Oil Spill Monitoring
BACKGROUND PAPER

Australian Government
Australian Maritime Safety Authority

MARITIME NEW ZEALAND

Wardrop Consulting

CAWTHRON

Acknowledgements

This Handbook has been prepared by Wardrop Consulting (Australia) in association with the Cawthron Institute (New Zealand) at the request of the Australian Maritime Safety Authority (AMSA) and New Zealand Marine Safety Authority (MSA). A number of people and Agencies have contributed to this work and are acknowledged below (in alphabetical order).

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National Library of Australia Cataloguing-in Publication Data: AMSA, 2003. Post Spill Monitoring: Background Paper. Prepared by Wardrop Consulting and the Cawthron Institute for the Australian Maritime Safety Authority (AMSA) and the Marine Safety Authority of New Zealand (MSA). Published by AMSA, Canberra.

ISBN: 0 642 70991 2

Authors Note: This document should be read in association with the Oil Spill Monitoring Handbook.

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Cover only updated (new AMSA and Maritime NZ logos) 2006.
Cover photo by Jamie Storrie, Department of the Environment and Heritage.

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1.0 INTRODUCTION

1.1 The Purpose of this Document

The purpose of this Background Paper is to provide guidance about the nature, justifiable scope, and scale of post spill monitoring programmes. It focuses predominantly on post spill monitoring of oil spills, although the concepts presented are generally applicable to all types of marine spills.

The Background Paper defines and discusses the rationale for classifying post spill monitoring into two general "types": Operational (Type I) and Non-Operational or Scientific (Type II) monitoring. It explains the significance of these terms, addresses funding and cost recovery aspects, and describes the key design aspects that must be considered when establishing a monitoring programme.

It directly supports the Oil Spill Monitoring Handbook (AMSA, 2003), which is designed to provide field guidance for the planning and execution of monitoring of oil spills for operational (response) purposes.

1.2 Reasons for Monitoring Oil and Chemical Spills, Response Actions and Effects

Oil and chemical spills pose a threat to the environment, and the potential for damage, or the actual damage caused, is a major public concern. Indeed, the most often stated objective of spill response efforts is to protect the environment, or to minimise environmental damage. The term "environmental damage" includes short-term and long-term effects on the natural, physical, economic and social environment (including risks to human health) that may be attributable to the spill or from subsequent spill response activities.

To address the various concerns raised about the effects of a spill, and any associated cleanup response, some form of monitoring is usually required. Spill monitoring has a very broad scope and includes all the procedures undertaken to obtain and process information relating to the behaviour and fate of a spill, its effects, and the effects of response activities.

As the feedback provided by spill monitoring will directly influence the priorities, strategies and methods employed during a spill response, it is important that relevant, quantitative and accurate information is obtained and made available. For example, monitoring to ensure particular response activities are justifiable and/or effective need to show that:

- Response efforts are directed at areas where the most oil/chemical has been spilled, and there is the greatest potential to recover spilt oil/chemical.
- Protection and cleanup strategies are directed at the most sensitive areas or resources.
- Cleanup strategies are effective and result in less damage than untreated oil or chemical.

Monitoring may also be required for reasons not directly linked to the spill response. For example, the collection of information to calculate economic damages, to quantify environmental impact, to identify the source of the oil for prosecutions, or for purely scientific reasons.

2.0 TYPES OF MONITORING

2.1 The Need to Define Operational and Non Operational Monitoring

Following an oil spill, both government and non-government agencies are likely to propose or implement the monitoring that they judge is necessary for the response and to gather relevant information about the spill. The monitoring scope and objectives will vary widely to reflect the roles and focus of the specific response and environmental agencies involved.

The need to provide guidance about the type of monitoring required has been the subject of considerable discussion in the Australian National Plan Environment and Scientific Coordinator's (ESC) Workshops (Storrie, 1996; Wardrop, 1997; Dutton, 1998, 1990), and elsewhere (Mearns, 1995).

Much of this discussion has been tied to issues of "who pays". In particular, what monitoring is likely to be considered a legitimate response cost that can be recovered from responsible parties (the spiller and their insurers), or which can be funded directly by National contingency funds (AMSA or MSA) or by other agencies. The need to identify wider sources of funding for various types of post spill monitoring was also identified following the "Era" spill in South Australia in 1992 (Wardrop and Wagstaff, 1996). Since then the International Oil Pollution Compensation (IOPC) Fund 1992 Claims Manual has clarified the position of the international compensation funds (IOPC, 1992).

One outcome of the ESC workshop discussions was the classification of post spill monitoring into two general "types" defined according to the primary objectives of the programme (Wardrop and Wagstaff, 1995):

- **Type I (Operational) Monitoring**; which provides information of direct relevance to spill response operations, i.e information needed to plan or execute response or cleanup strategies. These programmes are an integral part of the response and as such are funded from the same sources as other components of the response. They are also subject to the same constraints (see Section 2.2).
- **Type II (Non-operational or Scientific) Monitoring**; which relates to non-response objectives and includes short term environmental damage assessments, longer term damage assessments (including recovery), purely scientific studies, and all post spill monitoring activities. These programmes are usually not integral to the response, and funding is less well defined (see Section 2.3).

Figure 1 Subsurface Marine Monitoring
(Photo: Cawthron Institute)

Operational (Type I) and Non-Operational or Scientific (Type II) monitoring have very different objectives which significantly influence the monitoring methods likely to be used, the degree of scientific rigour required to meet the monitoring objectives, and the scope of studies. These in turn, have a significant bearing on the cost of the monitoring, and who will pay for it. The monitoring type does not relate to any consideration of whether a programme is justifiable.

The key difference between the two types of monitoring is the objective of the study, i.e. the reason it is undertaken. While both types of monitoring may be undertaken during a spill response, and both may be funded, the type of monitoring largely determines who has responsibility for determining the appropriate scale and design of the study, and who should pay the costs for the programme.

2.2 Type I Monitoring

Type I (Operational) monitoring is generally characterised by:

- Having well established methods.
- Being relatively straightforward to implement.
- Having a limited scope (area, time and scale).
- Being relatively easy to define in terms of its scope and objectives e.g. determining;
    - spill type.
    - spill volume.
    - trajectory.
    - where equipment staging posts should be located.
    - distribution and amount of oil at sea or on shorelines, etc.

Type I monitoring can include any physical, chemical and biological assessments which guide operational decisions (see Table 1).

Environmental damage assessments can also be considered Type I programmes if they are directly focussed on operational needs. For example, assessing potential or actual biological effects of spilt oil and various response methods in order to select appropriate response and mitigation methods or to determine when to terminate a response activity. Initially, such biological assessments usually combine existing data, local knowledge, and limited field assessment to quickly provide information to the response decision makers.

The design of a Type I monitoring programme requires judgements to be made about scope, methods, data inputs and outputs that are specific to the incident response. These judgements must balance the operational needs of the response with the logistical and time constraints of gathering and processing information, and the level of certainty needed.

Usually, there is a need for information to be collected and processed rapidly to suit response needs, with a lower level of sampling and accuracy needed than for scientific purposes. As a consequence, the scale of monitoring for Type I purposes is often quite different to that undertaken for Type II purposes.

2.3 Type II Monitoring

Type II (Non-Operational or Scientific) monitoring includes any monitoring that is undertaken for purposes other than providing information to guide a spill response. It almost always requires expert design and execution by trained individuals.

Type II monitoring will often extend well beyond the termination of response operations and generally has objectives relating to attributing cause-effects to the spill or to the associated response. This may be required for legal (prosecutions) or purely scientific reasons. Consequently, such studies are required to account for natural or sampling variation, and study designs must be robust and produce defensible data.

Examples of Type II monitoring include studies to help future operational decision-making e.g. comparison of the long-term effects of different response options, rates of biological recovery over time following a spill, or assess changes in community or population structure caused by a spill. However, there are a very large number of possible studies that could be, and have been, undertaken (Table 1, Table 2 and Section 6.2).

Figure 2 Plankton Sampling
(Photo: Cawthron Inst.)

3.0 DEFINING A JUSTIFIABLE SPILL MONITORING PROGRAMME

3.1 Type I Monitoring

3.1.1 Scope and Scale of Type I Studies

Establishing a rigid suite of Type I monitoring objectives, activities and methods that is of an “acceptable” scope and scale is difficult because monitoring needs will vary between spills according to a large number of factors. These include the size of the spill, the nature of the product spilled, the character of the environment into which it is released, the resources at risk, spill response needs, as well as prevailing legislation, insurers, political factors, etc.

Nevertheless, there are a range of Type I monitoring methods suited to obtaining information to meet operational objectives. Guidelines describing common Type I monitoring methods have been prepared and are included in the Oil Spill Monitoring Handbook (AMSA, 2003).

However, even with a defined method, a judgment must still be made about whether monitoring is “necessary”, and whether the scope of the monitoring is “reasonable”, to reach appropriate spill response decisions in an appropriate time frame, and with an acceptable level of accuracy. This is a judgment that must reflect the circumstances of the spill, so hard and fast rules are inappropriate. Guidelines are provided in Attachment A.

Table 1 Historical Examples of Type I and Type II Monitoring in Australia

Incident, Date and Location	Type I		Type II	
	Programme	Comment or Reference	Programme	Comment or Reference
Port Adelaide River 1985 South Australia	None recorded	-	Monitoring of mangrove defoliation, mortality, recovery	Small scale 2-year study funded by the (then) S.A Dept. of Environment and Planning Unpublished SA DEP Report.
			Monitoring of oil retention and degradation in sediments	
"Sanko Harvest" 1991 Esperance, Western Australia	Monitoring of Seals and Sea Lions during cleaning	Very detailed physiological monitoring of cleaned Seals and Sea Lions. Ref: Gales, N. 1991.	Effect of fertilizer on marine environment including nutrient levels	Report commissioned by WA EPA. Ref: WA State Committee report to the Min. Transport DMH No: DMH P4/91
"Kirki" 1991 Western Australia	Aerial surveillance of slick	Ref: Aust. Govt. Dept Transport and Communications, 1992.		
	Weather and sea state	See Attachment 1 to the above.		
"Era" 1992 South Australia	Survey and assessment of oil distribution	Limited scope study to determine whether cleanup was needed (i.e. whether there was likely to be any environmental benefit) or feasible.	Fate of oil in sediments	5 year study. Ref: Wardrop et. al., 1997
			Effects of oil on mangroves.	
	Assessment of mangrove damage		Effects of oil on seagrasses	Ref: Connolly, 1994
			Effects of oil on fish	Ref: Bellette et. al., 1994
"Iron Baron" 1995 Tasmania	Aerial surveillance of slick			
	Monitoring of shoreline oiling (Aerial and ground survey)	Programme extended throughout the 6 month response.	A number of studies of the effects of oil and cleanup on, and recovery of, various types of biological community.	Extensive monitoring programme over 1-2 years. Funded by the spiller. Ref: Govt. Tasmania, 1997
	Oil characterisation	Samples routinely collected. Some tested.	Fate of oil in sediments	
Port Stanvac Spill 1999 South Australia	Monitoring of dispersant effectiveness	Ref: AMSA, 2000a		
"Laura D'Amato" 1999 Sydney, N.S.W.	Aerial surveillance of slick	Ref: AMSA 2000b		
	Air and ground monitoring of shoreline oiling			

Table 2 Historical Examples of Type I and Type II Monitoring in New Zealand

Incident, Date and Location	Type I		Type II	
	Programme	Comment or Reference	Programme	Comment or Reference
"Dong Won 529" 1998 Stewart Island	Aerial surveillance of slick	–	–	–
	Air and ground monitoring of shoreline oiling	Predominantly aerial response due to exposed and remote location		
	Wildlife assessment	Identification of resources at risk		
"Sea Fresh 1" 2000 Chatham Island	Air and ground monitoring of shoreline oiling (diesel)	–	Biosecurity assessment and eradication of invasive exotic seaweed on vessel hull.	Funded by Ministry of Fisheries & Department of Conservation
"Jody F. Millennium" 2002 Gisborne	Aerial surveillance of slick	Daily overflights during response and following dispersant use	–	–
	Ground monitoring of shoreline oiling	SCAT based approach		
	Intertidal biological survey Subtidal video and SCUBA survey	Very limited scope targeting recreational seafood Tissue analysis results used to lift harvesting ban		
"Tai Ping" 2002 Bluff	Aerial surveillance	No oil spilt	–	–
	Shoreline assessment	Shoreline segmentation and response planning		
	Wildlife assessment	Identification of resources at risk		
	Trajectory modelling	Dye release to verify trajectory model		
"Taharoa Express" 2003 Northland	Air and ground monitoring of shoreline oiling	No oil spilt	–	–
	Assessment of dispersant effectiveness	Lab test of dispersant efficacy		
"San Domenico" 2003 Wellington	Air and ground monitoring of shoreline oiling (diesel)	Observation of sheens in relation to identified resources	–	–

Two useful "rule of thumb" guidelines are:

- Monitoring is probably necessary if monitoring data has a high probability of contributing to the response decisions and if the consequences of this influence on response decisions is likely to be significant.
- Monitoring scope and scale is probably reasonable if the cost and commitment of labour is within what would be expended by a response or other agency if costs were to be born by that agency.

3.1.2 Funding and Cost Recovery

Currently, Type I monitoring costs may be reimbursed by AMSA and the MSA under the respective National Contingency Planning frameworks, alongside other operational costs of a response. They are later recovered from the spiller's insurers; if the spiller is identified.

Like all other operational aspects of the response, Type I monitoring programmes must be "reasonable" in their scope, design and subsequent costs if these are to be paid without challenge. A good overview of the need for reasonable and cost effective response operations is provided by Gregory et al., 2002.

3.2 Type II Monitoring

3.2.1 Scope and Scale of Type II Studies

Compared to Type I studies, the objectives and scope of potential Type II studies encompass a far greater variation, depending on the purpose of the acquired data (e.g. scientific study, legal use, etc). Examples are provided in Section 6.3.

Consequently, considerations of what constitutes "reasonable" Type II monitoring is subject to greater debate. Some authors advocate continuous monitoring in areas where spills may occur (e.g. Batten et al., 1998, Dobroski et al., 1990), although this may be difficult to justify on the basis of spill risk purposes.

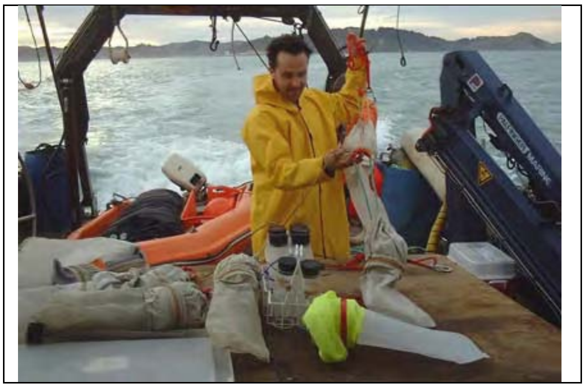

Figure 3 Marine Monitoring
(Photo: Cawthron Institute)

Others have highlighted the importance of understanding pre-spill conditions in determining possible spill effects (e.g. Cowell and Monk, 1979; Page et al., 1996; Pearson et al., 1999; Wooley, 2002), or have emphasised the need for multi-year sampling (Gilfillan and Page, 2003) and suggested that some long-term post spill monitoring can be of limited value due to confounding from other sources (e.g. Boehm et al., 2003).

Therefore, defining what is a "reasonable" scope and scale is vital, and relies, like all good monitoring programmes, on having a good design, clearly defined objectives and outputs, and appropriate resources. The discussion in Section 4 provides guidelines for the design of both Type I and Type II monitoring programmes.

3.2.2 Funding and Cost Recovery

Type II monitoring costs are not currently reimbursed by AMSA or the MSA, and in some past cases have not been funded from the vessel's insurer, the Protection and Indemnity Clubs (refer to Table 1).

New Zealand and Australia do not have legislation that requires ecological (i.e. non-economic) damages to be assessed, and there are no statutory provisions for claiming compensation for environmental damages. Therefore, any environmental effects monitoring must be funded by the responsible Government agencies or voluntarily by industry or academic organisations.

Costs of monitoring undertaken for prosecution purposes may be recoverable through the legal process but interim costs must be borne by the responsible Government agency. In some cases, the spiller may also independently commission monitoring programmes or agree to fund them.

To date, there has not been an adversarial approach to monitoring programmes in Australia or New Zealand, with a generally high level of co-operation between spillers response agencies and monitoring agencies. This may change in response to the increasing adoption of legislation which set fines for spills according to the level of environmental damage.

In some other parts of the world, post spill ecological damage assessments are required by legislation. For example, the United States' Oil Pollution Act (OPA, 1990), specifies a requirement for "Natural Resource Damage Assessment" (NRDA) (e.g. Ofiara 2002), and also the methodologies to be used (French et al. 1996, Huguenin et al. 1996, Reinharz and Burlington 1996, Reinharz and Michel 1996). NRDA costs are recoverable from the spiller, and outputs are used to define levels of environmental damage so that compensation can be sought.

Because of the high financial costs associated with undertaking NRDA studies, and in the subsequent compensation they may require, a high level of defensibility is needed for data used to quantify spill effects. For large spill incidents, conflicting damage assessments may be presented to court by the spiller or their insurers. The Exxon Valdez is a classic example of this (e.g. Holloway 1996).

Other nations have adopted a less proscriptive approach. The Russian Federation, for example, requires that post spill monitoring, including damage assessments, are undertaken but does not define the required scope or detailed objectives. These must be negotiated and approved on a case by case basis. Costs are met by the spiller.

Korea has produced a manual for fisheries and aquaculture compensation claims under the International Oil Pollution Compensation Funds (IOPC) which describes the scientific information needed to prove environmental damage (e.g. Lee, 2002). However, the funding of such investigations are constrained by the same aspects discussed previously and requires studies to be reasonable in their scope and scale.

These international examples of monitoring, particularly NRDA monitoring in the U.S., are widely reported in the literature, and paint a picture of monitoring that is of only limited relevance due to the absence of legislation requiring such monitoring in New Zealand and Australia.

4.0 MONITORING PROGRAMME DESIGN

For any monitoring programme, whether Type I or Type II, to be both "appropriate" and "reasonable" it is vital to have clearly identified objectives, good design, specified outcomes, and defined methods of data acquisition, transfer and assessment. If these are not in place before the programme is implemented, monitoring is unlikely to:

- Provide satisfactory answers.
- Be cost-effective, or
- Meet responder or stakeholder expectations.

Examples of the importance of good design in relation to oil spill response are provided by Gilfillan et al., 1996, Green and Montagna, 1996, Paine et al., 1996, and Peterson el al., 2001. A number of other texts provide a comprehensive overview of study design issues, e.g. AS/NZS, 1998; ANZECC, 2000; Baker and Wolff, 1987; Cooper and Rees, 2002; Davis et al., 1980;ISO, 1991; Kingsford and Battershill, 1998, PSEP, 1997; USEPA, 2001 (see Section 6.4).

The most comprehensive documents available on oil spill monitoring methods is the Guidelines for the Scientific Study of Oil Spill Effects (Petroleum Environmental Research Forum Project 94-10, 1999) described by Robertson, 2001, with a range of ASTM standard guides also available (e.g. ASTM 1986, 1997).

4.1 Setting the Objectives of the Study

Setting objectives is the first step in defining what a monitoring programme needs to deliver. In its simplest form it is a statement of what the monitoring programme seeks to measure (e.g. descriptive; measurement of change; determination of cause and effect), and defines the parameters to include in monitoring.

4.1.1 <u>Considerations when Setting Objectives</u>

When setting objectives it is important to understand how monitoring information will be used in the decision making process. If the available resources are insufficient to meet the set objectives of the monitoring programme, the programme is not worth undertaking. Some key aspects to consider when setting objectives are:

- What specific question(s) needs to be answered?
- Have knowledge gaps been identified and addressed?
- Have the limitations of not having information been evaluated?
- Will the information gathered address major stakeholders' needs?
- How will the information be managed and communicated?
- Do specific objectives:
    - Clearly and concisely communicate the purpose of monitoring?
    - Specify what the monitoring will achieve?
    - Indicate when the monitoring is complete?

It is also essential that objectives are achievable. For example coastal and estuarine systems are highly complex and natural ecological variation is almost always high. Detecting oil-water or oil-sediment interactions, establishing cause and effect links to a spill or response, or assessing longer-term effects (e.g. recovery) may be difficult. There is little value in commencing a study that is unlikely to unequivocally show impacts that are of environmental relevance and can be related to a particular spill event.

4.1.2 Responsibility for Setting Objectives

For Type I monitoring programmes, primary objectives will generally be determined by the Incident Controller or other nominated person within the Incident Management Team (IMT). Responsibility for designing or developing a monitoring programme should be clearly assigned within the IMT. The monitoring team(s) will then be tasked with collecting the information needed to meet the set objectives.

For Type II studies, responsibility for commissioning monitoring should be the relevant Government Agency, Statutory Authority, the spiller or an academic institution (for purely scientific studies) depending on programme objectives. Responsibilities will vary and guidelines for commissioning and, if required, approving Type II monitoring programmes should be documented in relevant State/NT or National Plans.

4.2 Determining the Scale of the Programme

While it may be stating the obvious, it is important that monitoring reflects the scale and potential effects of the spill, and addresses key environment issues relevant to the spill. A number of factors must be taken into account when defining monitoring requirements, but primarily:

- The characteristics of the oil or chemical;
- The type of discharge (single or continuous release);
- Dispersion and dilution rates; and
- The characteristics of the receiving environment.

The appropriate scale for a programme will be determined largely by the specific objectives of the programme. Where variability is high, the time and resources required to reliably detect an impact may require a large monitoring effort. The need for such effort must then consider whether the objective of the study is of sufficient importance to justify the monitoring needed, i.e. the time and resources required may be considered "unreasonable" unless the objective of the study is of high importance.

Figure 4 Buried Layers of Oil
(Photo: Wardrop Consulting)

A very wide range of different approaches can be taken when trying to detect environmental impacts (see Section 6.4).

The most common design is to compare one or more oiled sites to unoiled ("control") sites. Sometimes it is possible to compare post-impact conditions on a site with pre-impact ("background") conditions provided by baseline data collected before a spill, but this is usually not available.

In either case, variation in some parameters makes it difficult to establish a cause-effect relationship between the oil and the change. Variation may naturally occur between sites (spatial variation) or may occur over time (temporal variation). The latter may be seasonal or related to shorter-term factors such as weather sea state or tidal conditions.

4.3 Setting the Spatial Boundaries of the Study

The spatial boundaries of a monitoring study will depend primarily on the actual or potential area affected by the spill. Spatial boundaries should be sufficient to meet monitoring objectives; usually determining impacted areas and the level of effects, linking effects to the spill source, and supporting decisions on cleanup strategies.

The boundaries should also be sufficient to cover representative areas of each:

- Type of substrate.
- Ecological community.
- Shoreline energy level.
- Degree of oiling.
- Cleanup method employed.

4.4 Selecting Monitoring Sites

When attempting to detect impacts or compare areas it is important to account for pre-existing influences on the environment.

4.4.1 <u>Stratification of Sites</u>

Wherever possible monitoring sites should be selected on the basis of one or more defined “strata” such as substrate type (cobble beaches, rock platforms), tidal elevation, or areas of biological importance (e.g. seagrass beds). This “stratification “ minimises non-spill related variance and allows sites to be directly compared where the key difference is the impact of the spill or cleanup method used, not pre-existing differences like tidal elevation.

4.4.2 <u>Selection of Control Sites</u>

When comparing impacted sites to unimpacted sites, the unimpacted sites should be as similar as possible to impacted sites, should be representative of wider areas, and be free from obvious sources of confounding influences unrelated to the spill. In particular, key physical factors (i.e., temperature, salinity, currents, aspect, habitat type, shore profile, substrate) should not differ significantly between sites. Multiple sites are usually required to account for natural variability between control and impact sites.

Control sites can also include areas that have been impacted by the spill and are left to recover naturally. These sites are used to assess the effects of cleanup options, and/or natural recovery. It is often difficult to convince people that leaving impacted sites uncleaned is an appropriate thing to do.

4.5 Defining the Level of Accuracy Required

As noted in Section 4.2, natural variation of parameters can make it difficult to obtain data that clearly show changes attributable to a spill. Generally, detection of small changes will require more sampling and replication than detection of gross changes. However, other constraints may limit the scale of the monitoring programme.

The required level of accuracy will depend entirely on the objective of each monitoring study and the end-use of the data.

Some guidelines are provided in the Oil Spill Monitoring Handbook about what is appropriate (AMSA, 2003). For example, a few samples may be sufficient to guide response decisions in ranking oiled areas for cleanup priorities, however, data for damages assessment or legal use will require a high level of accuracy and consequently this may require a large number of samples.

Even in the case cited above, there may be no clear consensus on this as it could be argued that cleanup priority in some cases may be vital in minimising environmental damage and that some precision is required. This of course would have to be assessed in consideration of the time that may be required to obtain precise data.

Again, compromise is required and it is worth remembering that these monitoring programmes are usually designed and executed during an emergency situation where time and resources are likely to be limited. This is particularly true in the design of Type I monitoring programmes.

4.6 Selecting Suitable Parameters for Measurement

Key components to consider when deciding what parameters to include in monitoring include:

- Are human, equipment and other required resources available?
- Are selected parameters able to detect changes/ trends?
- Can parameters be measured in a reliable, reproducible and cost-effective way?
- Are parameters appropriate for the time and spatial scales of the study?
- Are appropriate field techniques available?

4.6.1 <u>Initial Reconnaissance</u>

For any spill, it will nearly always be necessary to collect basic information on the type and volume of the spill, and its trajectory. This information can assist in identifying key design elements of a monitoring programme and areas where further information is required. Without knowledge about where a spill is likely to end up, it is difficult to select monitoring sites or sampling and analysis methods.

In most spill situations, information on the spill trajectory can be assessed by direct spill tracking (e.g. visual observations, remote sensing), or estimated using wind and current data (manual or computer calculations) e.g:

- **Aerial Surveillance** provides a reliable and rapid method for defining the overall extent of a spill area, and identifying oiled shorelines and those at threat from the spill. Photos, video, mapping and verbal feedback all provide basic information that can be used to define information needs and response priorities.
- **Ground Surveys** allow more detailed observations of shoreline conditions including the physical structure, ecological character, and human use of shorelines. This monitoring approach can provide comprehensive detail on the resources and activities likely to be affected by a spill, the potential extent of oiling and level of impact, likely recovery, and logistical considerations for different response methods.
- **Remote Sensing** includes a wide range of techniques to detect spills using remote sensing equipment (e.g. infrared thermal imaging, side-looking airborne radar, satellite images). See Brown et al., (1999) for a comprehensive review. These techniques are not always available or suitable but can provide very useful data in some situations.

4.6.2 Sampling of the Oil

Information on the oil spilled, and samples of oil from the source of a spill, should be obtained wherever possible. This is to provide information on the properties of the oil to assist in prediction of oil fate and effects, and the selection of appropriate response options. This is clearly Type I monitoring.

For cost recovery and prosecution purposes, samples of the oil should also be collected from the slick and impacted areas to provide a direct link between the source of a spill, and the areas affected by it. These samples should be collected using techniques that allow chemical fingerprinting of the oil (including weathering) and should be collected periodically throughout the response. Samples should also be collected from other possible sources in the vicinity of the spill.

Figure 5 Water Column Sampling
(Photo: Cawthron Institute)

Oil is usually sampled via collection of discrete samples that target areas where information on oil in the water is likely to be needed e.g. adjacent to aquaculture facilities, spawning areas, food gathering sites, swimming beaches, etc. If samples are to be used for comparative purposes, reference samples should also be collected from either representative areas not directly impacted by the spill, or from areas before they are impacted (but ideally, both).

For all sampling, details need to be recorded by all personnel of the location, timing and nature of sampling and appropriate "Chain of Custody" procedures must be followed.

4.6.3 Sampling the Water Column

The water column is subject primarily to dissolved contaminants and, to a lesser extent, dispersed particulates. Background environmental conditions tend to be highly transient and will vary diurnally, seasonally, and inter-annually, as well as in relation to climatic events like storms.

Monitoring programmes need to recognise and account for such variability when determining whether to monitor, and if so, when, where, and how often.

In most spill situations, there will be very limited Type I water column sampling or monitoring. It is usual for grab samples to be taken at the water surface to collect samples for determination of oil or chemical characteristics to help guide decision-making, and for prosecution purposes. Where dispersants are used to disperse large surface slicks it is also common to use visual observations or fluorometry to monitor the effectiveness of the operation. The latter will involve sampling at a number of depths over the affected area and control areas.

However, water column monitoring for the assessment of a spill's effects on phytoplankton, zooplankton or fish is rarely undertaken due to the difficulty and cost in establishing a direct cause and effect relationship with a spill. Population level data for phytoplankton, and or zooplankton and fish, should only be considered if:

- There is a very high level of concern over water column organisms and
- Response decisions could be influenced by the outcome of monitoring.

An example of this would be where a local fishery relies on seasonal zooplankton for recruitment (e.g. juvenile lobsters). In this case monitoring may be needed to assess if zooplankton are present and what the most appropriate response decision may be. Because of potential large natural variations, establishing a cause-effect relationship is often very difficult without extensive research and timeframes seldom allow for the provision of information suitable for operational decision making.

4.6.4 Sampling Sediment and Associated Biota

In contrast to the water column, sediment is a relatively stable medium. The physical, chemical and biological characteristics of the sediment substratum may integrate transient changes from both dissolved contaminants in the water column and also deposited material. While substratum characteristics (e.g. sediment contaminants, ecological communities) will change over scales of months (e.g. seasonally) and years, they remain relatively stable over smaller time scales, and provide a good way of detecting change before and after an impact.

Except where floating slicks affect intertidal areas, the substratum in marine systems will generally only be exposed to oil or chemical impacts when the spill products sink (are either denser that the surrounding water or oil becomes entrained within sediments). Sampling outside of shallow and intertidal areas is generally a low priority, and is very unlikely to be needed for small spills, or spills of volatile, non-persistent oils. Where oil is thought to have impacted offshore marine sediments, the most common methods for sampling are core or grab samples collected by SCUBA divers or remote operated sampling devices from the sea surface. To accurately detect oiling in marine sediments, repetitive sampling at systematically selected sites is usually required.

The identification and enumeration of seabed macrofauna is usually performed on preserved samples in the laboratory with the aid of a binocular microscope, and requires specialist expertise.

The two main ecological components of the seabed environment are:

- **Infauna**, which is the assemblage of animals (often microscopic) that live buried or partially buried with the sediment matrix (e.g. worms, bivalve shellfish). Because infaunal communities may be variable or patchy, it is standard practice to take replicate samples from any one site to provide an average picture of species richness and abundance, and provide a representative sample of the species present.
- **Epibiota**, which refers to the animals and plants (e.g. sea stars, urchins, seaweeds) that inhabit the surface of the seabed. Epibiotic assemblages may be a significant feature of both rocky and soft-sediment habitats, although epibiota can be relatively impoverished in both. Infaunal assemblages, on the other hand, are a unique feature of soft-sediment habitats.

For an assessment of seafloor contaminant levels it is most relevant in ecological terms to target surface sediments (e.g. the sediment surface down to a depth of 50-100 mm) since sediment-dwelling fauna generally inhabit these sediments, and any correlation between contaminant levels and biological effects can then be determined.

4.7 Determining the Method for Obtaining Data

Monitoring methods for Type I monitoring are included in the Oil Spill Monitoring Handbook (AMSA, 2003) and for Type I and II monitoring in the Guidelines for the Scientific Study of Oil Spill Effects (Petroleum Environmental Research Forum Project 94-10, 1999) described by Robertson (2001).

Most biological sampling methods require expert input and this should be sought early in the development of a programme if there is any doubt about the appropriateness of a technique, or there are questions about whether the selected method can provide the type of information required.

When selecting monitoring methods, the following questions address some of the key aspects that must be considered:

- Can sampling be undertaken safely?
- Can appropriate data be obtained by field measurements?
- Does the design account for spatial and temporal variability?
- Will the study provide meaningful information in a relevant timeframe?
- Will samples need to be collected?
- Will sampling devices collect representative samples?
- Will sampling devices contaminate or affect the sample?
- Will samples contaminate or affect the sampling devices?
- What size of samples are required?
- Will samples need to be preserved before analysis?
- Are procedures in place to track samples and field data?
- Can potential sampling error be minimised (e.g. sampling protocols, training)?
- Can potential sampling errors be managed (see inset)?
- Can data be analysed and accessed in a timely manner?
- What resources are needed and are available for the monitoring programme?

4.7.1 Selecting Sample Locations within a Site

The choice of sampling location selection is at the discretion of the designer of the monitoring programme and no particular method is recommended. Some commonly used methods for selecting sampling locations are:

- **Authoritative or Selective Sampling.** In this case samples are taken from selected locations, e.g. from both oiled (or otherwise impacted) sites and unoiled (unimpacted) sites. These are assumed to be “representative”. This allows for a small number of samples, and hence is ideal for small Type I monitoring programmes, but has a relatively high potential for error.
- **Random Sampling**. This is a more scientifically valid method but usually requires a large number of sample locations. For monitoring that may be legally challenged, or scientifically scrutinised, this method is recommended. This is unusual for Type I monitoring though.
- **Systematic Sampling:** This sampling uses a grid or consistent pattern across the defined area. This approach is most suitable when looking for none– obvious contaminated locations, such as subsurface oil.

In consideration of the method personnel should also consider the need for repeated sampling or measurements. If sampling is non-destructive (e.g. counts of sessile invertebrates) then each location can be recorded and re-used. This reduces chance variation over time but requires careful consideration be given to whether each location is really representative of the site (if this is required of course).

If sampling is destructive (e.g taking of sediment samples) then the location cannot be reused and care needs to be taken in the design of the programme to ensure that sampling location selection methodology remains consistent. For example, if selective sampling is undertaken on the basis of “oiled” and “unoiled” areas, a method must be developed for being able to identify oiled areas in the future when, perhaps, the presence of oil is not so obvious.

4.7.2 Quadrats and Transects

Area based measures (e.g. number of animals per square metre) often use small sampling perimeters or “quadrats”. The size of the quadrat used will depend on what is being sampled and the numbers that need to be counted. If the quadrat size is too big the numbers become unwieldy, if they are too small then sampling variability problems may arise. Generally, for shoreline work, an area of 0.2 to 0.3 sq m is sufficient. The number of quadrats used will be determined by the method of selecting the sample locations and the level of confidence required by the study.

Figure 6 Intertidal Transect
(Photo: Cawthron Institute)

Transects are surveyed lines, usually passing from high to low tide, along which samples are taken. A transect is usually a straight line of a few metres to tens of metres long and perhaps 1-2 m wide, and is suited to the sampling of large, sparsely populated, or patchy epibiota. Like quadrats, transects can be positioned selectively, randomly or at regular intervals, and sampling points or quadrats can be distributed along the transect continuously, selectively, randomly, or at regular intervals.

Again, selection of method is discretionary but should be consistent within a monitoring programme and, as far as possible, between programmes.

4.7.3 Data Types

Data can be obtained in a number of forms:

- **Samples**. Oil, sediment or biological samples will require preservation, transport, storage and eventual analysis. In terms of logistics and other management resources, samples are the most costly form of data and this should be considered when detailed laboratory analysis is required. However, samples may be collected relatively easily in the field and only analysed if required.
- **Field Data**. This includes results from field tests and other on site assessments. It avoids the need for sample processing or analysis following collection, but does require a data management system encompassing quality assurance, data storage and retrieval, and systematic assessment.
- **Photo Documentation**. Photographic documentation can range from video or photo-surveys of coastlines or slicks at sea to detailed photographs of quadrats or impacted plant and wildlife. Photo documentation has the advantages that skilled interpretation of data can be done later, remotely and be centralised, and that it is a fast and relatively cheap data collection process. This overcomes problems of a shortage of skilled staff and the need to calibrate estimates by different field staff. More accurate calculations of percentage cover and numbers may also be possible.
- **Analytical Data**. This includes results of chemical and physical analysis of sediments, oils and biological samples, biological assessments of samples (e.g. plankton identification of water samples or photographs). This is usually an expert task and is consequently relatively expensive.

Data, and assessments of the data, need to be made available to the appropriate response team personnel in a suitable timeframe and in a simple and usable form. Creating the mechanism for disseminating information is a response management issue. Developing mechanisms for ensuring that information is presented appropriately and on time is a monitoring programme design issue.

4.8 Determining Sample Numbers and Sampling Schedule

As previously discussed, sample numbers and sampling frequency depend on the objectives of the study. Sampling should adequately address spatial and temporal variation, but needs to be balanced against logistical constraints of sample collection and processing, and the ability to provide meaningful information within a relevant timeframe.

Often, careful planning of sampling effort to address specific questions can reduce the number of samples that need to be collected and/or analysed. Alternatively, samples can be collected and only analysed if needed.

The frequency of sampling will depend on what is being assessed and should reflect the natural cycles of the assemblages and the type of habitat being assessed at scales relevant to the parameters being measured.

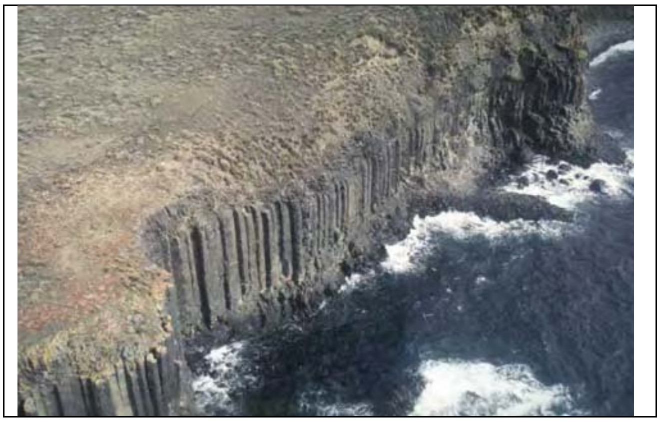

Figure 7 Aerial Surveillance to Monitor Remote or Inaccessible Shorelines
(Photo: Wardrop Consulting)

4.9 Determining the Likely Duration of the Study

Timing of sample collection could vary from a one-time sample collection (e.g. oil properties, key species present), up to a multi-year monitoring programme where sampling is conducted monthly or seasonally (e.g. TPH levels in shellfish or sediment, oiled wildlife surveys). Timing will depend on the questions being addressed, and the system being monitored e.g. dispersant monitoring, in the order of hours to days, shoreline impacts, in the order of days to years or decades.

For any Type I monitoring, the duration of the monitoring programme will be tied directly to the operational response. That is, monitoring must provide information needed for operational decisions. Occasionally, Type I monitoring extends beyond the termination of a response, for example, testing to approve the reopening of a fishery closed during a spill.

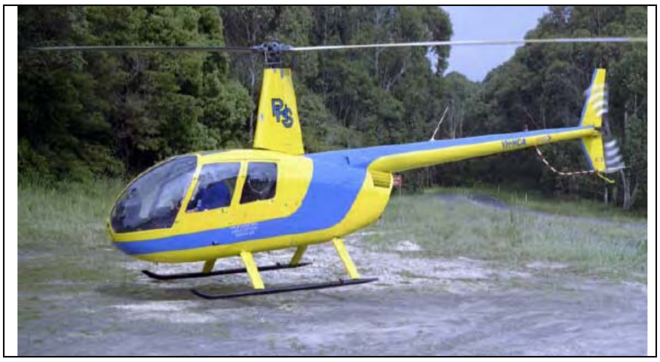

Figure 8 With Low Speed and Good Visbility, Helicopters Provide an Effective Tool for Aerial Surveillance
(Photo: Wardrop Consulting)

4.10 Logistics

Monitoring is a core component of a spill response operation. While the initial focus of any response is to prevent further spillage and contain and clean up spilt product, someone within the response team should be assigned the role of coordinating monitoring. This is to avoid unnecessary duplication of information collection, and to ensure that adequate resources are available to undertake the monitoring *necessary* to provide decision makers with the information needed to appropriately plan a response.

4.11 Data Management

Data integrity can be compromised in many and varied ways. Losses or errors can occur at the time of collection, during sample preparation and analysis, during recording of results, and during data processing, interpretation and reporting.

QA/QC programmes should always be used to minimise the risk of data being compromised and to provide a system for detecting possible sources of error. A wide range of QA/QC procedures are available. Most analytical testing laboratories will have internal procedures including sample blanks, matrix spikes, etc. It is also advisable to include a range of chemical and field blanks in a testing programme. It is particularly important during sampling for prosecution purposes that data are managed in a suitable way.

A key aspect of effective data management is accurate and timely record keeping. While time may be limited during field sampling, there is no better time for recording sample information and observations. All information should relate to a specific location and date, and should use standard descriptive terminology.

Once data are collected they need to be both accessible and conveyed to decision-makers in a meaningful way. Often this is in the form of summary reports that provide an overview of findings, rather than raw data. Adequate time and resources must be allowed to compile and check data, and to convey it appropriately.

5.0 SUMMARY

The distinction between Type I and Type II monitoring is defined according to the primary objective of the programme. Type I monitoring includes all studies relating to spill response and can be considered a response (or "operational") activity. Type II monitoring encompasses all other monitoring activities.

The type and scope of studies needed and undertaken during or after a spill response will reflect the circumstances of the particular spill.

Generally, only Type I monitoring, undertaken during a spill response, will be funded by National contingency plan s through AMSA and NZ MSA. Again the scope and scale of programmes covered will vary between spills, and even within different stages of the same spill. This, in itself, should not cause confusion or uncertainty. Rather, it means that the approach to monitoring should be flexible and that monitoring programme design should reflect the circumstances of the spill and be prepared using acceptable procedures or guidelines.

Perhaps the most difficult concept to define is when monitoring is both "appropriate" and "reasonable" in its scope and scale and it is not possible to state a single rule to stipulate what these terms mean for particular incidents.

For all monitoring programmes appropriate and realistic objectives must be set. In the case of Type I monitoring, this will generally be done by the Incident Controller or other nominated person on the Incident Management Team. The responsibility for determining "appropriate" and "reasonable" Type II monitoring is the relevant agency commissioning the work. Programmes must then be designed to meet these objectives and to deliver results in a timeframe and format that is for appropriate for their intended purpose. Guidance for Type I monitoring is provided in the Oil Spill Monitoring Handbook (AMSA, 2003) and in Attachment A. .

Figure 9 Sheen from Small Spill
Note: Oil samples are being taken from the small boat
(Photo: Wardrop Consulting)

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ATTACHMENT A: RAPID REFERENCE FOR SPILL RESPONSE MONITORING REQUIREMENTS

Trigger	Primary Objective	Rationale	Secondary Objectives	Monitoring/ Data Requirements	Ref. or Guideline
Oil spill is at sea	**Spill surveillance and tracking**	• Guide planning of cleanup activities • Indicate time and physical constraints to mounting a response, e.g. prevailing weather, site access, habitat type, etc.) • Provide information on the size, type, location, and movement of oil to identify whether sensitive areas may be impacted • Identify appropriate monitoring sites, plus sampling & analysis methods	1. Determine the extent and character of a spill. 2. Track slick movement. 3. Identify areas/ resources potentially affected. 4. Determine sea conditions/ other constraints. 5. Plan response actions. 6. Plan extent of monitoring/ assessment studies. 7. Document justification for response actions (to assist cost recovery).	Estimating sea state	**M.1**
				Locating slicks at sea.	**M.2**
				Characterising slicks at sea	**M.3**
				Aerial surveillance	**M.4**
				GPS tracking.	**-**
				Manual or computer predictions of oil movement.	**-**
				GIS maps/resource database	**-**
	Oil or Chemical Source identification	• Source investigation can usually identify the oil type and volume spilled (Type I) • Prosecution requires evidence to link spill with identified source and to eliminate alternative sources (Type II monitoring)	1. Confirm source of spill. 2. Collect legally defensible samples to link source to spill or to eliminate possible alternative sources 3. Characterise the oil by chemical fingerprinting 4. Determine the likely fate of the oil	Samples from source.	**M.6**
				Samples from slick.	**M.6**
				Water column samples.	**M.7**
				Field detection of oil in water	**M.8**
				Biological samples.	**G.1**
				Sediment samples.	**M.9**
				Chemical analysis.	**G.3**
	Oil character	• See above also. • To characterise oil and/or receiving waters, to link spill with effects. • Document/confirm the weathering of oil.	1. Determine physical character to better predict behaviour or 2. To predict efficiency of response methods 3. To determine weathering of the oil.	Chemical analysis.	**G.3**
				Physical properties of oil.	**G.3**
				Sample from slicks and films.	**M.6**
				Sample handling, control/ management	**G.1**
Oil may impact sensitive marine resources	**Identification of sensitive areas**	• Sensitive areas must be identified to assess potential impact and effects. • Potential impact to sensitive areas determines priorities for protection, response or cleanup.	1. Identify sensitive areas (geomorphology, habitat, human use etc.) and 2. Prioritise for protection or cleanup. 3. Identify logistics data (access limitations, equipment staging areas etc). 4. Use above data to define appropriate response strategies based on NEBA.	GIS maps/resource database.	**-**
				Aerial video surveys.	**M.4**
				Expert evaluation.	**-**
	Water quality	• Define environmentally important oil compounds. • Provide real-time feedback of response activities such as dispersant use. • Detect low-level water borne contaminants and assess safety of water usage e.g. contact recreation, seafood gathering.	1. Define pre-spill baseline water quality. 2. Monitor potential effects of dispersant use or shoreline washing. 3. Identify low-level waterborne contamination. 4. Assess biological exposure / bioavailability of contaminants in edible resources. 5. Monitor effect of oil and response activities.	Water column sampling.	**M.7**
				Continuous water column sampling.	**M.7**
				Sentinel organism monitoring	**M.10**
				Visual monitoring of dispersant effectiveness	**M.5**
	Water column (marine) organisms	• Resources (e.g. fish, plankton) may be of significant value • May be affected by spill or response actions • Monitoring rarely required.	1. Monitor spill and response impacts 2. Document post response recovery (Type I) or post-spill recovery (Type II)	Numerous methods depending on target species	**M.10**

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RAPID REFERENCE FOR SPILL RESPONSE MONITORING REQUIREMENTS CONTINUED

Trigger	Monitoring Type	Rationale	Objectives	Monitoring/Data Requirements	Ref. or Guideline
Fisheries present	**Effects on fisheries**	• Oil can cause a tainting of commercial species.	1. Collect samples of seafood species and 2. Analyse tissue for hydrocarbons.	Taint testing	M.11
				Sampling of tissues	M.11
				Sample handling	G.1
Oil may impact shoreline	**Shoreline assessment**	• Geographical distribution and persistence of oil influences response and monitoring design. • Determine the effectiveness and efficiency of spill response actions • Detection of spill and response physical effects.	1. Collect baseline data on impacted or potentially impacted areas, e.g. oil/ physical/ ecological character, human use etc. 2. Verify aerial surveys and existing. 3. Assess the effectiveness and effects of response activities. 4. Support decision-making for protection or restoration and document post-spill recovery	Video/photographic records	S.4
				Determine Sector/Segment boundaries	S.1
				Characterise substrate	S.2
				Determine beach profile	S.3
				Deterine surface oil	S.5
				Determine subsurface oil	S.6
				Field detection of petroleum hydrocarbons	S.7
Oil may effect sensitive shoreline resources	**Sediment quality (oil on sediment)**	• Oil may enter intertidal/ subtidal sediment. • Determine the effectiveness and impact of response activities. • Oiled sediment may release oil over time.	1. Collect baseline information on oil in sediments and extent of sinking oil. 2. Determine the likely source and extent of spill related effects. 3. Assess the effectiveness and impact of response activities. 4. Document post-spill recovery.	Discrete sediment samples	S.8
				Shoreline surveys.	S.2-S.7
				Photo quadrats and video transects.	S.10
				Estimating hydrocarbon content of sediments (based on analysis).	S.9
	Effects on marine and coastal birds, seals/ sea lions	• High level of public interest. • Shoreline organisms such as birds and seals are susceptible to direct oil impacts.	1. Identify populations and seasonal susceptibility. 2. Determine appropriate response strategies. 3. Monitor impact of oil and response activities.	Shoreline surveys.	S.2-S.7
				Databases	-
				Expert evaluation.	-
	Effects on Intertidal benthos	• Contains resources of high value; biological, human uses, cultural, commercial. • Susceptible to oil impacts. • Susceptible to response activities. • Often slow to recover from oil and response impacts. • Support decision-making for protection or restoration	1. Document baseline conditions. 2. Determine the cause and extent of spill-related effects. 3. Assess effectiveness and effects of response activities. 4. Document post-spill recovery.	Photo quadrats and video transects.	S.10
				Estimates of percent cover and diversity.	S.10
				Infauna and epifauna composition.	S.10
				Ground-truthed aerial photos	S.2-S.7
	Subtidal benthos	• Often contain resources of high value (biological, human uses, cultural, commercial). • Susceptible to oil impacts. • May be directly impacted by response actions (e.g. dispersant use).	1. Document baseline conditions 2. Determine the actual cause and extent of spill related impact 3. Assess the effectiveness and impact of response activities. 4. Assist planning for protection or restoration. 5. Document post-spill recovery.	Photo quadrats.	S.10
				Video transects.	S.10
				Estimates of percent cover.	S.10
				Fauna/flora composition.	S.10
				Habitat zones.	S.10

NOTES