenishment has been depleted so that there is little prospect of material being replaced without intervention. The difficulty in such a situation is finding materials locally which closely match the original to avoid it being quickly eroded.
- Given the above considerations, it is important to recognize that the circumstances in which this technique would be appropriate or successful are highly limited.

Method outline

- Sand or shingle is trucked from a local source of suitable replacement materials and distributed over the beach either manually or by heavy equipment.

Timing

This is a final (phase three) clean-up operation suitable in highly limited circumstances.

Suggested end point

Worksite overlain with clean sand or shingle, hence no visible oil, no buried oil, no sheen, no greasy texture and no oily smell.

Section 4: Shoreline types and associated oiling features

As oil strands on a shoreline the interaction between the oil and shoreline depends on both the characteristics of the oil and the shoreline type. This section describes the oiling features resulting from that interaction and discusses the clean-up implications for a selection of representative shoreline types.

Wetlands

In general, oil deposited on mudflats does not penetrate into the substrate because the water table is sufficiently high to provide a barrier against the downward migration of oil, including light oils. It is most likely that the oil will refloat and migrate elsewhere. However, there are exceptions. For example, oil can get into muddy sediments through the open stems of broken plants, and through animal burrows, wormholes, etc. Alternatively, if the oil is spilled during a storm, rough seas can lift substantial quantities of sediment into suspension which then becomes associated with dispersed oil. When the storm abates the mixture of suspended solids and oil is deposited and the oil is incorporated into the sediment. Without agitation the oil can remain within the sediment undergoing very slow anaerobic degradation unless another storm of similar proportions brings about its redispersal. Two well-studied examples of this phenomenon, which are often cited, are the *Florida* barge incident (Massachusetts, USA, 1969) and the *Braer* incident (Shetland, UK, 1993). In the *Florida* barge incident⁵, evidence of the oil incorporated into the sediment of a marsh has been observed two decades after the original incident. In the case of the *Braer*,⁶ oil/sediment mixtures representing some 30% of the oil lost were accounted for in sediments around the Shetland islands, a substantial proportion of which was found on the seabed close to Fair Isle, some 120 km from the site of the spill.

While an open water response can minimize the amount of oil approaching wetlands, the typically large geographical extent of such habitats makes them difficult to defend. However, erecting barriers across major inlets can sometimes restrict the amount of oil that gets into a wetland

system. In some cases impermeable earth barriers have been built but, where water exchange is important, barriers have to be designed to let water pass through while keeping the oil out. For saltmarshes, straw, netting and oyster shells have all been used successfully, although attention should be given to the tidal currents that such barriers need to withstand.

On oiled muddy shores, the greatest challenges can be presented by the oil trapped in vegetation, i.e. in mangrove root systems in tropical regions, and saltmarsh vegetation in temperate zones. In most cases the drivers are environmental concerns rather than socio-economic, and the dilemma is how best

Example of an oyster shell barrier



Source: ITOFF

⁵ Teal, J. M. et al., (1992). ⁶ Davies, J. M. and Topping, G. (eds) (1997).

to minimize the impact of the spill while taking care not to do more harm than good by intervening in these sensitive habitats. On the one hand, leaving the oil in place is likely to result in mortalities of the plants and animals that these habitats support, while on the other, the clean-up operations themselves could damage the habitat, delaying recovery and leading to much longer-term damage. For this reason, oiled wetlands are often left to recover naturally.

Mangroves

Mangroves are known to be highly susceptible to the effects of oil spills depending on the type of oil spilled. Experience shows that in, general, light refined products are more damaging than crude oils and crude oils are more damaging than heavy fuel oils. The sediment type also seems to have a bearing on the degree of damage inflicted, with mangroves in fine sediments (muds) being more susceptible than those in coarser grain sediments. The implication from these observations is that, while heavy oils can, with care, be removed manually, efforts to remove lighter refined products should be made at the earliest opportunity to flush the oil away from the mangroves and into open water from where it can be recovered.



Source: ITOPIF

Manual clean-up of a heavy fuel oil spill in mangroves

Saltmarshes

The experience drawn from a number of incidents, in particular the *Amoco Cadiz* incident (Brittany, France, 1978), has informed responders for many years on the damage which results from overzealous clean-up operations in saltmarshes. The use of heavy equipment, poorly supervised manpower and the removal of oiled sediment have led to long-term damage due to trampling, damage to root systems and consequent erosion. Closely supervised manual removal with the use of duckboards to avoid compression of the substrate, in-situ burning and cutting of oiled vegetation have all been used with varying degrees of success. The viability of cutting or burning

oiled vegetation depends on the time of year when a spill occurs and the type of oil spilled. At the end of the year, when vegetation is dying back, cutting and burning would be less damaging than in the spring when new shoots are pushing through. In general, cutting vegetation has not been found to improve recovery rates except for spills of heavy fuel oil or heavy crude oils. In-situ burns are restricted to light and medium oils since heavy oils tend not to burn well. Controlled burning is found to be most effective if initiated shortly after the oil has stranded and before the oil penetrates into the marsh substrate. Oil within the substrate is likely to survive the burn. The attraction of burning over cutting is that it requires less intervention on the ground although it also represents a greater risk to fauna living or sheltering within the marsh, especially since it can be difficult to control the fire and keep it within the oiled area; in several cases where oiled marsh vegetation was set on fire, large areas of unoiled marsh were also burned.

Restoration

For both oiled saltmarshes and mangroves, once gross contamination has been removed and residual oil has weathered with the dissipation of toxic components, replanting has successfully enhanced recovery rates. However, replanting programmes, especially those involving mangroves, should be assessed against the potential for natural recolonization from adjacent surviving trees. This allows for the prevailing mangrove biodiversity and an ecologically-driven distribution to remain in place (as opposed to planting rows of a single species).

If, following such an assessment, replanting is determined to be an appropriate restoration measure, a supply of healthy seedlings of the appropriate species will be required, either from an undamaged area or by cultivating seeds in a nursery. Seedlings are planted with a large volume of good quality, clean sediment surrounding them to allow good growth before the roots extend into contaminated sediments.

Sand beaches

Buried oil

While oils can more easily penetrate into coarse, dry sand, finer-grained sands form wet, hard-packed beaches, less likely to permit oil penetration. However, as noted earlier, if oil is left lying on the surface of the beach and not removed in a timely manner, it can become buried by wind-blown sand or by natural sand accretion. Beach profiles can change dramatically in a matter of hours under the right sea conditions, with a depth of sand as much as a metre or more being washed away from one location and deposited at another. The existence of significant quantities of buried oil can be ascertained by digging a series of exploratory holes to get an idea of how extensive this might be. Once established, the first considerations are whether the processes that brought about the burial of the oil are just as likely to result in its rapid removal, and whether natural sand movement will occur faster than clean-up operations could achieve the same result. This depends on expected weather and sea conditions and whether there is a predictable cycle of deposition and accretion. If the oil became buried in storm conditions, it is likely that it will take another storm to remove it, but it is also under such conditions that the rapid dispersion of the oil released would occur. Nevertheless, if the area of buried oil appears to be extensive or if it seems

likely to remain buried in the beach for some time, and if there is an environmental or, more probably, an amenity driver for its removal, its extent needs to be mapped and its removal addressed.

The mapping of buried oil requires a methodical survey with a series of transects established across the beach perpendicular to the water's edge at low tide. Holes are dug at intervals along each transect, or a trench is dug along its length, and the presence of oil is noted together with its depth below the surface and the thickness of the oil layer. The separation between transects depends on the estimated scale of the area, and new transects may need to be added if seams of oil are lost between transects. By interpolating between the transects, a three dimensional representation of the buried oil can be developed (Figures 7 and 8).

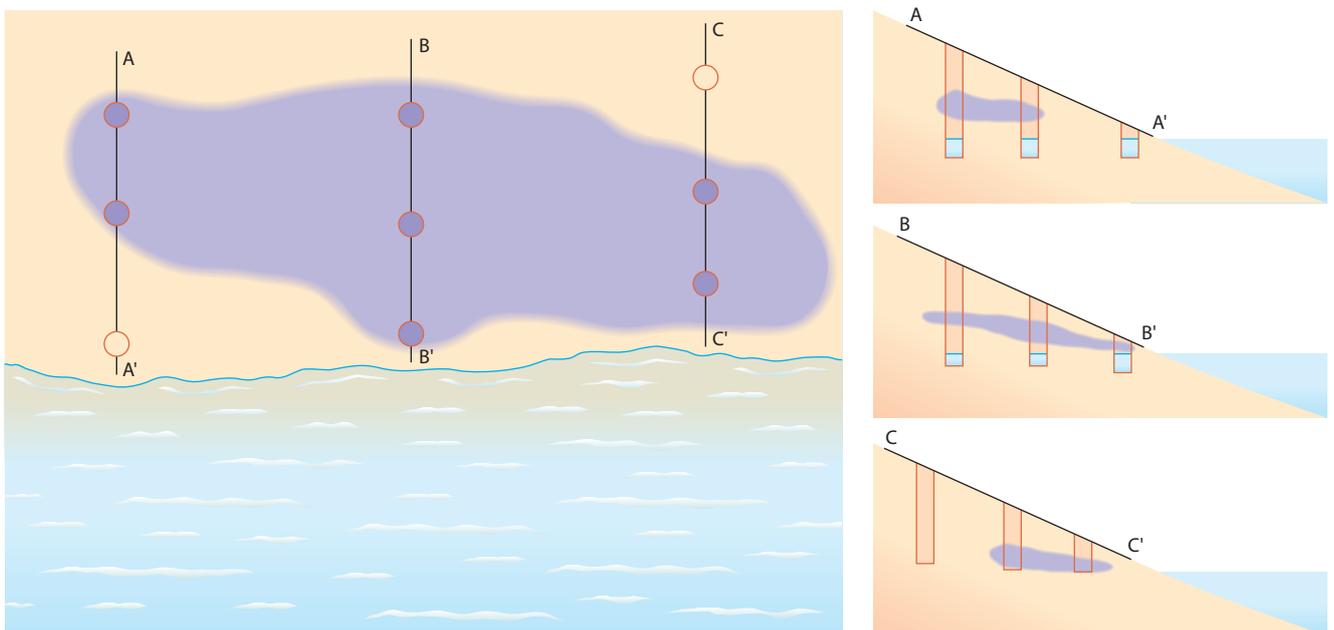


Source: © Shutterstock.com

The options for removal of buried oil include lifting the clean overburden and moving it aside to expose the band of buried oil to be removed and transported off the beach for disposal. Another option is to transport the band of buried oil to the water's edge for surf washing. If relatively close to the surface, the oil might be mobilized through harrowing or ploughing, or by using flushing lances to release the oil and flush it to the water's edge where it can be recovered with skimmers or sorbents.

Removal of oil from a sandy beach; if oil is left lying on the surface, it can become buried by wind-blown sand or by natural sand accretion.

Figure 7 Simplified diagram of a buried oil survey



The 'strand-sink-strand' cycle

Another commonly observed feature of oil stranding on coarser sand beaches, particularly for heavier or weathered oils, is that the oil penetrates sufficiently to form a weak agglomeration of oil and sand. A subsequent rise in water level driven by storms, tides or onshore winds can lead to some of this material being washed back into the sea where the additional density of the incorporated sand causes it to sink. Depending on the conditions under which it was removed from the shoreline, this mixture of oil and sand may simply remain on the bottom in nearshore waters. For example, if the oil was washed off the beach in storm conditions it may take similar sea conditions to drive it back onto the shoreline. For less stable agglomerates, warmer daytime temperatures and the agitation of waves breaking on the shoreline may be sufficient to release some of the oil, allowing it to float back to the water surface and strand once again (Figure 9).

To break the cycle of repeated stranding, sinking and oil release, oil has to be removed from the system. Three options are available depending to some extent on the depth of water into which the oil/sand mixture has settled. Perhaps the simplest option is to continuously remove the oil as it strands so that, over time, progressively less oil remains available to strand. A second option, which is more applicable in deeper waters, is to use divers to recover the oil manually from the seabed. In one incident where this technique was implemented, a novel approach involved providing an incentive to recover the most heavily contaminated material by rewarding the diving contractor according to the calorific value of the oil/sand mixture recovered. A third solution, where sea conditions and water depths allow, is to use semi-amphibious excavators to lift the oil which has sunk close to the shore.

Shingle and cobbles

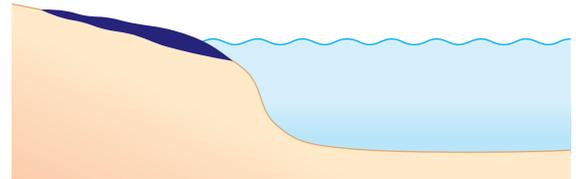
Oil penetration into shingle and cobble shorelines

These are among the most difficult shoreline types to clean because oils, particularly lighter oils such as crude oil, are able to penetrate deeply into this type of substrate. The loose structure allows water to move freely through it and, as the water level falls, oil floating on the water surface follows it down through the shingle. Heavily contaminated shorelines can be flushed to move fluid oil into trenches or to other collection points for recovery with skimmers, pumps or sorbents. On exposed tidal coasts a passive cleaning approach using sorbent mops made from fine mesh nets has been used successfully for collecting heavier oils.

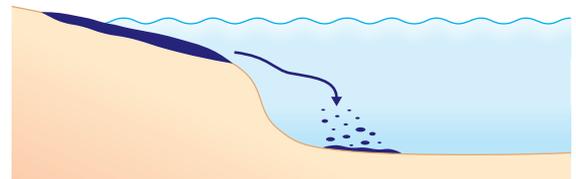
The most successful technique for treating oil that has penetrated into shingle is surf washing but, as the name implies, the technique requires an active shoreline with strong wave action to be

Figure 9 The 'strand-sink-strand' cycle

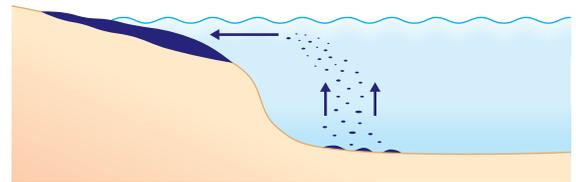
(a) Heavy oil strands on a coarse sand beach



(b) Oil/sand mixture washes off the shoreline and sinks



(c) Agitation of waves and warmer temperatures cause the oil to be released and float to the surface to strand again on the shoreline



effective. The oil released is largely dispersed by the interaction with mineral fines (OMAs) but some free oil is also likely to be released which may need to be recovered with sorbents. Since the distribution of shingle and cobbles is determined by the wave energy to which the shoreline is exposed, large cobbles and boulders may need to be redistributed higher up the shoreline and away from the water's edge once clean, to maintain the shoreline's original profile.

Another approach that is more appropriate for areas where wave action is less vigorous is to use lances to provide water jets to agitate the substrate and dislodge oil trapped between the stones. The technique is usually combined with low-pressure flooding to carry the released oil to the water's edge for recovery.

An alternative technique in areas where there is insufficient wave energy for surf washing is for the oiled shingle to be transported to a location where batch washing in concrete mixers can take place. If the material has to be returned to the same site after it has been washed it will be important to keep track of each batch. If the cleaned product is then deposited at the water's edge, the greasy texture that often remains after being discharged from the concrete mixer will soon dissipate.

Attempts to wash shingle and cobbles in a continuous process, rather than a batch process, using industrial mineral processing plant has met with mixed success primarily because of the difficulties of dealing with the accumulation of fine sand particles. In addition, the size of the equipment is substantial and, once constructed, is not easily moved. Even if the practical issues can be overcome, transport between the source of the material to be washed and the processing plant will dictate whether the approach is viable.

Asphalt pavement

If oil stranded on a shingle beach is allowed to weather it can form what is known as an asphalt pavement, so called because the agglomeration of weathered oil and pebbles forms a resilient surface reminiscent of tarmac. It is resistant to further wave action and the oil beneath this protective layer is trapped within the beach substrate where it can remain unchanged almost indefinitely. Degradation of the oil proceeds only slowly because the oil is not exposed to air or light. Once the surface layer has been broken up, and if necessary removed for disposal, the oil in the underlying layer can be flushed out or the material transported to a wash station for treatment.

Cliffs and rocky coves

In many cases the base of cliff faces can be accessed only with great difficulty, and can present an extremely hazardous working environment. Typically, cliffs and inaccessible rocky coves are highly exposed and are best left to clean naturally unless there are overriding reasons to do otherwise. Unless the oil has been thrown up to extreme heights by exceptional weather conditions, and is therefore unlikely to be reached by the sea under normally prevailing conditions, residual staining would be expected to diminish markedly over two or three seasonal cycles. However, if cleaning is necessary, for example, due to specific environmental issues, public accessibility or visibility from commercially important amenity areas, strict safety precautions are called for. Such precautions are vital to manage the risks of hazards such as rock falls or becoming cut off by the tide or strong

waves, or simply to ensure that personnel can be recovered safely in the event of a work-related injury.

A further consideration is how to retrieve waste from such locations. If there is foot access, bagged waste can be passed hand-to-hand along a human chain. Depending on the configuration of the cliff face or rocky cove, an aerial ropeway might be a possible alternative, or a crane located at the cliff top could be used both to lower personnel to the worksite and to lift out oily waste. In cases where a substantial quantity of waste needs to be removed, an approach from the sea might be considered, but even in clement weather swells can produce dangerous conditions, not least with regard to submerged rocks which are frequently found at the base of cliffs. The use of heavy-lift helicopters has been employed where there is no other option. However, because of the constraints on recovering waste by air or sea, and to make the most effective use of these resources, the retrieval of waste will need to be undertaken as a single one-off operation where possible. Careful consideration should also be given to choosing an appropriate site where waste can be amassed and stored securely until it can be collected; such a site will need to be accessible either from the water or the air depending on which option is chosen.

Ports and harbours

One of the main concerns when working in ports is that clean-up operations are appropriately managed so that the disruption of port activities is minimized. However, in principle, once bulk oil floating within a port or harbour has been recovered, the solid faces of wharves are relatively easy to clean. On the other hand, wharves or docks suspended on piles may present a more difficult task once oil has drifted underneath them.

Mobile oil migrating beneath wharves can be a continuing source of oil contamination and sheens, as water currents generated by vessel movements flush it out. It may be possible to position vessels intentionally and use propeller wash to flush out free oil from underneath the wharf so that it can be recovered from the water surface. The remaining residues may require physical intervention. If clean-up crews are able to access the area beneath the wharf, issues such as adequate ventilation and tidal rise and fall should be carefully evaluated. In areas of significant tidal range it may be possible to work from the water at certain states of the tide, or from negative-reach hydraulic platforms (i.e. 'cherry pickers' where the working platform is able to extend below the level of the base unit) operating from on top of the wharf or quay.

In ports and harbours hot-water high-pressure washing is almost exclusively used to clean residual oil from berths and wharves in conjunction with light inshore booms and skimmers or sorbents to contain and recover the oil released. However, as well as removing the oil from concrete structures, hot water applied at high pressure can also remove the protective surface layer of the concrete, exposing the less resistant material beneath. It is therefore advisable to optimize temperatures and pressures on a test area before embarking on a full-scale operation.

In many ports, various residues such as mixtures of sediment, algae and historic oily residues tend to accumulate along the waterline at the same points where spilled oil accumulates. When oil is removed using hot-water high-pressure washing these deposits fall into the water and sink, and

can become a source of persistent sheens. To avoid this, it is advisable to incorporate the use of nets, sorbent mats or a gutter arrangement to catch this material as it is washed off.

Oiled marine fouling, such as shellfish and algae attached to the surfaces of port structures or under wharves can also be a source of continuous sheens. If accessible, such fouling can usually be scraped off with little difficulty, carrying the oil with it. As mentioned earlier, material removed in this way needs to be caught before it drops into the water, for example by using nets or by working off a floating pontoon where debris falling onto the deck can be collected and bagged.

Sea defences

The wide variety of sea defences, including broken rock or rip rap, rock armour, gabions, concrete blocks of various designs (Tetrapods, Dolos, Xblocs, Accropodes, etc.), that are used to build revetments and breakwaters present significant difficulties for clean-up. They are designed to absorb wave energy by presenting a permeable barrier, allowing seawater to pass through them while dissipating its energy. Unfortunately this also allows all types of flotsam and jetsam to become lodged within the open structures as well as allowing floating oil to move freely through it. The trapped debris acts as a sorbent material, retaining oil and providing a source of continuous oil release and sheens that diminish slowly over time.

With the appropriate safety measures in place (e.g. recognizing the risks of being washed off the structure by waves, slipping on oily surfaces and falling into the gaps between the blocks) the exterior of these structures can be cleaned with high-pressure washing. However, cleaning inside the structures is more difficult. If it is possible to enter safely into the structure it may be possible to take out much of the contaminated debris, thereby removing the source of leeching oil. Even with most of the debris removed, some of the oil may continue to flush out for some time. Flushing lances might be used to flush out oil from within the structure or, in temperate climates with the approach of summer, a passive approach might be considered as warmer water temperatures encourage the remaining oil to be flushed out naturally. The released oil might be left to dissipate naturally or a sorbent array could be deployed to recover it.

The clean-up approach selected will depend on the degree of contamination and level of sheening produced, but more importantly on the types of services provided by the adjacent shoreline. Passive cleaning with sorbents may be an appropriate solution in certain circumstances, but in cases where sheens affect a prestigious tourist facility or aquaculture centre it may be justifiable to consider more radical remedial action. One option in extreme circumstances might be to dismantle the structure during the summer months when there is less need for sea defences and transfer the individual components to a cleaning station; after cleaning, the components can then be returned and reassembled. Whether this is economically viable depends on the risk of significant commercial consequences being weighed against the cost of such an operation. In countries where sea defences form a significant part of the coastal infrastructure and manipulation of the block-work is carried out routinely, the necessary machinery is likely to be readily available and the costs may not be prohibitive. However, in most countries, putting in sea defences represents a one-off civil engineering undertaking of considerable proportions, and the cost of dismantling them would probably be judged disproportionate.

Summary

Shoreline clean-up is the most publically visible aspect of oil spill response, and its success very often depends on how it is perceived by the public. This, in turn, is usually determined by how well the incident management team are able to interact and communicate with the public and the media, explaining the actions that are being taken and providing up-to-date information on progress but also on any setbacks suffered. In many cases, public interest will focus on the effects of the spill on the environment and the efforts being made for the rehabilitation of oiled wildlife. The incident management team will be concerned as much with these aspects as with the appropriate response strategies, volunteer management, effective supervision of a large workforce and the various types of equipment necessary to clean the shoreline.

The clean-up techniques selected should be informed by NEBA which provides a process for balancing environmental concerns against the demands of human uses of the shoreline. When tested against NEBA, the techniques that are likely to score highly are those that minimize the quantities of waste for disposal; these are often likely to include techniques involving manual rather than mechanical removal of contaminated sediment. In the right conditions, techniques that avoid the removal of beach materials entirely, such as surf washing, are likely to score higher still.

The skills and abilities of the management team will be fully tested in achieving the agreed end-point criteria and in reaching consensus on the consequent termination of the shoreline response. Authorities and officials who become involved in the response to a spill would be well advised to note these pressures. Ultimately a successful and effective response can only be achieved by all concerned parties making active and constructive contributions and working together towards the common goal of mitigating the impact of the oil spill, both with respect to the environment and to the affected communities.

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Appendix 1: Example volunteer registration form

▶ Volunteer details

Full name:

Address:

E-mail:

Phone number: Home: Mobile: Work:

Assigned to team: Assigned to task:

Availability: (specify period).....

Registration date (DD/MM/YY) :

Time:

▶ Skills and Training

Organisation membership? (specify):

Profession:

Previous training:

▶ Health and Welfare

Allergies none yes, specify

Dietary requirements none yes, specify

Particular chronic disease none yes, specify

Blood group A+ B+ AB+ O+
 A- B- AB- O-

Vaccination Tetanus Polio Hepatitis A
 Hepatitis B Rabies

Family doctor

Full name:

Address:

Phone number:

Contact in case of emergency

Full name:

Relationship:

Address:

Phone number:

▶ Image Rights

While volunteering, I am liable to be photographed and videoed for non-commercial use, for educational and worksite monitoring purposes. I agree to give up my image rights by ticking this box

Registered by

Full name (authority):

Date and location:

Signature

The volunteer

Full name (volunteer):

Date and location:

Signature:

Appendix 2: Example daily worksite sheet

ONE SHEET PER WORKSITE

MUNICIPALITY:

SITE:

DATE:

to be sent each evening to fax n°: email:

PERSONNEL		TECHNIQUES ⁽²⁾	EQUIPMENT USED			POLLUTED WASTE		ADDITIONAL COMMENTS	EXPECTED REQUIREMENTS FOR NEXT DAY
NUMBER	ORIGIN ⁽¹⁾		QUANTITY	TYPE ⁽³⁾	ORIGIN ⁽¹⁾	QUANTITY _(m3)	NATURE ⁽⁴⁾	INCIDENTS, BREAKDOWNS, TEAM CHANGES	PERSONNEL / EQUIPMENT

ORIGIN ⁽¹⁾		TECHNIQUES ⁽²⁾	TYPE OF EQUIPMENT ⁽³⁾			NATURE OF POLLUTANTS ⁽⁴⁾
Equipment* Municipality Nearby municipalities, fire brigade, stockpile... Civil protection, Army, private* Other*	Personnel* same as equipment + <ul style="list-style-type: none"> • Local fire brigade • Nearby fire brigades • Municipality reserve • Volunteers 	Manual collection Mechanical sand screening Pressure washing	Heavy machinery Earthmoving equipment (e.g. excavator) Farm machinery (e.g. tractor, trailer...) Water supply means Tyrolean traverse, nautical means, Other*	Specialised equipment Booms, skimmer Sand screeners, pressure washers, transfer pump, impact hose Storage: tanks, containers, big bags... suction pumps...	Disposable products Geotextile, sorbents washing agents Other*	Liquids to pastes Heavily polluted solids Lightly polluted solids Polluted stones Polluted sorbents/nets Polluted seaweed Polluted litter

* Specify

Source: Cedre, 2013a

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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.

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