Developing Consensus Ecological Risk Assessments:

Environmental Protection In Oil Spill Response Planning

A Guidebook

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TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS, SYMBOLS, AND ACRONYMS

Term	Abbreviation, Symbol, or Acronym
Area Contingency Plan	ACP
Automated Data Inquiry for Oil Spills	ADIOS
Barrels	bbls
Cubic Kilometers	Km cu
District Response Advisory Team	DRAT
Ecological Risk Assessment	ERA
Ecosystem Management & Associates, Inc.	EM&A
Environmental Protection Agency	EPA
Environmental Sensitivity Index	EIS
General NOAA Oil Modeling Environment	GNOME
Geographic Information System	GIS
Hours	hrs
In-Situ Burn	ISB
Knots	kts
Meters	m
Miles per hour	mph
National Oceanic and Atmospheric Administration	NOAA
National Institute of Standards and Technology	NIST
Office of Response and Restoration (NOAA)	OR&R
Parts per million	ppm
Sub-Aquatic Vegetation	SAV
Scientific Support Coordinator	SSC
Society of Environmental Toxicology and Chemistry	SETAC
Square Kilometers	Km sq
United States Coast Guard	USCG
United States Coast Guard, Headquarters	USCG HQ

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Developing Consensus Ecological Risk Assessments:

Environmental Protection In Oil Spill Response Planning

Guidance Manual

Abstract

Over the last four years, members of the United States Coast Guard (USCG) have participated in localized Ecological Risk Assessments (ERAs) in the states of Washington, Texas, and California. The purpose of these workshops was to provide response planners and other stakeholders with a forum for discussing oil spill response measures, with an emphasis on chemical dispersants. After reviewing this ERA process, staff at USCG Headquarters (HQ) began to consider the feasibility of incorporating the ERA process into the maintenance and modification of their own Area Contingency Plans (ACPs). Their goal was to create a tool that could be used by USCG staff to teach the ERA process. This guidebook is the result of that effort. It was produced with the support of members of the USCG Area Contingency Planning (ACP) committees, Scientific Support Coordinators (SSC) from the National Oceanic and Atmospheric Administration (NOAA), and multiple state and Federal agencies.

INTRODUCTION

SUMMARY

This guidebook is the result of several years' worth of efforts to determine the best way to obtain consensus among stakeholders regarding spill response options. The ecological risk assessment consensus process allows participants to estimate and compare the relative environmental risks of spill response options on the environment. This is important because some environmental damage is inevitable once oil is released into the environment, and no single response option is likely to be successful in minimizing the impacts. Instead, the most effective response is one that uses all appropriate response options in a manner that reduces the overall consequences of the spill. This is easier to propose as a concept than it is to achieve in practice. This introduction presents background information explaining the origins and fundamental concepts that are the basis of the guidebook. The guidebook presents a simplified ecological risk assessment approach that can be used during the planning process to obtain a consensus on which response options are most likely to minimize environmental consequences and encourage recovery after an oil spill.

In order to use the rest of this guidebook effectively, all the participants in the ERA will need to review and understand the following topics:

- The process leading to the development of this guidebook
- The basic concepts of Ecological Risk Assessment (ERA)
- How to apply an ERA approach to the oil spill planning environment
- The importance of a cooperative effort to complete the analysis
- The basic steps necessary to complete an ERA analysis of a scenario

Each of these topics is discussed below. References on the general concepts presented herein are provided at the end of the section. When the review of this background material is complete, begin the analysis, starting with Activity One.

How Do We Use this Guidebook?

This guidebook is designed to allow a team of spill response planners to analyze the relative consequences of using different response options on a specific oil spill scenario. The objective is to determine the environmental acceptability of each response option as well as the "best mix" of options to facilitate the overall recovery of the environment. In order to use the approach fully, repeat the analysis for a variety of scenarios. Repetition provides a range of results that can then be interpreted and applied in the regional planning process.

This document is organized into a series of "Activities," to be completed in sequence in order to produce a comparative ecological risk analysis of a response-planning scenario. For each activity, the guidebook outlines the steps that each party must complete before moving on to the next. This includes gathering background information necessary for that activity, as well as information on where to obtain or develop additional information. Appendix A provides standardized forms or summary sheets to aid in completing the activities.

Why did the Coast Guard Decide to Develop this Process?

This manual was developed to encourage oil spill response planners to adopt a "risk based" analytical approach in developing contingency plans. Once human health and safety are provided for, the over-riding concern in oil spill response is to minimize damage to the environment. Deciding how to do that can be difficult. No single response option is likely to be completely effective. Therefore, the consensus among oil spill planners for a number of years has been that minimizing impacts can best be achieved by having as many "tools in the toolbox" as possible. In practice, this means increased consideration of "unconventional" techniques, such as dispersants, in-situ burning (ISB), or shoreline cleaners, to supplement mechanical on-water and shoreline recovery techniques.

> *Some sort of risk evaluation occurs whenever a regulator approves or disapproves of an action with environmental consequences.*

These "unconventional techniques" raise concerns, especially for natural resource managers, that the consequences of these technologies may lead to new, undesirable environmental consequences. Often these perceived concerns are strong enough to limit these options without a serious examination of the relative costs and benefits of their use. The key concept here is "relative". All response options have both limitations and potential benefits. The goal is to identify both, and then realistically evaluate the trade-offs inherent in the use of each technology relative to other technologies and to the baseline (i.e., no response). The approach outlined in this guidebook is designed to help oil spill planners accomplish that goal.

What does the expression "Ecological Risk Assessment" Mean?

Ecological Risk Assessment (ERA) *is a process through which to evaluate the possible ecological consequences of human activities and natural catastrophes*. An ERA emphasizes the comparison of exposure to a stressor or stressors (i.e., oil and/or the response options) with an ecological effect (e.g., population disruption, changes in ecological community structure or function, toxicological effects). As much as possible, this comparison is made quantitatively, including an estimation of the probability that the predicted consequences will occur and of the associated severity and magnitude of the effects.

Some sort of risk evaluation occurs whenever a regulator approves or disapproves of an action with environmental consequences. An ERA brings structure and defensibility to this process by utilizing a defined methodology that results in a consistent written record of the results. ERAs should:

- Use quantitative data whenever possible
- Define uncertainty
- Incorporate information into conceptual or mathematical models of the affected system
- Interpret information against clear, consistent, predefined endpoints (action thresholds) related to the protection of resources

How Can ERA Benefit Oil Spill Response Planning?

After protecting human health and safety, oil spill response planning should focus on *minimizing ecological impacts*. Response planners often base risk perceptions on the expected consequences of individual response actions, rather than on an analysis of how response options can be combined to minimize ecological effects. ERA offers a mechanism for this comparison.

How does ERA Relate to other Oil Spill Planning Considerations?

Ecological consequences are only one element of spill response planning. ERA methods help ensure that ecological considerations are properly analyzed and presented. The potential consequences still need to be integrated with other factors (social, economic, aesthetic, and legal) as illustrated in Figure I.1. The integration of these ecological consequences is the responsibility of risk managers (e.g., Federal or state On-Scene Coordinators, natural resource Trustees, industry emergency response managers).

How Was the ERA Approach in this Guidebook Developed?

The goal of developing a comparative risk methodology to evaluate oil spill response options is an old concept. It received particular attention as a better way to evaluate the use of dispersants - perhaps the most controversial option. Suggested approaches for achieving this methodology

> *This guidebook is designed to allow a team of spill response planners to analyze the relative consequences of using different response options in a specific oil spill scenario.*

were developed by Baker (1995) and Aurand (1995). The general concept of "environmental trade- offs" can be seen in many publications on oil spill planning in the 1980s and 1990s. Building on the aforementioned concepts, the US Coast Guard (USCG), industry, and state agencies in Washington, California, and Texas, sponsored a series of projects to develop a standardized process for using a simplified ERA approach. The intended use of this

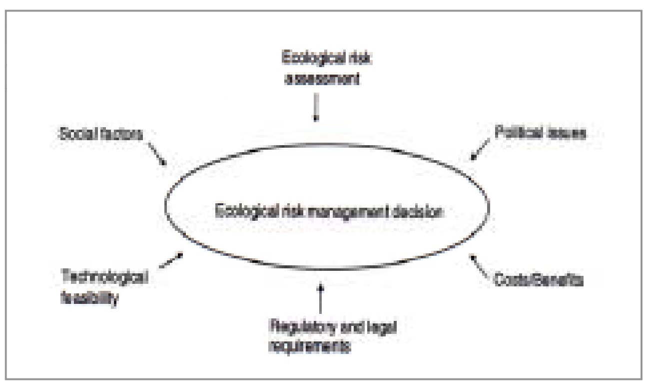


Figure I.1 Factors in Ecological Risk Management Decision-Making

process was then to facilitate oil spill response planning. The approach presented in this guidebook is the result of these efforts.

The initial effort occurred in the Puget Sound area, and while not fully successful, it did identify a number of techniques that worked. A modified approach was then developed for use in Galveston Bay and San Francisco Bay. In both projects, the participants successfully completed the ERA and prepared summary reports (Pond et al. 2000 a, b). Figures I.2 and I.3 compare the basic ERA process, as defined by the EPA guidelines, to the process used in California and Texas. These illustrations are the basis for the activities presented in this guidebook, but are not identical.

All of the preliminary projects used a team of professional facilitators to guide the analysis and document the results. The two successful projects involved participation at three multi-day workshops, as well as interim assignments for the participants. These steps were necessary since the goal of the projects was to develop and test potential standardized tools for a simplified analytical approach that could then be used by planners in other areas without additional outside support.

This guidebook is designed, based on the aforementioned efforts, to incorporate ERA principles into the planning process simply and efficiently to produce a defensible analysis. Compared to many other examples of ERA use, the proposed approach is unsophisticated and lacks analytical detail. Nevertheless, if completed according to the instructions it allows a clearly defensible approach to evaluating environmental trade-offs when planning for oil spill response operations.

When implementing the process described in the guidebook, organizations should modify the process described in Figure I.3 to fit their circumstances. While group meetings are an excellent approach, much of the work, especially during the planning phase, can be accomplished through conference calls. Any individual or small group assignments can be followed with review and comment by the entire group. It is important, however, to conduct the discussions of environmental consequences and relative risk during at least one meeting involving all of the risk assessors, as well as representative risk managers to ensure that a consensus is achieved. The people who need to be involved are highlighted for the various activities as they are presented in this guidebook.

What are the Basic Elements of the Simplified Ecological Risk Assessment?

Federal and state regulatory agencies and industry are all actively investigating or implementing ERA methods in support of their environmental programs. In the United States, the primary Federal proponent of the approach is the US Environmental Protection Agency (EPA). In 1998, EPA published "Guidelines for Ecological Risk Assessment", which is the standardized view, and the basis for most Federal efforts to develop the ERA process.

Due to limitations on resources normally available for oil spill response planning (people, time and money), the process relies heavily on expert opinion existing information, and consensus building, rather than on new data collection or development of detailed mathematical or statistical analyses.

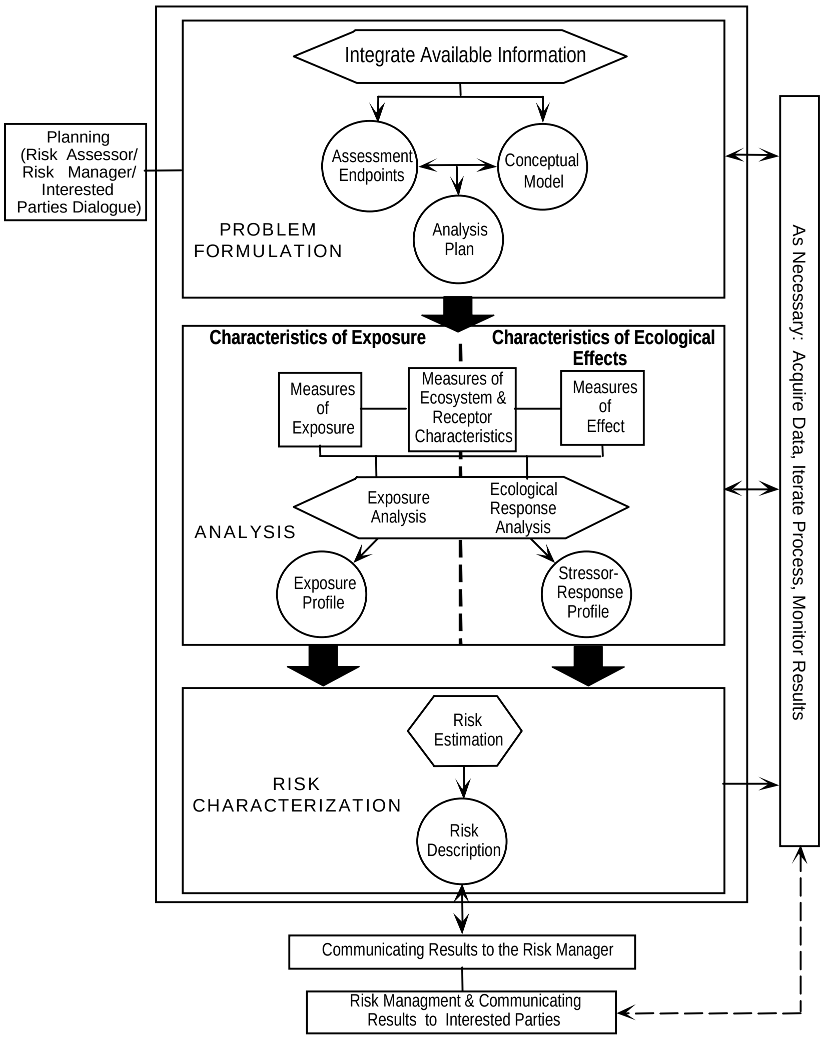


Figure 1.2 **Ecological Risk Assessment Framework (USEPA, 1998)**

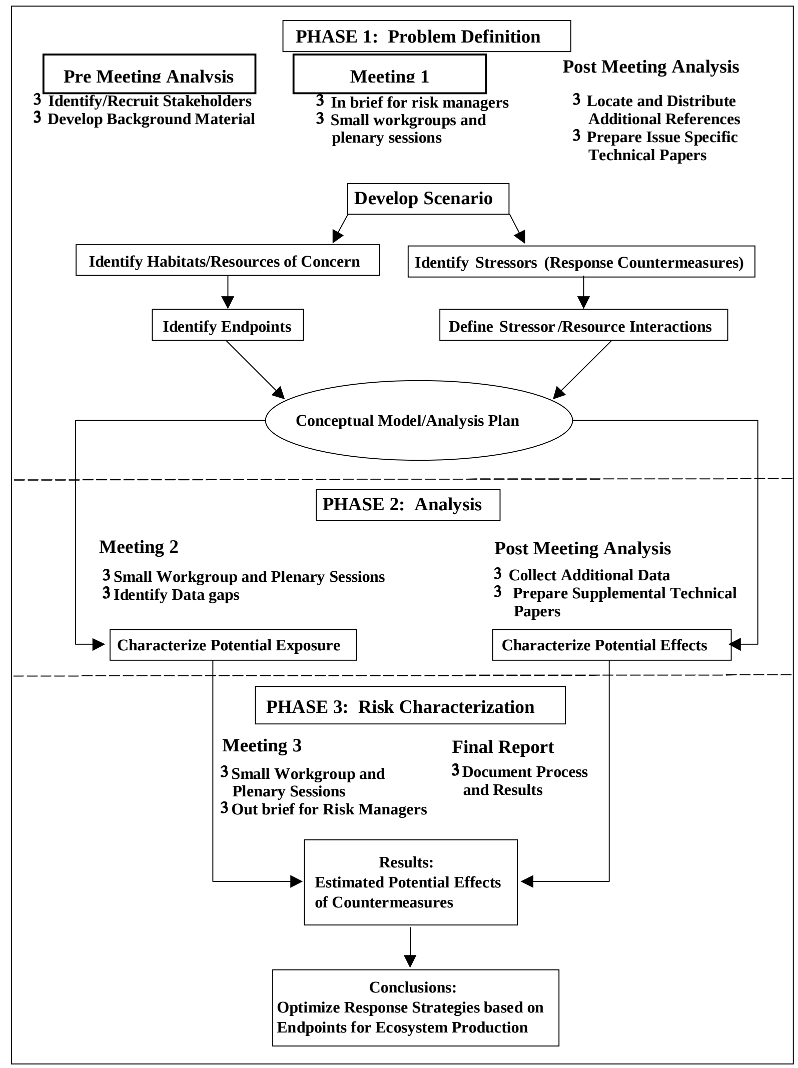


Figure 1.3 **Ecological Risk Assessment Strategy Used in Galveston & San Francisco Bay ERAs.**

An ERA includes *three primary phases* - **problem formulation, analysis,** and **risk characterization**. In the first phase, **problem formulation**, participants *develop a scenario for analysis, identify resources of concern and associated assessment thresholds, and prepare a conceptual model to guide the subsequent analysis.* In this stage, the early interaction of risk managers (spill response managers) and risk assessors (ecological or natural resource technical experts) is essential in order to define the problem clearly. Without this interaction, the results of the analysis may not be appropriate for guiding management decisions. The development of **assessment endpoints** (or t**hresholds**) is critical. These are *levels of exposure or effect related to a level of concern or need for management intervention.* These thresholds can then be related to the potential **stressors** (i.e., *oil or single/combined response options*) by developing a conceptual model that defines interrelationships between stressors, exposure, receptors, and thresholds.

In the **analytical phase**, participants characterize exposure and ecological effects. The conceptual model, developed in the problem formulation phase is used to direct the analysis. In the approach presented here, this is accomplished using standard templates and simple analytical tools that define and summarize the analysis for each resource of concern and each response option.

Key Elements of a Risk Assessment

Problem Formulation

Analysis

Risk Characterization

Finally, the participants complete a **risk characterization**. During this phase, participants interpret the results in terms of the costs and benefits of each of the response options to overall environmental protection, in comparison to the natural recovery response (i.e., baseline). In addition, the strengths, limitations, assumptions, and major uncertainties are summarized. A short summary report is prepared describing the results of the analysis and presenting the data and analytical templates used in the analysis.

After the risk assessment is completed, the risk managers must decide how to integrate this information into the decision process, along with other relevant considerations. Suggestions as to how to accomplish this objective are presented in Activity 11.

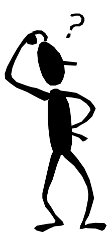
Who Needs to be Involved and What do They Need to Do?

A **broad, multi-stakeholder involvement** is essential to effectively adapting ERA protocols to oil spill response planning. Due to the nature of oil spill response and oil spill response planning, **consensus-building** is a critical element. This means that *Federal, State, and industry response managers, natural resource trustees, environmental advocacy groups, and technical experts **all** need to participate in the ERA process*. Other groups, such as *local governments, concerned private citizens, and the press,* must also have access to and understand the process. This is essential to the process, because the results of the analysis carry more weight when there is broad stakeholder involvement.

Individuals who agree to participate in this project will be expected to support the process through:

1. Their attendance and participation in meetings and conference calls
2. Their identification and summarization of appropriate technical data
3. Their preparation of any analytical papers or summaries needed to complete the risk assessment

This means that individuals, or groups, will prepare overview material in their area of expertise for consideration during the planning phase, and will also prepare the data necessary for the exposure and effects analysis and the risk characterization.



Where Can I Find More Information?

There are many excellent references on ecological risk assessment, its benefits, limitations, and procedures. A few of the references used as the basis for this manual are listed below. A similar reference section appears at the end of each Activity.

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Activity 1: Assembling the Project Team

SUMMARY

Building a cooperative, analytical effort is key to completing a credible risk assessment. This guidebook is designed to help you develop consensus interpretations on a wide range of topics, including efficiency of response options and the significance of ecological effects. If the group that develops this material does not appear to represent all of the stakeholders, then the process will not have the necessary support to implement its findings. Therefore, it is important that the effort has broad support and involve all of the stakeholders.

In order to begin the risk assessment process, the assessment coordinator needs to assemble an interdisciplinary project team using the following guidance:

- Identify assessment coordinator
- Establish an assessment management team
- Identify oil spill response and natural resource managers (Federal, state and local)
- Identify subject matter experts for response options, resources, and ecological effects
- Identify appropriate industry representatives
- Identify special interest or citizen groups
- Obtain a commitment of support from both the individuals and their agencies for the process - including a commitment to apply sound science and individual expertise, and to work for a balance in bias

Specific suggestions as to how to assemble and use the project team are provided in the following sections. When the project team is assembled, you can begin the analysis.

Who Is in Charge?

If a District decides to pursue the ERA approach to oil spill response planning, the first task is to identify an individual to lead the effort. There are no specific criteria for this position, but there are two logical choices in most Districts. The first is the National Oceanic and Atmospheric Administration's (NOAA) Scientific Support Coordinator (SSC). The second is the senior member of the District Response Advisory Team (DRAT). Either of these individuals should have the expertise necessary to organize the effort and serve as the assessment coordinator. Ideally, they need to have a general understanding of spill countermeasures, including their environmental consequences and some prior experience or training in conducting or participating in an ERA. The designated leader should review this guidebook in detail before undertaking the activities so as to have a clear understanding of the commitment required.

The **assessment coordinator's primary role** is to *oversee the process and ensure that the activities described in this guidebook are accomplished and properly documented*. When the project is completed, it is also his/her responsibility to see that the results are considered during District planning efforts. At the beginning, however, the assessment coordinator's first task is to assemble the project team.

Setting the Stage – Using a Cooperative Approach

The success of this process relies first, on the inclusion of all stakeholders, and second, on its completion in an environment where an open exchange of ideas is encouraged. It is essential that the results represent a true consensus on the part of all participants, and not a small group of technical experts. While technical expert input is required, many issues discussed herein will center on value judgements, and, in those cases, acceptance by all parties is important.

Establish an Assessment Management Team

As soon as a decision is made to try to use the simplified ERA approach, assemble the assessment management team, including:

- the assessment coordinator
- a representative of the local Coast Guard office (assumedly coordinating the effort), if possible a member of the Area Contingency Planning (ACP) committee
- the NOAA Scientific Support Coordinator, and/or the Coast Guard DRAT (if not already serving as the assessment coordinator)
- a representative of the state response organization
- one or more representatives from state or Federal resource agencies who agree to assist in coordinating the project
- one or more representatives from industry
- if available, a representative from a public interest or citizen group

This group should consist of no more than six to eight individuals. They must agree to assist in planning the assessment, the facilitation of any conference calls or meetings, and the review and preparation of the summary report. In essence, this group coordinates the process, with the assessment coordinator serving as the team lead.

> *Many environmental debates represent conflicts over competing societal values, and stakeholders are perceived as more legitimate and representative interpreters of societal values than scientists*
>
> - Yosie and Herbst, 1998

According to comments from "practice ERAs" with two USCG Districts (Mississippi Sound and Long Island Sound), at least one member of the management team needs a background in or prior experience with the ERA process, either as a participant or facilitator. They need to review and understand the background of this approach before undertaking an assessment.

It is their responsibility to make sure that the other participants understand the purpose of the project, and their roles in the process. Normally, this person is the assessment coordinator. He or she needs to be unbiased, so as to guide the process without directly influencing the outcome. Opinions of the stakeholders and response experts need to form the basis for the ERA analysis. The assessment coordinator serves only as a technical expert, guide, and mediator throughout the process.

Once the management team is in place, they have two immediate responsibilities:

1. Develop a basic spill scenario (see Activity 2)
2. Identify the remaining participants

The assessment team oversees the risk assessment process and assembles the necessary stakeholder representatives, a total of 25 to 35 participants.

Identify the Participants in the Assessment Process

Once the management team is in place and they have a basic scenario in mind, the team needs to identify all the other potential participants. From a practical standpoint, no more than approximately 25 to 35 individuals should be involved. Coordinating material and meetings for more than 25 to 35 becomes difficult. That number of participants should allow inclusion of all necessary groups; but if not, remember, it is more important to include all the stakeholders than to restrict the number of participants. Including all the stakeholders ensures a balance in the bias and expertise.

Recruit individuals from all stakeholder groups, especially those who provide input to revisions of the area or port response plan, or who may be involved in the decision-making process in case of an actual spill. Subject matter experts should supplement this group as needed (to evaluate the ecological consequences of various response options). Usually these individuals can be found within the natural resource management agencies. Other possible sources include local universities or environmental organizations. Invite individuals who represent all of the viewpoints that will be present during a spill.

Spill Response Managers

These representatives from the Coast Guard, state agencies, and industry are responsible for managing the spill response. Their input is critical in the planning stage so that the final scenario and the response options selected for analysis are meaningful to them. If not, then the results of the effort are unlikely to influence future decisions. In addition, they need to understand and support the assessment process.

Natural Resource Managers

These are representatives from state and Federal agencies responsible for managing natural resources in the area of the scenario that may be at risk. They need to be involved because of their technical expertise as well as for their management insight. Include all important resource groups, based on both geography (parks, wildlife refuges, marine sanctuaries, etc.) and resource type (marine mammals, fisheries, migratory waterfowl, wetlands, etc.). In many cases, one individual may be able to represent multiple resources.

Subject Matter Experts

These are individuals selected based on their specialized expertise in a particular natural resource, ecological or biological process, fate and effects of oil, or response option. Often individuals who are also response or resource managers can fill this role. In other cases, a particular issue may be so important (or controversial) that a particular expert or balance of experts may be needed to ensure the credibility of the analysis.

Representatives of Special Interest or Citizen Groups

Often local or regional environmental groups are important in defining the overall reception to new planning initiatives. In addition, other special interest groups (sport fisherman, boaters, hunting organizations, the Chamber of Commerce, etc.) may also play an important role in defining the success of a response. As appropriate, encourage these groups to participate. Due to limited time, travel funds, etc., it may be difficult to have someone from every interest group represented. However, efforts need to be made to include as many points of view as possible. Base your invitations on the knowledge of the assessment management team regarding which local groups have a vested interest in this kind of process.

Explain the Purpose of the Assessment and the Participants' Role in It

Once the assessment management team is in place, the participants selected, the assessment coordinator needs to explain the basic process to the entire group and make sure they can participate fully in the process. The assessment management team then needs to confirm that the actual participants can provide the breadth of knowledge necessary to produce a credible assessment. If this does not appear to be the case, then it may be necessary to wait until such support is present before proceeding.

Activity 2: Developing the Scenario

SUMMARY

Developing an appropriate scenario is essential to all subsequent activities. It should reflect risks that are realistic and significant to the local or regional stakeholders. The scenario must also be based in reality (real time, efficacy of response options, etc.) It is not appropriate to analyze scenarios where only one, or in some cases no, response option is feasible. Ultimately, it is important to evaluate a range of scenarios, different oils, volumes, locations, seasons, etc., so that response planners will begin to develop an understanding of the sensitivities of acceptable options to different conditions. This will allow better definition of the proper use of each response option, and the potential range of benefits.

In order to complete this Activity, the assessment management team will need to accomplish the following tasks:

- Review oil spill scenarios in existing planning documents
- Either select one of these scenarios, or develop a new one for analysis
- Scenario production must include the following:
    - Oil type
    - Size of the spill
    - Spill location
    - Specific date and time
    - Weather at the time of the spill
    - Nature of the spill

Specific suggestions as to how to accomplish these tasks are provided in the following sections. After reviewing this background material, the assessment management team will complete the scenario summary sheet (Sample Form 1) in Appendix A.

Setting the Stage – Defining the Need

Participants need to develop spill scenarios that allow a balanced examination of all relevant issues, including the response options of interest. Scenario selection is critical to the risk assessment process because the scenarios establish the spatial and temporal parameters of the risk analysis. The assessment management team should develop the basic spill scenario, and then coordinate that scenario with the rest of the participants. Keep the scenario relatively simple, particularly in the first use of this simplified ERA approach, so that it does not interfere with the ability of the team to evaluate the potential effects. More complex scenarios, especially ones involving large volumes, should be avoided until you obtain some experience with the process. If possible, use existing scenarios developed in the ACP process to avoid "re-inventing the wheel."

Essential Elements of the Spill Scenario

Oil Type

Base the scenario on a type of oil that is either produced or transported in your area. Concentrate on the oils that pose the greatest risk to your local resources. You can base this on the frequency of past spills, or on environmental concerns caused by the chemical or physical nature of the oil. Participants need to be aware that the types of variables they choose for their scenario may limit the use of some response options. This may or may not be a critical consideration. For example, if your objective is to evaluate alternative technologies such as dispersants or on-water *In-Situ* (ISB) burning, certain oils might be inappropriate. Ultimately, your goal is to evaluate any and all oils that pose a threat in the planning area. Therefore, it is probably best to start with oils that pose the greatest risk.

Spill Size

The spill size used in the analysis needs to be large enough to warrant a response, but not so large that it becomes impossible to differentiate between response options. Once you analyze the consequences and trade-offs involved in small to moderate-sized spills, it will be easier for the assessment team to 'scale up' the analysis for the larger event. Experience in the Puget Sound, Galveston Bay, and San Francisco Bay assessment projects indicated that spills ranging in size from 500 barrels (bbls) to 4,000 bbls (20,000 to 165,000 gallons) represented a good analytical range for initial assessment attempts. (Pond, et al., 200a,b). Base the volume on your area's historical spill record, and on the geography and hydrography of the area. Focus on only one volume for the initial assessment. Later efforts can then focus on the consequences of a larger or a smaller volume with all other parameters being equal.

Spill Location

The scenario must occur in a realistic location that will threaten valuable resources. It would not be meaningful, for example, to prepare a scenario that involved a small spill in a remote offshore location where no significant resources were present and the oil could be left to weather naturally. In the San Francisco Bay assessment, the participants selected two locations. The first was just outside of the mouth of the Bay at a point where pilots are taken aboard, and the second, inside the bay near a bridge where the channel was difficult to navigate. In the Galveston Bay scenario, a location at the intersection of the Intracoastal Waterway and the Houston Ship Channel was selected, the general site of many historical incidents. In each case, releases at the selected points rapidly threaten very valuable natural resources (Pond et al., 200b).

Spill Date, Time, and Tidal Stage

Many natural resources vary with season, and oil spill weathering is affected by seasonal climactic conditions, especially air and water temperature. The efficacy of some response options is also sensitive to seasonal considerations, especially day length. The scenario needs to be defined with enough precision so that all of the participants will be clear as to the implications for seasonal resources as well as climactic conditions. You may want to avoid transitional months so that misunderstandings do not occur. Select a date that reflects the issues that the assessment management team wishes to address.

The time of the spill is important because response operations cannot begin in darkness. For example, a spill that occurs just at sunset will have a period of time to move as a surface slick before beginning a response. Conversely, a spill at 1200 allows for an immediate response (subject to the availability of equipment), but, again, the response will be interrupted with darkness.

Tidal stage (if in a tidal environment) is obviously important for the movement of oil, especially if dispersants are being considered.

Weather at the Time of the Spill

Weather is always a critical element in oil spill response, and it is equally important in designing a scenario. While the specified weather must be plausible, it also must lead to the consequences that the assessment team is trying to address. For example, if a key element is the evaluation of threats to a salt marsh habitat to the east of the spill, the prevailing winds at the time of the spill must be appropriately defined. While some wind and weather is necessary for realistic evaluations, it is of no value to try to analyze a spill in such severe weather that no response option is feasible.

Description of the Spill

For the last element of the scenario develop a description of the events needed to cause the spill. While this is not, strictly speaking, necessary for the analysis, it serves as a “reality check” on the scenario. The public and spill response managers are unlikely to be impressed by a scenario that had to invoke a sequence of improbable events to create the situation under consideration.

Final Spill Scenario

Table 2-1 shows a sample scenario used in the San Francisco Bay ERA (Pond et al., 2000a). This same type of information, at an appropriate level of detail, should be developed by the assessment management team and forwarded to the rest of the participants for comment. The team then develops and summarizes a final scenario, and a brief paragraph describing the overall objectives of the scenario. They also need to prepare any important assumptions made during the scenario’s creation. The location of the spill should be marked on an appropriate chart and made available to all participants. A sample scenario form is provided in Appendix A (Sample Form 4).

Table 2-1 The Summary of One of the Two Scenarios Used in the San Francisco Bay ERA (Pond et al., 2000a)

Location	Richmond Bridge
Target:	Northern and Central San Francisco Bay and shore
Oil Type:	Alaska North Slope crude oil (ANS)
Spill Size:	2,500 bbls ANS
Weather:	Wind: calm (0001-1000 hrs), NW at 5 kts (1000-1400 hrs) (Wind pattern repeated every 24 hours) Water Temp: 55 °F Waves: 1 - 2 ft chop Waves: flat then 1 ft, Salinity: 25 t
Date or Time of Year:	Late Fall (Nov/Dec)
Time of Discharge (and Tidal Stage):	Midnight Tide: slack before ebb Tide: slack before flood
Nature of the Spill:	A tanker is involved in a collision while navigating in a restricted channel near the Richmond Bridge.

Activity 3: Estimate the Fate of the Oil and the Potential for Exposure for the Resources of Concern

SUMMARY

In this activity, the assessment team will use appropriate models to develop information about how the spilled oil behaves in the environment with and without the response options. In addition, they will obtain site-specific information on resource distribution and abundance, along with any additional information on the various hazards you feel are necessary for your analysis.

In order to complete this Activity, the assessment coordinator will organize the ERA participants into subcommittees to accomplish the following tasks:

- Model the fate of the surface oil
- If dispersants are being considered, model the fate of dispersed oil
- If ISB is being considered, model the fate of the smoke plume
- Develop an oil budget for the scenario
- Estimate shoreline contamination levels
- Prepare exposure profiles for hydrocarbons in the water column and the smoke plume
- Present the results to all participants for concurrence

Specific suggestions as to how to accomplish these tasks are provided in the following sections.

Beginning the Analysis – Defining Fate and Exposure

The ERA process provides the basis for comparing and prioritizing risks. The basis for this comparison relies on knowledge about the distribution of oil in the environment, and its effects on various resources. For example, if every alternative presents some level of risk, then the ERA process provides the basis for choosing between alternatives (Suter, 1993). In the process outlined in this manual, the goals in this analysis are to determine:

- if the available response options offer environmental benefits over no response

- the relative benefits of these options, whether used alone or in combination

Keep in mind that you are trying to improve the ***overall*** environmental benefits. The goal is to identify options that produce better results than natural recovery or on-water mechanical recovery alone. In this activity, participants will gather and organize the basic data needed to complete the analysis. The analysis will be finalized in subsequent activities.

Once the assessment management team agrees on a general scenario, they need to obtain information on the distribution and amount of oil in the environment. This information will be critical in future sections, where the participants define the effects of various options. They can accomplish this through three or more subcommittees. Instruct the subcommittees to prepare the analyses based on the scenario. In the US, it is reasonable to request the NOAA SSC or a state resource agency participant to serve as the coordinator for this effort.

Subcommittees must be assigned for transport, resources, and effects issues. The assessment coordinator should maintain a record of the participants in each group for future reference.

The **transport subcommittee** is responsible for *developing information on the surface oil trajectory, the behavior of the dispersant plume, and the behavior of the ISB smoke plume* (assuming all three options are included). Details about the various response options will be developed in Activity 4. At this point (scenario development), you only need to determine whether you intend to consider using dispersants or ISB since those are the only options influencing the transport of oil. A surface trajectory must always be developed. This effort is usually coordinated by the NOAA SSC.

The **resources subcommittee** is responsible for *collecting data on the ecological resources within the study area*. The study area was generally defined during the scenario development. Now they will refine the area based on results provided by the transport subcommittee. Details about resource definition will be generated later in Activity 5.

Next, the subcommittee obtains information on resource distribution/ location and potential sensitivity to oil and response options under consideration. Where appropriate, obtain information on life history stages, protected species status, and the relationship of the local resource to the regional resource. For example, you might examine a Mid-Atlantic estuary that supports a portion of the regional waterfowl population. The primary sources for this information will usually be maps or GIS databases (maintained by state or federal resource agencies), the Environmental Sensitivity Index (ESI) maps prepared by NOAA, and the knowledge and experience of the subject-matter experts involved in the assessment. At this stage in the process, the subcommittee should focus on obtaining *basic source information*, not on analysis.

The **effects subcommittee** must *collect any additional data they feel is necessary concerning hazards relative to the endpoints and resources identified in the conceptual model*. This usually means data on toxicity and/or physical effects of the stressors relative to resources of concern.

What does the Transport Subcommittee Do?

The transport subcommittee has the most complicated assignment, and their data must be available before the other two groups can complete their data collection. In order to conduct the risk analysis, it is necessary to examine oil movement and oil volume over time. The best way to do this is to use simulation models to produce modeled trajectories and oil budgets that provide the necessary data for each response option.

Oil Transport and Exposure Modeling

To cover all of the possible response options, the transport subcommittee needs to model four things:

1. The distribution of floating surface oil
2. The areas of impact and the concentration of oil that contacts the shoreline
3. The distribution of a dispersed oil plume
4. The distribution of a smoke plume from the site of an ISB operation

You can generate this information in a variety of ways, including commercially available models. In most circumstances, however, the NOAA SSC can arrange for the NOAA Office of Response and Restoration (OR&R) to assist in the effort.

The OR&R can use a series of standard oil spill tools to support this effort. The two basic components are GNOME (General NOAA Oil Modeling Environment), which is an oil trajectory model, and ADIOS (Automated Data Inquiry for Oil Spills), which is an oil weathering model. In some cases, they may be able to offer support using TAP (Trajectory Analysis Planner), a new program that develops a probabilistic estimate of how oil moves and spreads in a particular body of water. At present, NOAA does not have an automated subsurface dispersed oil plume model, but can assist in developing an estimate for this element. Whatever approach the transport subcommittee takes, they need to develop the following items:

- Maps showing the distribution of the surface oil plume at approximately 6 hour intervals for the time period of concern (usually 72 hours or until the slick impacts the shoreline). This should include some estimate of the error associated with the modeled trajectory, and any weathering assumptions used in the analysis.
- Maps showing the distribution of the subsurface dispersed oil plume at approximately 6 hour intervals for the time period of concern (usually 72 hours or until the slick impacts the shoreline). The analysis begins at the time and location where dispersant operations commence.
- Summary tables and/or graphs showing the expected average dispersed oil concentrations in the water column through time and at selected points along the trajectory.
- An oil budget based on weathering data and the modeling results, that examines two conditions, natural recovery and application of dispersant. All other situations can be derived from these two tables.

For each of these elements, your subcommittee must make sure that all of the assumptions they used are clearly stated. Figures 3.1 and 3.2 respectively, are examples of the NOAA modeling results for the surface oil slick and the dispersed oil plume at a single time set in the San Francisco Bay ERA (Pond et al., 2000a). Table 3-1 shows the average dispersed oil concentration over time for this same project. Note that the NOAA model assumed that the areal extent of a surface or subsurface plume is independent of the quantity of oil spilled. Thus, a spill of 4,000 barrels has the same “footprint” as a spill of 100 barrels. The NOAA SSC can assist during discussions of the limitations of this assumption. When calculating the concentration of oil at any particular point in a plume, the model used to develop Table 3-1 assumed a spill quantity of 100 barrels. To calculate point concentrations of oil for the 2,500-barrel spill scenarios, participants simply multiplied the reported concentrations times 25. Table 3-2 is an example of exposure profiles, also from the San Francisco ERA (Pond et al., 2000a), at selected sites along the trajectory, based on average concentrations.

Estimate the concentration of dispersed oil at sites of particular interest along the trajectory. Doing this, will assist you with exposure characterizations in later stages of the analysis.

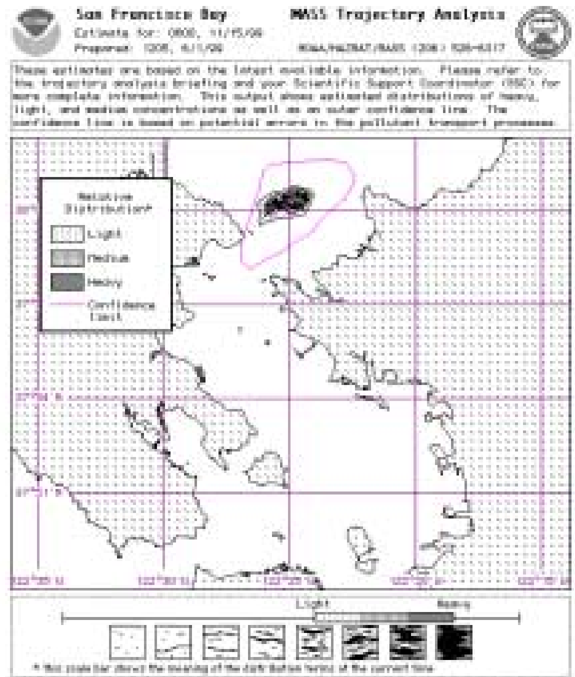


Figure 3.1 San Francisco Bay Slick Trajectory (Pond et al., 2000a)

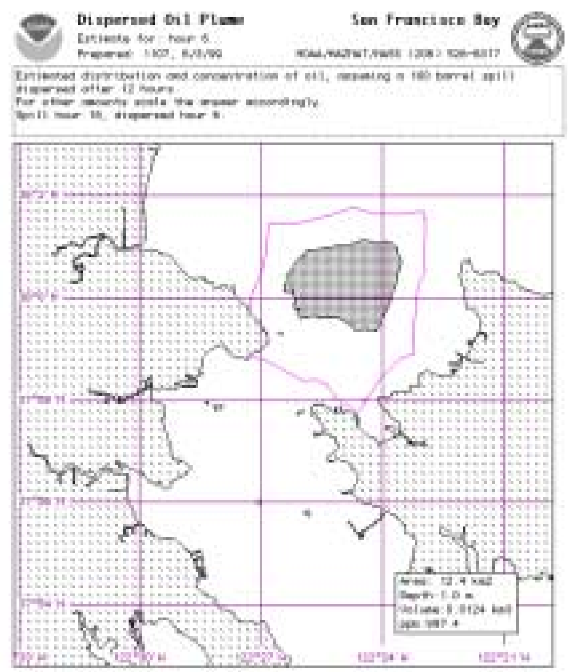


Figure 3.2 San Francisco Bay Slick Trajectory (Pond et al., 2000a)

Table 3-1 Estimated Dispersed Oil Concentrations (Pond et al., 2000a)

				Concentration (ppm)		
D+ (hrs)	A (Km sq.)	Depth (m)	Vol. (Km cu.)	100 bbl (1)	2,500 bbl (2)	2,500 bbl (3)
6	12.4	1.0	0.0124	0.8974	17.9	7.9
12	14.2	5.0	0.0711	0.1564	3.1	1.4
18	14.9	7.0	0.1041	0.1059	2.1	0.9
24	15.8	7.0	0.1105	0.1007	2.0	0.9
36	32.1	7.0	0.2245	0.0496	1.0	0.4
48	32.4	7.0	0.2265	0.0491	1.0	0.4
72	83.4	7.0	0.5839	0.0191	0.4	0.2

(1) Dispersed oil concentration for 100 bbls scenario (complete dispersion).
(2) Dispersed oil concentration for 2,500 bbls scenario (80% complete dispersion).
(3) Dispersed oil concentration for 2,500 bbls scenario (35% dispersion).

**Table 3-2 Exposure profile (80% effectiveness) Sites A - D. (Pond et al., 2000a)
Note, no dispersed oil is predicted by the model to impact in Site D (2,500 bbl spill vol.)**

Pilot Station Scenario:			Concentration (ppm)		
D+ (hrs)	Plume	Site A	Site B	Site C	Site D
6	45.1	0	0	0	0
12	6	6	0	0	0
18	3.2	3.2	0	0	0
24	2.6	2.6	0	0	0
36	1.1	0	1.1	0	0
48	0.9	0	0.9	0.9	0.9
72	0.7	0	0	0	0

Developing the Oil Budgets

Oil budgets for each of the four major response options (natural recovery, on-water mechanical recovery, dispersant application, and ISB) can be prepared using calculations based on data from the NOAA Adios model results. The budgets estimate oil volume over time as a result of the natural processes of weathering and evaporation, as well as by the application of individual clean-up techniques. Prepare budgets for natural recovery, and for dispersant use at the anticipated efficiency level. Generic examples of oil budgets for natural recovery and dispersant application at 80% effectiveness (generated from data from the Galveston Bay ERA [Pond et al., 2000b]) are shown in Tables 3-3 and 3-4. The following notes explain the calculations used to achieve the numerical values in Tables 3-3 and 3-4. The corresponding number is noted within the table.

Table 3-3 Oil Budget for 4,000bbl spill of Arabian Medium Crude (Pond et al., 2000a)

(Conditions = average wind speed [8-10mph], average water temperature [70-75°])

Natural Recovery

TIME (hours)	0	6	12	24	36	48	72	96
Total floating oil [1]	4000	2976	2818	2531	2171	1668	1116	2
Emulsion [2]	4000	4251	4697	10123	8686	6671	4463	7
Evaporated [3]	0	1000	1149	1290	1391	1456	1506	1528
Dispersed (natural) [4]	0	24	33	39	44	48	50	51
Mechanical recovered [5]	0	0	0	0	0	0	0	0
Dispersed (chemical) [6]	0	0	0	0	0	0	0	0
In-situ burned [7]	0	0	0	0	0	0	0	0
Stranded [8]	0	0	0	141	394	828	1329	2419
Stranded oil emulsion [9]	0	0	0	235	1247	2984	4986	9348
Oil Budget validity check [10]	4000	4000	4000	4000	4000	4000	4000	4000
water in oil [11]	0	1275	1879	7686	7367	7159	7004	6934
emulsion factor [12]	0	0.3	0.4	0.75	0.75	0.75	0.75	0.75
% evaporation [12]	0	0.25	0.05	0.05	0.04	0.03	0.03	0.02
% natural dispersion [12]	0	0.006	0.003	0.002	0.002	0.002	0.001	0.001
% stranding [13]	0	0	0	0.05	0.1	0.2	0.3	0.9775
% mechanical recovered [14]	0	0	0	0	0	0	0	0
% dispersion (chemical) [14]	0	0	0	0	0	0	0	0
% in-situ burn [14]	0	0	0	0	0	0	0	0

*See the list following Table 3-4 for explanations of notations 1-14

Table 3-4 Oil Budget for 4,000bbl spill of Arabian Medium Crude (Pond et al., 2000a)
(Conditions = average wind speed [8-10mph], average water temperature [70-75°])

80% Effectiveness Dispersant application

TIME (hours)	0	6	12	24	36	48	72	96
Total floating oil [1]	4000	2976	437	393	337	259	173	0
Emulsion [2]	4000	4251	729	1571	1348	1035	693	1
Evaporated [3]	0	1000	1149	1171	1186	1196	1204	1208
Dispersed (natural) [4]	0	24	33	34	35	35	36	36
Mechanical recovered [5]	0	0	0	0	0	0	0	0
Dispersed (chemical) [6]	0	0	2381	2381	2381	2381	2381	2381
In-situ burned [7]	0	0	0	0	0	0	0	0
Stranded [8]	0	0	0	22	61	129	206	376
Stranded oil emulsion [9]	0	0	0	36	194	463	774	1451
Oil Budget validity check [10]	4000	4000	4000	4000	4000	4000	4000	4000
water in oil [11]	0	1275	292	1193	1144	1111	1087	1076
emulsion factor [12]	0	0.3	0.4	0.75	0.75	0.75	0.75	0.75
% evaporation [12]	0	0.25	0.05	0.05	0.04	0.03	0.03	0.02
% natural dispersion [12]	0	0.006	0.003	0.002	0.002	0.002	0.001	0.001
% stranding [13]	0	0	0	0.05	0.1	0.2	0.3	0.9775
% mechanical recovered [14]	0	0	0	0	0	0	0	0
% dispersion (chemical) [14]	0	0	0.8	0	0	0	0	0
% in-situ burn [14]	0	0	0	0	0	0	0	0

*See the following list for explanations of notations 1-14

1) Total Floating Oil = Calculated as total volume spilled - evaporation - dispersed (natural) -mechanical recovery-dispersed (chemical) - ISB-stranded oil
2) Total oil/water emulsion = total oil in current column divided by the inverse proportion of the emulsion factor
3) Total oil evaporated = total floating oil from previous column x the % evaporated in the current column + the total evaporated from the previous column
4) Total volume naturally dispersed = total floating oil from previous column x the % naturally dispersed in the current column + the total dispersed (natural) from the previous column
5) Total volume recovered on water with mechanical equipment = total floating oil from previous column x the % mechanically recovered in the current column + the total mechanically recovered from the previous column
6) Total volume chemically dispersed = total floating oil from previous column x the % dispersed (chemical) in the current column + the total dispersed (chemical) from the previous column
7) Total volume burned in situ = total floating oil from previous column x the % ISB in the current column + the total ISB from the previous column
8) Total volume stranded on the shoreline = total floating oil from previous column x the % stranded in the current column + the total stranded from the previous column
9) Total volume of oil/water emulsion stranded on the shoreline = the total

floating oil emulsion from previous column x the % stranded in the current column + the total stranded oil emulsion from the previous column

10) Validity check should always = original spill volume (calculated by adding current column numbers for total floating oil) + evaporated + dispersed (natural) + mechanically recovered + dispersed (chemical) + ISB + oil stranded
11) Total volume of water emulsified in the oil = Total floating oil emulsion in the current column + total stranded oil emulsion in the current column - the total floating and stranded oil emulsions in the previous column
12) The emulsion factor, % evaporation, and % natural dispersion are extracted from NOAA Adios program
13) The % stranded is based on review of NOAA surface spill trajectory model, calculated according to the % of oil, over time, that reaches the shoreline.
14) The % mechanically recovered, % dispersed (chemical), and % in situ burn were estimated by Galveston Bay ERA participants based on scenario and equipment availability and efficiency assumptions
15) Estimates produced by the model may be adjusted by the SSC to account for real-world experience.

Smoke Plume Modeling

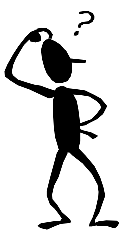
There is a plume model available from the National Institute of Standards and Technology (NIST) that can be used to estimate the dispersion of the smoke from ISB (http://response.restoration.noaa.gov). The NOAA SSC can assist in this effort. The results of that analysis can be used to estimate downwind exposure concentrations. The primary concern is for human health and safety, and there are standards available for exposure limits. In the ERAs conducted to date, the downwind distance to any receptors was so great that no detailed modeling was needed. Examine this element prior to running the model.

What Does the Resource Subcommittee Need to Do?

Once the transport subcommittee's information is available, the resource subcommittee needs to collect reference material to answer questions that others may have about the resources at risk. This includes, but is not limited to, the size and distribution of habitat types, seasonal distribution or usage information, and life history information. These data should be available for both the local areas affected by the spill, and for the region as a whole. The definition of "region" is at the discretion of the subcommittee, but should represent a logical extension of the local area so that the value of the resources to regional ecosystem can be put into perspective. The definition does not have to be the same for all resources. For example, if the local area includes the only salt marsh in a particular estuary, then that is a logical regional area. On the other hand, more mobile organisms, such as migratory waterfowl, may be part of a regional population that covers a much larger geographic area. Since you cannot know in advance which details will be most important, concentrate on collecting maps, data compilations, or summary reports containing the necessary information, rather than on compiling a new summary of the information.

What Does the Effects Subcommittee Need to Do?

This group is responsible for collecting necessary data to address any issues that participants may have when they decide how to interpret potential consequences of the spill in conjunction with response options. Supporting information in Appendix C will help you interpret toxicity data. In most instances, this group needs to focus on acute toxicity and sublethal effects. You will need this for all animals exposed to oil. If dispersants are included, give special attention to animals in the water column. You also need to evaluate the effects of physical smothering, smoke inhalation (if ISB is used), and the potential hazards of other response options, such as hot water washing or mechanical beach cleaning. Again, the NOAA SSC can serve as a good source of initial information. There is no set format or expected output for the effort of this group. It is quite likely that this subcommittee will need to collect data in phases as the analysis leads to new questions.



Where Can I Find More Information?

NOAA website response planners:
http://response.restoration.noaa.gov

Pond, R.G., D.V. Aurand, J.A. Kraly (compilers). 2000a. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the San Francisco Bay Area. California Office of Spill Prevention and Response.

Pond, R.G., D.V. Aurand, J.A. Kraly (compilers). 2000b. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the Galveston Bay Area. Texas General Land Office, Austin, TX.

Suter, G.W. (Ed.) 1993. Ecological Risk Assessment Lewis Publishers, Ann Arbor. 538 p.

Activity 4: Defining the Response Options for Consideration

SUMMARY

Preliminary selection of the response options must occur prior to Activities 2 and 3, but the details can only be developed once the scenario is complete. For each response option ERA participants need to agree on estimates regarding 1) how the response option will be used, 2) what logistics are necessary to implement the option, 3) what its limitations are in the scenario under consideration, and 4) what its efficiency is likely to be.

In order to complete this Activity, a response operations subcommittee will need to accomplish the following tasks:

- Identify all response options commonly used in the study area
- Determine if you wish to consider additional response options
- Develop a description of each response option
  - List the resources required (logistics) to use the option
  - Define the operational limitations of the option
  - Arrive at a consensus of the likely overall efficiency in the scenario being used
- Determine the effect of using the option on the fate of the spilled oil
- List any environmental concerns that result from using the response option
- Present this information to all participants for concurrence

Specific suggestions as to how to accomplish these tasks are provided in the following sections. When you finish reviewing this background material, complete the response option summary sheet (Sample Form 2) in Appendix A.

First Review Current Response Options

Once your scenario is complete, the assessment management team should designate a response operations subcommittee (consisting primarily of response managers). This subgroup will collect and summarize information on the equipment currently available in the area, and specified in response plans. Information on any equipment likely to be implemented if the spill occurs under present planning conditions should be summarized and distributed to all participants. Then, use this information to define the basic logistic considerations for the possible response options. It is not necessary or even appropriate, however, to limit the assessment to consideration of existing options.

Try to Consider all Realistic Options

The most common response options considered when combating oil spills are:

- Natural Recovery
- On-Water Mechanical Recovery (including diversion and protection booming)
- Chemical Dispersion
- ISB (either on-water or shoreline)
- Mechanical Shoreline Cleanup
- Bioremediation
- Chemical Shoreline Cleaners

Some basic information for each of these response options is presented in Appendix E.

The analysis must always consider natural recovery, which will *serve as the baseline condition in this analysis for evaluation of the other options*. Since on-water mechanical recovery and mechanical shoreline cleanup are the primary response options in the US, they would normally also be included. Beyond that, the assessment team should select remaining options depending on the interests of the response planners, the resources at risk, and the specific scenario. It is important to be realistic, but the selection should not be limited by existing stockpiles. For example, if on-water ISB is to be considered in an area where it is not currently used, it is reasonable to assume that two or three sets of fireproof boom might be available in the future. It is not reasonable to assume that ten or 15 sets could be provided.

Develop a Description of the Response Option

Once you decide which response options to include, each must be examined in terms of uses, logistics, limitations, and efficiency. Having a subcommittee prepare this material, with a subsequent review by the entire group, is the most effective way to complete the task.

Purpose of the Response Option

Each of the various options has a different purpose. It is useful to prepare a short narrative statement for each, explaining why an alternative might be useful, to make sure that all participants understand the justification for using that option.

Logistics Requirements

For each response option, the response operations subcommittee must agree, first, on what equipment and manpower is required. Second, they must develop a hypothetical level of logistics support for the scenario, and a timeline in which to implement the scenario.

Limitations

All options have intrinsic limits to their use. This "window of opportunity" is influenced by weather, location, time of day, and logistics needs. Specify these limitations in the analysis because they will influence your calculation of the efficiency of the option.

Estimate of Efficiency

This is perhaps the most important part of each response option description. It involves an estimate of how much oil is likely to be removed or treated by the technology during the portion of the scenario when the oil is amenable to treatment. It must reflect local experience when possible. There are a number of conceptual ways to accomplish this. One relatively easy alternative is to use the NOAA Spill Tools software set (http://response.restoration.noaa.gov), which includes a Mechanical Equipment Calculator, a Dispersant Mission Planner, and an In-situ Burn Calculator. Similar protocols are available commercially, or may have been developed locally for use in your region. It is also likely that one or more of the participants in the assessment team may have experience in conducting such analyses. Whichever option you select, the participants must agree that the results (in terms of the overall amount of oil recovered or treated) are realistic in terms of the scenario being used and their own experience in real spills. This is critically important later in the analysis because it is a determining factor in calculations of oil fate and also of

Efficiency estimates for response options are a key element in the risk assessment

On-water Mechanical Recovery as Described in the Galveston Bay ERA (Pond et al., 2000b)

Use**:** Removal of oil from water for disposal and possible reuse to prevent or minimize impacts to sensitive nearshore and shoreline habitats.

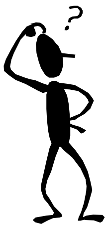
Logistics**:** Booms, skimmers, vessels, sorbents, deflection/collection booms, oil storage devices, and/or vacuum trucks.

Limitations**:** Water depth is a challenge in Galveston Bay; large-capacity equipment is generally limited to waters of greater than 8 feet in depth. Although most on-water mechanical recovery operations occur in open water, some efforts extend into shallow water habitats. Shallow water operations increase opportunity for damage to resource as a result of physical contact with clean-up equipment. Managers estimated it would take approximately 6 hours (from notification to arrival on-scene) to mount an effective response. Managers agreed that effectiveness of mechanical recovery is encounter rate-dependent.

Efficiency**:** Estimated effectiveness of 38% for a 500-barrel spill and 27% for a 4,000-barrel spill. On-water recovery efficiencies were based on the following assumptions: Percent effectiveness is based on total volume spilled.

Spill occurred at 0400.
Effective cleanup involves use of skimmers, booms, and recovered oil storage equipment.
Effective cleanup with all equipment operational at 1000.
Day 1- Effective cleanup with all equipment continues for 8 hours until 1800.
In an 8-hour period, all equipment will be fully operational for 6 hours, with 2 hours downtime for repositioning to new oil patches, decanting, and other miscellaneous activities.
For the 500-barrel scenario, no on-water mechanical recovery would occur after Day 1 due to spreading.
For the 4,000-barrel spill, mechanical recovery operations would continue at a reduced level throughout the night and the following day.

exposure of resources of concern to oil in the environment.



Where Can I Find More Information?

NOAA website: http://response.restoration.noaa.gov

Lewis, A., D. Aurand. 1997. Putting Dispersants to Work Overcoming Obstacles. Technical Report IOSC-004. API, Washington, D.C.

Buist, I.A., S.L. Ross, B.K. Trudel, E. Taylor, T.G. Campbell, P.A. Westphal, M.R. Myers, G.S. Ronzio, A.A. Allen, and A.B. Nordvik. 1994. The Science, Technology and Effects of Controlled Burning of Oil Spills at Sea. Marine Spill Response Corporation, Washington, D.C. MSRC Technical Report Series 94-013, 382p.

Activity 5: Defining the Environmental Resources of Concern

SUMMARY

In this activity, the resource subcommittee will develop a habitat-based characterization of the local environment. The basis of the risk assessment is the examination of the relative risk to the communities, habitats, or species of special concern in the geographic area affected by the spill. In order to conduct this analysis, they need to develop a list of the ecological resources to include. Then organize this list so that everyone can systematically compare the effects of the oil spill and/or the response options on your chosen resources.

In order to complete this Activity, the resource subcommittee will need to accomplish the following tasks:

- Identify the scenario's geographic area of concern
- Identify the ecological communities and/or habitat types present in that area
- Identify characteristic and/or key species or groups of species for each resource type
- Map the location, areal extent, or prime usage areas for the resources listed
- Obtain information on seasonal presence and life histories of all important species or groups of species
- Present this information to all participants for concurrence

Specific suggestions as to how to accomplish these tasks are provided in the following sections. When you finish reviewing this background material, complete the resources at risk matrix (Sample Form 3) in Appendix A.

Geographic Area of Concern

During a spill response, risk managers are generally responsible for identifying response measures. Risk assessors, on the other hand, focus on identifying resources with the potential to be adversely affected by the spill. The first step in this identification process, i.e., determining the general area of concern based on the likely trajectory of the surface oil, was completed by the resource subcommittee in Activity 3. Now they will fully develop the information about the area. If possible, this area should be identified on an ESI map. This map can serve as a base map to facilitate subsequent discussions.

Identify Resources of Concern and Key Species for Each

Use the following considerations to assist participants in developing the list of resources:

- Group species/resources into categories (i.e., related species or habitats)
- Keep in mind that while resources can be affected by one stressor, but not another, they all must be identified
- Have some basis of value for all resources (e.g., ecological, economic, or cultural value)
- Consider the status of a species or condition of a population (e.g., is that community already stressed or protected?)
- Think about the exposure pathways that will affect a resource
- Keep the spill scenario in mind

During this activity in the San Francisco Bay and Galveston Bay ERAs (see Pond et al., 2000a,b), the participants identified lists of very similar resources. Table 5-1 summarizes the classification systems used by the two groups.

Table 5-1 Resource Classification Systems Used in the Texas and California ERAs

Galveston Bay	**San Francisco Bay**
	Zone
Broad Habitat	Habitat
Sub-habitat	Sub-habitat
Resource Categories	Resource Categories
Example Organisms	Example Organisms

These systems allowed the development of a hierarchical table that identified all of the resources of concern. Tables D-1 and D-2 in the Appendix D show the resource lists for Galveston Bay and San Francisco Bay, respectively. The lists are quite similar for

An Example from the Resource Classification Matrix from the Galveston Bay ERA (Pond et al., 2000b)

Broad Habitat	Sub-habitat	Resource Category	Example Organisms
Benthic (sub-tidal)	reef	algae	benthic diatoms
		birds	American oyster-catcher; gulls; terns; white and brown pelicans; wading birds
		crustaceans	stone crab
		fish	pinfish; sheepshead; flounder; gobies; blennies
		infauna	amphipods; polychaetes
		mollusks	oyster*; oyster drills; barnacles
	Sub-Aquatic Vegetation (SAV)	algae	??
		birds	great blue heron; diving ducks;
		crustaceans	white shrimp; blue crab;
		fish	killifish; sheepshead; sheepshead minnow; spotted seatrout; spot; seahorse; pipefish
		infauna	amphipods; polychaetes
		mollusks	northern quahog; lightening whelk; snails
		seagrass*	eelgrass; American seagrass; ruppia

both assessments. The differences are the result of the local conditions and the proposed scenarios. For example, in the San Francisco Bay ERA, resources within the Bay as well as offshore were at risk. Consequently, both geographic areas had to be included in their resource tables.
Table 5-2 shows the Resource Categories developed in the Galveston and San Francisco Bay ERAs.

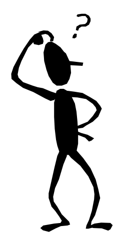
The differences in these lists are relatively minor, and reflect the differences in priority assigned to some resources in the two areas, as well as difference in the structure of the two estuarine systems. For example, certain terrestrial insects (butterflies) are protected in the California coastal zone, while in Galveston Bay resource managers attached high significance to the remaining seagrass beds.

Examine the examples shown in the call out box from the Galveston Bay ERA and in tables D-1 and D-2 as you develop your own tables for use in your assessment.

As you complete the resource matrix (Sample Form 3, Appendix A) during this activity, identify the key species or groups of species in each Resource Category present in each sub-habitat. This resource information is important in making sure that all of the critical potential consequences are considered.

Table 5-2 Resource Categories Used to Identify Taxonomic or Functional Groups in various sub-habitats

Galveston Bay	San Francisco Bay
Vegetation	Vegetation
Algae	
Seagrass	
Mammals	Mammals
Birds	Birds
Reptiles/Amphibians	Reptiles/Amphibians
	Insects
Fish	Fish
Crustaceans	Crustaceans
Mollusks	Mollusks
	Polychaetes
Jellyfish	
	Meiofauna
Infauna	Infauna
	Epifauna
Phytoplankton	
Zooplankton	
Microlayer Associated plankton	
	Plankton



Where Can I Find More Information?

National Research Council. 1985. Oil in the Sea: Inputs, Fates and Effects. National Academy Press, Washington, D.C. 601p.

NOAA Shoreline Atlases (ESI maps)

US Environmental Protection Agency. 1994. Ecological Risk Assessment Issue Papers EPA/630/R-94/00. USEPA, Washington, DC

Activity 6: Consider All of the Important Relationships

SUMMARY

In this activity, participants will develop a simplified model of the interactions between the chosen stressors (oil and/or the response options) and ecological resources. The model is based on " hazards" presented by the response options developed in Activity 4. It is the basis for the risk analysis. It also provides your team with the opportunity to clarify and prioritize the interactions between stressors and resources, based on the hazards they may present.

In order to complete this Activity, the entire group will need to accomplish the following tasks:

- Arrive at a consensus regarding
  - type of oil
  - appropriate response options for that oil
  - predicted effects/stressors on the resources
- Develop an understanding about how the resources of concern can be affected by the potential hazards
- Determine how these hazards relate to the response options
- Develop a matrix that defines the relationships between exposure to stressors, resources, and hazards
- Use this information to diagram the conceptual model

Specific suggestions as to how to accomplish these tasks are provided in the following sections. Once the review of this background material is complete, the entire group should cooperatively develop a conceptual matrix using Sample Form 4 in Appendix A.

Setting the Stage-Building the Framework

The key to a successful risk assessment is to develop a credible model demonstrating how the various components interact. The model must show the potential environmental consequences of various stressors (oil, or oil in the presence of a response option) on all of the ecological resources of concern. In order to do this, your team must first have a clear understanding of all of the possible interactions between stressors and resources (e.g., how ISB affects marsh vs. sandbar). This may take some time, but it is a necessary step. Everyone must understand the interactions of stressors with the environment before the group develops a systematic method for comparing relative risks from the stressors. Once everyone understands these interactions, you will take that information and turn it into a standard format (the matrix). The matrix will then guide the rest of the risk assessment process. It will define the connections that your team needs to analyze, i.e., connections between stressors and resources.

What is the Best Way to Accomplish this Activity and Who Needs to Participate?

While the earlier activities can be completed by a subcommittee, and then distributed for comment and revision, this activity works best when completed in a group setting, by the full assessment team, led by the assessment coordinator. The resource managers and subject matter experts need to be actively involved, including some industry representatives or other individuals who have practical experience with the various response options. This ensures that everyone understands and accepts the relationships you will use to structure the analysis. The assessment coordinator has the responsibility of guiding the group to a consensus. *If some members of your team do not agree on the elements of the conceptual model and how to use it, then subsequent activities will be unsuccessful.*

What is a Conceptual Model?

A **conceptual model** *is a depiction of how various ecological resources might respond when exposed to stressors*. The model must include ecosystem processes that influence the potential responses. Conceptual models consist of two principal products:

1. A written description of the *potential for* and *degree of* contact between stressors and ecological resources of concern, based on the exposure pathways (hazards)
2. A diagram that illustrates the relationships defined above

In many ERAs, the conceptual model is used to develop a complex, mathematical representation of the situation under consideration. That level of detail is not feasible for this analysis. Here, we will use a basic representation of the interactions of concern to develop a qualitative analysis.

Effect of the Response Option on the Fate of the Spilled Oil (Hazard Definition)

Response options are a source of potential ecosystem stress in addition to stresses caused by the spilled oil. The mechanisms that cause this stress are not always the same, and may differ in magnitude between options. Seven “hazards” determine potential exposure pathways that link the stressors (including natural recovery) to resources. These hazards are:

1. Air pollution
2. Aquatic toxicity
3. Physical trauma (a mechanical impact from people, boats, etc.)
4. Oiling or smothering
5. Thermal (refers to heat exposure from ISB)
6. Oil-contaminated waste materials
7. Indirect (refers to a secondary effect such as ingestion of contaminated food)

Use the response options selected for analysis (stressors) and the seven associated hazards to develop a conceptual model and guide the analysis. Certain stakeholders may have particular concerns with some of these hazards, based either on their previous experience or on concerns about a new technology. If this is the case, then these concerns should be identified now and included in the description of the response option. Ensure that all participants agree with the interpretation of each hazard. *This is crucial to this activity*.

> *Hazards for Evaluation*
>
> *Air Pollution*
> *Aquatic Toxicity*
> *Physical Trauma (mechanical, disturbance)*
> *Oiling or Smothering*
> *Thermal (heat from ISB)*
> *Oil-Contaminated Waste Materials*
> *Indirect (secondary)*

Development of the Basic Conceptual Model Matrix

At the beginning of this Activity, participants examined a list of hazards. The list represents a summary of all the possible ways an oil spill and associated cleanup activities might affect a resource. Refer to this list of hazards to relate the response options to the ecological resources.

Table 6-1 shows a portion of the conceptual model matrix developed for the San Francisco Bay ERA (Pond et al., 2000a). It is only a portion of the full matrix, and includes only a portion of the habitats and sub-habitats. The numbers in the various matrix cells represent the path by which a stressor affects a resource. For example, on-water recovery affects mammals through Oiling/Smothering. *On-water recovery* is the **stressor**. **Mammals** are *the resource*. **Oiling/Smothering** is *the path by which the mammals are affected*. At this stage of the analysis, the hazard connections are indicated for the various resource categories in each habitat. This is so that a record will exist of the specific reason for the concern with that habitat.

It is important to understand that the connections represent *changes from the natural recovery (or oil only) situation*. When the resource and the stressor cannot be connected through a hazard, the box contains NA. Shading indicates that in the initial development of the model the participants viewed at least one of the hazards in that box to be of particular concern.

Once you develop an entire matrix, you can use it to prepare a series of visual presentations showing these interactions in a summary fashion, one for each of the stressors. An example from the San Francisco Bay ERA is shown in Figure 6-1 (Pond et al., 2000a). This is not a requirement for the analysis, but some participants may find it more meaningful in guiding their considerations than the matrix.

> *Natural Recovery is the baseline condition in the conceptual model.*

A sample conceptual model matrix form is provided in Appendix A (Sample Form 4). Multiple iterations of this form may need to be completed, and then combined to form the completed conceptual model matrix before all participants become comfortable with the presentation. If desired, a conceptual model diagram can be prepared, using Figure 6.1 as a guide.

Table 6-1 Sample Portion of Conceptual Model Matrix: San Francisco Bay ERA (Pond et al., 2000a)

Zones:	Terrestrial					Water Surface				Intertidal				
Habitats:	Upland and Supratidal									Marsh				
Sub-Habitats:														
RESOURCES:	Vegetation	Mammals	Birds	Reptiles/Amphibians	Insects	Mammals	Birds	Reptiles/Amphibians	Vegetation	Mammals	Birds	Fish	Crustaceans	Mollusks
STRESSORS:														
Natural Recovery	7	1,7	1,7	1,7	1,7	1,4,7	1,4,7	1,4,7	2,4	1,4,7	1,4,7	2,7	2,4,7	2,4,7
On-Water Recovery	3	3,6	3,6	3,6	3,6	3	3	3	3	3	3	3	3	3
Shoreline cleanup	3,4,6	3,4,6	3,4,6	3,4,6	3,4,6	4,7	4,7	4	3,4	3,4	3,4	3,4	3,4	3,4
Oil + Dispersant	NA	NA	NA	NA	NA	7	7	NA	2	4,7	4,7	2,7	2,7	2,7
ISB	1	1	1	1	1	1,5	1,5	1,5	4,5	1,4,5,7	1,4,5,7	5,7	4,5,7	4,5,7

Note: On-water recovery includes protective and diversion booming
Note: N/A indicates that stressor and resource do not contact each other
These hazards represent changes from oil only scenario.
Shaded zones indicate areas of emphasis for the risk analysis

Hazards:
1. Air Pollution
2. Aqueous Exposure
3. Physical Trauma (mechanical impact from equipment, aircraft, people, boat bottoms, etc.)
4. Physical Oiling/Smothering
5. Thermal (heat exposure from ISB)
6. Waste
7. Indirect (food web, etc.)

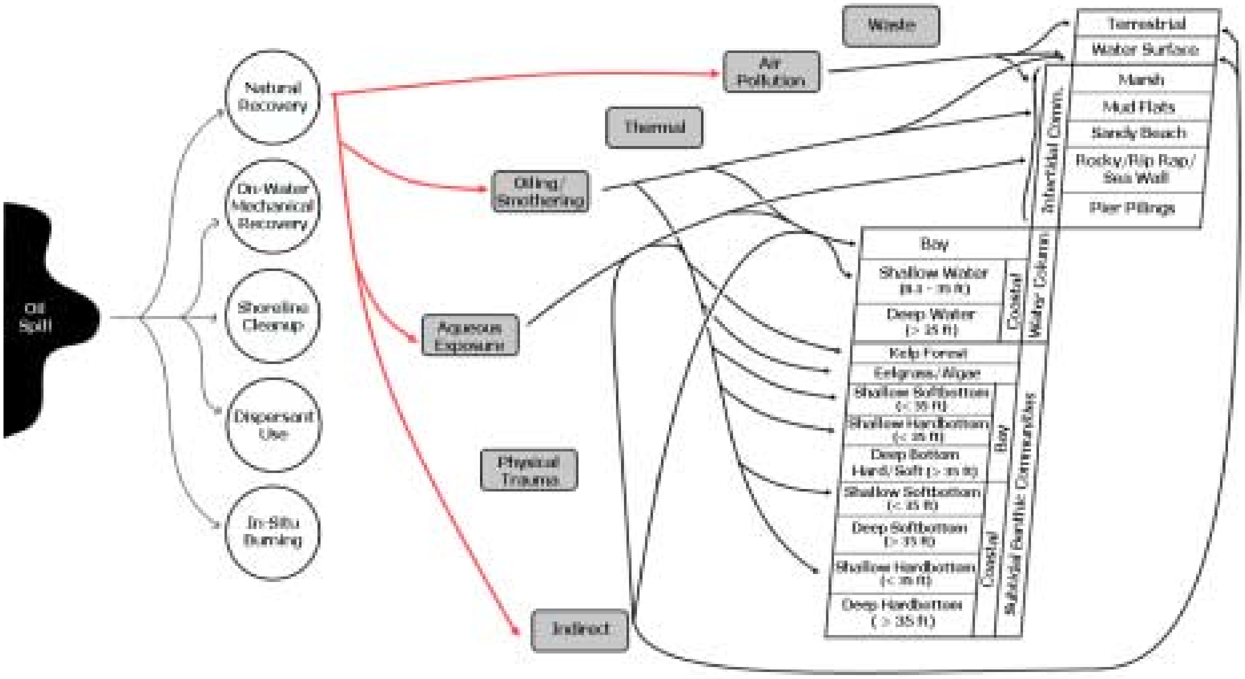
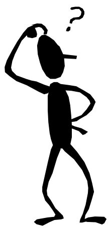


Figure 6.1 **Example of a Portion of a Conceptual Model (taken from the San Francisco Bay ERA) (Pond et al., 2000a)**



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US Environmental Protection Agency. 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/002Fa. US EPA, Washington, D.C.

Activity 7: Develop Thresholds to Estimate the Sensitivity to Oil of the Resources at Risk

SUMMARY

Once you develop the basic conceptual model, the entire group will need to discuss how to evaluate the severity of your predicted ecological effects. ***This is an important discussion****! If you have no consensus on these thresholds, then you cannot evaluate the risks.*

In order to complete this Activity, the group will need to accomplish the following tasks:

- Establish general goals for the analysis
- Identify general measures of environmental effects that are appropriate to the analysis
- Review available information on how the stressors may interact with your chosen environmental resources of concern
- Determine thresholds for concern to apply in the analysis

Specific suggestions as to how to accomplish these tasks are provided in the following sections. When the participants finish reviewing this background material, develop a list of general response goals and general measures of ecological effects.

Setting the Stage – Defining Effects

Once you identify the connections necessary to define the conceptual model, the participants need to develop "thresholds" to consider when evaluating the actual effects and consequences of response actions. This is another activity that is best to do in a group setting where all participants can be involved. This is where your model matrix becomes useful. A **threshold** refers to *a measurable level of exposure to a hazard that results in a definable level of effect in a resource of concern*. In this context, the term is similar to the concept of endpoints as developed in the EPA Ecological Risk Assessment Guidelines. A summary sheet providing additional information on this subject is provided in Appendix B. Develop a threshold for each of the seven hazards as they relate to each exposed resource. It is impractical to do this for every species, but data on sensitive or key species will guide your discussions.

What are the General Objectives of the Analysis?

Before you select specific thresholds, you need to develop appropriate response objectives from an ecological standpoint. The following list provides the goals developed at the Galveston Bay and San Francisco Bay ERAs (Pond et al., 2000a,b). Similar goals should be developed for every assessment.

- Prevent or minimize taking of protected species
- Prevent or minimize degradation of water quality
- Prevent or minimize degradation of sensitive habitats
- Prevent or minimize the long-term disturbance of relative abundance and diversity of communities within habitats (no net loss)

What Constitutes an Acceptable General Measure of Effect?

Based on your general response objectives, develop a list of general measures to judge the significance of environmental effects. The following list presents the measures identified in the Galveston Bay and San Francisco Bay ERAs (Pond et al., 2000a,b). A similar list should be developed for each assessment.

- The proportion of killed resources within the projected trajectory
- The amount of exposure leading to impaired reproductive potential of the resource
- The proportion of oiled resources within the proposed trajectory
- The extent of disturbance

Once you complete this, your assessment team needs to agree on data to assess the likelihood of these effects occurring as a result of the spill or the response options.

What Exactly Does Threshold Mean in the ERA Process?

As used in this approach, the term **threshold** refers to *taking measurable data from the laboratory or the field, and relating it to a predicted level of effect*. Achieving a consensus on a threshold is often difficult because the term contains subjective elements. Establishing water column concentrations that are predicted to have lethal or sublethal consequences for organisms exposed to them is an example of setting a threshold. In some cases, experts are able to agree where to place a threshold value. For example, in the two trial ERAs, participants had little trouble accepting that adult fish in the water column exposed to 10 ppm of oil for 3 hours are likely to survive without serious consequence (Pond et al., 2000a,b). The figure 10 ppm was their threshold. However, the effects of other stressors may not have fixed points. For example, how can anyone directly predict what percentage of a marsh can be oiled without serious consequence? That figure can change based on the dynamics of the marsh you choose to examine and the value placed upon it. In either case, keep in mind that every threshold contains a value judgement to some degree.

How do you Determine if a Proposed Threshold is Ecologically Significant?

Define the thresholds you will use, basing them on the following:

- Include resources with biological and societal relevance
- *Ensure that everyone on your team understands the reasoning behind the proposed values for your thresh-*

olds (You will use the numbers created here in the next section.)
- Choose thresholds that you can predict and measure to some degree
- Ensure the thresholds align with experience from historical spills
- Choose your thresholds based on susceptibility to the hazardous substance or alteration

For this type of qualitative assessment, thresholds may be based on habitat loss, physical degradation of habitat below some effect level, or biological effects. No matter what effects you examine, everyone involved in your team's assessment process must accept the threshold definitions.

Determining the ecological significance of an event requires that you place it in the following context:

- The types of other anticipated events associated with the stressor
- The magnitude of the other events caused by the stressor
- Its role in the structure and function of the system in question
- Its relationship to other events within the system (cumulative analysis)

A threshold must be relevant to what you are trying to analyze, and must relate to a susceptible resource.

What Does Susceptibility Mean?

Susceptibility has two components, **sensitivity** and **exposure**. **Sensitivity** refers to *how readily a resource is affected by a particular stressor*. It is related to the proposed mode of action of the stressor as well as to variability in individual and life history stages. **Exposure** refers to *co-occurrence, contact, or the absence of contact*, depending on the nature of the stressor and the properties of the ecological resource in question. One central assumption of risk assessment is that *effects are directly related to exposure*. Life history considerations are often very important in determining susceptibility, and can be very complex. Remember to consider delayed effects.

Susceptibility

Sensitivity = How acutely will a stressor affect a resource? (pathway & magnitude)

Exposure = What kind of contact did the resource have with the stressor? (duration, spatial coverage)

What Data Will be Available to Use to Develop Specific Thresholds?

In Activity 4, you developed information on the potential consequences of the spill and the response options. This consisted of four different types of estimates:

- The distribution of floating oil over time
- The distribution of oil on the shoreline
- The distribution of physically or chemically dispersed oil in the water column through time
- The distribution of smoke from ISB

Use these data to define the severity and magnitude of the exposure that might result from scenario options. This can be a difficult task on which to achieve a consensus. The approach used in previous workshops relied on the professional experience of the participants and selected published literature. Generally, participants used this information to develop conservative positions on appropriate thresholds for each analysis. Table 7-3 shows the relationship between the seven hazards and the types of data that will be available. It also suggests the type of thresholds that might be useful in each case.

In the San Francisco Bay and Galveston Bay workshops, participants felt they had a reasonable grasp of shoreline effects, based on the experience of many of the participants. They were concerned, however, about interpreting water column effects based on toxicity. The participants cooperated to prepare an "exposure effects template" for ranking the risk of dispersant use. The criteria developed in the Galveston Bay ERA are shown in Table 7-4, and those used in San Francisco were very similar (Pond et al., 2000a,b). For the purposes of the assessment, your team needs to review this table and agree on any needed modifications.

Discussing thresholds may be difficult, and you may find it necessary to go through several iterations before this table or any of the thresholds proposed are acceptable to all participants. However, *this information is absolutely necessary for future discussions*. This is where the Effects subcommittee becomes critical. They may have to examine the basic literature and report back to the participants periodically until their concerns are resolved. In the following paragraphs, some of the considerations used in the development of Table 7-4 are presented to illustrate this point.

In the table, all numbers are in parts per million (ppm). (Typically, the numbers provided in the NOAA trajectory report are in parts per billion.) Values are intended to indicate thresholds for resources. For example, if adult fish are exposed to a dispersed oil plume of 100 ppm for 3 hours, concern should be high. If they are exposed to a 10-ppm plume for 3 hours, concern should be low (because there is little or no potential for acute effects).

In the workshops, there was considerable uncertainty as to what constituted a "return to background levels" of petroleum hydrocarbons in the water column. This is important because Table 7-4 is based on "total petroleum hydrocarbon" levels, while most studies of pollutants look at individual compounds, any one of which is only a small component of the numbers in the table. The values in the table are conservative in terms of effects, but firm data are not available to raise the values.

Participants agreed that exposure of organisms to the dispersed oil plume is limited in duration. Mobile animals (other than plankton) can swim out of the plume, and the plume affects sessile organisms only for the period of time when it is over their location. Mature fish and mobile adult invertebrates do not appear to be affected by exposure to dispersed oil plumes at the concentrations typically encountered.

Oil slicks are patchy, which means the dispersed oil plume is patchy as well. As it mixes into the water column, thicker patches diffuse into deeper waters. In shallow water, parts of the plume may reach the bottom. This is unlikely offshore and in water over 30 feet deep.

Data is limited regarding the effects of dispersed oil on reproduction and fertility of aquatic organisms. Such effects should be similar to those for petroleum hydrocarbon compounds alone, which occur mainly in situations where exposure is long-term (i.e., leaching of oil from a beach for long periods after a spill). The fact that this issue remains open supports the conservative

Table 7-3 Relationship Between Hazards, Data, and Possible Thresholds for Analysis

Hazard	Type of Data	General Threshold	Comments
Air Pollution	Concentration, distribution, and duration of model plume	Inhalation exposure of smoke particulates	Use human standards to estimate level of concern
Aquatic Toxicity	Concentration, distribution, and duration of total hydrocarbons in the water column	Toxicity table can be used to set thresholds (See Table 7-4)	Most quantitative of all information (also most confusing). Table of suggested thresholds is conservative
Physical Trauma	General area and length of time	Assume sensitive organisms can be harmed if in operating area	Generally not a critical factor, but it has been an issue in some spills (e.g. steam cleaning of rocks)
Oiling or Smothering	Surface area where slick could be located and density and duration of coverage. Linear extent of shoreline where slick might come ashore and rough estimate of amount of oil per unit of shoreline	Assume sensitive organisms can be harmed if in slick area or in area of oiled shoreline	Estimates are very imprecise. Assuming contact equals effects will overestimate concern. Must be interpreted with care, especially for shoreline
Thermal (ISB)	Area under the location of the burn	Loss of sensitive species	This is only important on shoreline if done improperly
Oil-Contaminated Waste Materials	Amount of waste likely to be generated (bbl) by shoreline cleanup	Compare to disposal or storage capacity	Not usually critical ecologically unless improperly done
Indirect	Persistence of exposure and the level of acute effect for species of concern	Estimate food chain effects from expected level of contamination. Estimate aquatic sublethal effects by comparing them with data on long-term exposure	Most sublethal and biochemical problems appear to be related to chronic exposure.

Table 7-4 Workshop consensus on exposure thresholds of concern in parts per million (ppm) for dispersed oil in the water column (Pond et al., 2000b)

Exposure	Level of Concern	Protective of Sensitive Life Stages	More Protective Criteria	Protective of Adult Fish	More Protective Criteria	Adult Crustacea/ Invertebrates	More Protective Criteria
0-3 hours	Low	<5	<1-5	<10	<10	<5	<5
	Medium	5-10	5-10	10-100	10-100	5-50	5-50
	High	>10	>10	>100	>100	>50	>50
0-24 hours	Low	<1	<0.5	<2	<0.5	<2	<0.5
	Medium	1-5	.5-5	2-10	.5-10	2-5	.5-5
	High	>5	>5	>10	>10	>5	>5
0-96 hours	Low	<1	<0.5	<1	<0.5	<1	<0.5
	Medium			1-5	.0-5	1-5	.5-1
	High	>1	>0.5	>5	>5	>5	>1

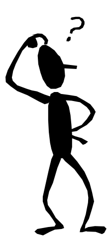
thresholds in Table 7-4. The use of dispersants lessens the probability that oil will reach and adhere to the shoreline, which decreases the concern regarding chronic shoreline exposure.

Interestingly, despite the general concern over water column toxicity, it is easier to define quantitative thresholds for that measure than for floating surface oil and shoreline exposure. Based on this information, we recommend that surface oil thresholds be based on

1. the proportion of the surface area within the study area that is affected
2. period of time oil will be present
3. the density of the oil coverage

In the case of shoreline contamination, an appropriate measure includes the length of the shoreline oiled, the percentage of the total resource affected, and the amount of oil per unit area.

The distribution and concentration of smoke from ISB can also be modeled. You can use existing information on effects concentrations for human populations to develop thresholds.



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Activity 8: Determine the Level of Concern About Potential Effects

SUMMARY

Completing a risk matrix is the key to the analysis. It is a screening approach that allows participants to apply numerical estimates of concern regarding the potential impact of each individual stressor on each resource and habitat of interest in the environment. The completed matrix facilitates the comparison of impacts of each stressor individually as well as a determination of impact tradeoffs between stressors.

In order to complete this Activity, the participants will need to accomplish the following tasks:

- Develop the risk-ranking matrix
- Obtain a consensus on scales for the ecological risk-ranking matrix
- Develop preliminary risk scores for the resource option/resources at risk using focus groups
- Obtain a consensus on summary scores for use in the risk-ranking matrix
- Convert preliminary risk scores to summary scores
- Allow focus groups to review and reconsider their initial risk scoring
- Review revised scores and develop consensus on final risk scores
- Identify scores that cross summary categories for separate consideration

Specific suggestions as to how to accomplish these tasks are provided in the following sections. When participants finish reviewing this background material, complete the risk-ranking matrix (Sample Form 5) in Appendix A. Use this information to complete the summary risk matrix (Sample Form 6) in Appendix A.

Conducting the Analysis – Defining Effects

At this point, you have obtained the basic data necessary to determine the relative risks associated with each response option. In order to visualize these risks, the group must now develop a standard ranking system. This is a qualitative effort based on the criteria you are about to define. Present the analysis in a format that can be used to arrive at a group consensus. To this end, employ a simple risk-ranking matrix as a scoring key (Sample Form 5). The matrix allows you to evaluate two parameters, the severity of exposure versus length of recovery for the resource. You will use these parameters to describe your level of concern for each possible interaction between a stressor and a resource of concern.

What is a Risk Ranking Matrix?

Each axis of the square represents a parameter used to describe risk. For example, participants could use a square in which the x-axis rates "recovery" and ranges from "reversible" to "irreversible," and the y-axis evaluates "magnitude" and ranges from "severe" to "trivial." In its simplest form, the risk matrix is divided into 4 cells. Each cell is assigned an alphanumeric value to represent relative impact. Thus, a "1A" represents an irreversible and severe effect, while a "2B" represents a reversible and trivial effect (Figure 8-1). Obviously, a 2 by 2 matrix does not allow much in the way of resolution and is ineffective in rating impacts. On the other hand, if you use something like a 10 by 10 matrix, the scaling becomes challenging and the resulting 100 ranks are difficult to interpret. In the two test ERAs used to develop this process, one group used a 4 by 5 matrix and one a 4 by 4 matrix (Pond et al., 2000a,b). This general size is appropriate for your effort. The exact size is up to you and your participants depending on the results of your discussion about scaling the matrix.

	Recovery	
MAGNITUDE	1. IRREVERSIBLE	2. REVERSIBLE
A. Severe	1A	2A
B. Trivial	1B	2B

Figure 8.1 **Basic Ecological Risk Matrix**

What Should You Use for a Scale?

The scaling of the risk ranking matrix needs to be discussed by everyone in the assessment, even though natural resource managers are likely to have the most practical experience with the relevant information. You need to discuss this as a group because you have to have a consensus on the ranking system or the rest of the analysis will be impossible.

For the vertical axis, use the area of impact or number of organisms (percentage of total resource affected) as the magnitude factor. The scale should be divided into four or five levels to address the degree of resolution you think is appropriate. These criteria can also address the ecological level of effect, ranging from community level effects at the high end to the loss of a few individuals at the low end. Remember, the data you have to work with is very general, so do not try to design a scale that delineates very fine differences. Figure 8.2 is an example of a final matrix (Pond et al., 2000a).

	> 7 years (1)	3 to 7 years (2)	1 to 3 years (3)	< 1 year (4)
High (> 60 %) A.	A1	A2	A3	A4
Mod/High (40 – 60 %) B.	B1	B2	B3	B4
Moderate (20 – 40 %) C.	C1	C2	C3	C4
Moderate/Low (5 – 20 %) D.	D1	D2	D3	D4
Low (< 5 %) E.	E1	E2	E3	E4

Figure 8.2 Final Ecological Risk Ranking Matrix for the San Francisco Bay ERA. (Pond et al., 2000a)

Preliminary Risk Scoring – Using the Ranking Matrix for Natural Recovery

Once you design the risk ranking matrix, hold a group meeting where all of the assessment team can get together to develop risk scores. In order to facilitate the process, and to get a range of opinions, divide into groups of about 7 to 10 people to conduct the risk ranking process. You want to have at least two groups, preferably three. In each group, include members from as many stakeholders as possible and a good mix of expertise (i.e., don't put all the fish biologists in one group). *Each group must rank natural recovery first in order to evaluate the approach, and to provide a baseline against which the other stressors can be compared.*

Risk scores for natural recovery are the base-line against which all other options are com-pared.

Using the risk ranking matrix values, each group should score individual resources first and then derive consensus sub-habitat scores (Sample Form 6). This process is based on the matrix developed in Activity 6. Focus your discussions regarding scores around the relative magnitude of the hazards for each box. The consensus score represents the consensus of the group regarding the overall risk to the sub-habitat, and is based on the risk to individual resource groups. A portion of a scoring sheet (natural recovery option) from one group in the San Francisco ERA (Pond et al., 2000a) is shown in Figure 8.3, as an example. The letters A, B, and C on the vertical scale refer to scores from three separate ranking teams. Each team filled out their own row and then a session coordinator compiled them into one form.

The consensus score can be difficult to develop. This is why it is important to have multiple scoring groups. By having each group complete the process independently, you can avoid missing important considerations. For example,

	Terrestrial					Water Surface			Intertidal																							
	Upland and Supratidal								Marsh						Mud Flats						Sandy Beach					Rocky/Rip Rap/Sea Walls						
RESOURCES:	Vegetation	Mammals	Birds	Reptiles/Amphibians	Insects	Mammals	Birds	Reptiles/Amphibians	Vegetation	Mammals	Birds	Fish	Crustaceans	Mollusks	Vegetation	Birds	Fish	Mollusks	Crustaceans	Polychaetes	Mammals	Birds	Fish	Crustaceans	Meiofauna	Vegetation	Mammals	Birds	Fish	Crustaceans	Mollusks	Epifauna
A[1]	NA	NA	NA	NA	NA	2e	1b	4e	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4e	1b	4e	3e	4e	4e	1e	1d	4e	4e	4e	4e
A[1]	NA					1b			NA						NA						1b					1d						
B[1]	NA	NA	3d	NA	NA	4e	2c	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4e	2c	4e	4c	4d	4d	4d	3d	4e	4c	4c	3c
B[1]	3e					3d			NA						NA						2c					3d						
C[1]	4e	4e	4d	4e	4d	1d	1c	1e	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4e	1b	4d	4e	2b	2d	1e	1d	3e	3e	3e	3e
C[1]	4e					1c			NA						NA						2b					3e						

[1] Consensus Score

Figure 8.3 **A sample portion of the preliminary risk ranking matrix for the Natural Recovery option from the San Francisco Bay ERA (Pond et al., 2000a)**

large differences in scores suggest differences of opinion about exposure, sensitivity, value, or some combination of the above. The assessment coordinator will lead discussions of these issues in a plenary session. For example, a single resource may drive the score for that particular habitat because it is a keystone or protected species. In other cases, it may be appropriate to develop an average for all the resources. In general, the larger the proportion of the effected resources, the greater the risk. You also need to consider the relationship of the resource in the study area to the resource on a regional basis. In some cases, the appropriate basis for determining magnitude may be the local availability and in others, the regional availability of the resource.

Blank forms for your use are provided in Appendix A (Sample Form 5 and 6).

Once all three groups complete the ranking, review the results and have the entire assessment team compare them in plenary. The purpose of this review is to determine if everyone understands the process. It will also allow you to identify and discuss any fundamental differences in opinion about the consequences of the oil spill (natural recovery) described in the scenario. If necessary, allow groups to adjust their scores based on these discussions.

Completing the Initial Risk Scoring

Once your groups complete the scoring for natural recovery, have them complete preliminary risk ranking matrices for each of the response options. *Remember, your scores for all the options should be relative to the scores assigned to natural recovery*. In other words, if the situation got worse, the score should be higher, and if the situation improved, the score should be lower. Prior to starting work on a matrix, the three subcommittees should meet in plenary session to discuss any special issues related to the response option under consideration.

Defining Levels of Concern - Simplifying the Scores

Now that you have some results, begin to focus on defining what they mean. Even to the participants, comparing a score of 3A to a score of 4B will be difficult and those numbers will mean nothing to a state or federal spill response manager. Therefore, now you need to define relative levels of concern in the risk-ranking matrix. This provides a method of grouping stressor effects in terms of a "high", "medium", or "low" level of concern, based on the alphanumeric codes described earlier. As an example, participants in the San Francisco Bay ERA suggested the pattern shown in Figure 8.4 (Pond et al., 2000a). As a group, you should discuss how you wish to develop your own summary system. You may wish to develop your own terms to make sure everyone in your assessment team is comfortable with the connotations. For example, while the participants in the Galveston Bay ERA referred to a "low" level of concern, the San Francisco Bay group used the term "limited" level of concern.

Concentrate on resolving scoring differences that cross between levels of concern.

Once you agree on this ranking system, prepare a table that shows the scores, by group, coded to indicate the appropriate level of concern. Figure 8.5 shows an example taken from the San Francisco ERA (Pond et al., 2000a). Notice that scores for the three separate scoring groups are now in horizontal columns with their consensus score and the level of concern indicated by shading. You should also notice that in most sub-habitats, the scores of the three groups are not exactly the same numerical score, but are in the same level of concern. When your groups complete this process, you will undoubtedly find the same thing. Do not worry about making the three group's scores match. If the level of concern is the same, your analysis is complete enough for the level of detail possible here.

You do need to worry about group scores that are not in the same level of concern. Discuss those so that, if possible, the differences can be resolved. Sometimes that is not possible either because of lack of data or because of different interpretations of the many intangible values each participant brings to the process.

		RECOVERY PERIOD			
		> 7 years (SLOW) (1)	**3 to 7 years (2)**	**1 to 3 years (3)**	**< 1 year (RAPID) (4)**
% of RESOURCE	**> 60% (LARGE) (A)**	1A	2A	3A	4A
	40 - 60% (B)	1B	2B	3B	4B
	20 - 40% (C)	1C	2C	3C	4C
	5 - 20% (D)	1D	2D	3D	4D
	0 - 5% (SMALL) (E)	1E	2E	3E	4E

Legend: Cells shaded dark gray represent a high level of concern, cells shaded gray represent a moderate level of concern, and cells not shaded represent a limited level of concern.

Figure 8.4 **Definition of Levels of Concern within the Risk Matrix as Defined in the San Francisco Bay ERA (Pond et al., 2000a)**

Zones:	**Terrestrial**			**Water Surface**			**Intertidal**															
Habitats:	Upland and Supratidal						Marsh			Mud Flats			Sandy Beach			Rocky/Rip Rap/Sea Walls			Pier Pilings			
Sub-Habitats:																						
Nat. Rec.	4e	NA	4e	1b	3a	3c	1b	2a/ 2b	2c	1c	3d/ 2a	3d	2c	3c	4e	2c	3c	3c	3c	3d	3d	
Mech. Rec.	4e	NA	4e	1b	3a	3c	1b	2a	2d	1c	2a	3d	2c	3c	4e	2c	3c	3d	3c	3d	3d	
Shoreline Cleanup	4d	3e	4d	1b	3a	3c	1b	2a	2c	1c	2c	3d	2c	3d	4e	2c	3b	3b	3c	2b	3c	
Dispersant use (35%)	4e	NA	4d	1b	4b	3c	1b	2b	2c	1c	2b	4a	2c	3d	4e	2c	3c	3c	3c	4e	3d	
Dispersant use (80%)	4e	NA	4d	1d	4d	3d	2d	3d	3d	2d	3d	3d	3d	4d	4e	2d	4d	4d	3d	4e	4d	
ISB	4e	4e	4d	1b	3a	3c	1b	2a	2d	1c	2a	3d	2c	3c	4e	2c	3c	3d	3c	3d	3d	

- Indicates high level of ecological concern
- Indicates moderate to high level of ecological concern
- Indicates moderate level of ecological concern
- Indicates low level of ecological concern

Figure 8.5 **A sample section of a preliminary summary matrix from the San Francisco Bay ERA (Pond et al., 2000a)**

Completing the Analysis - Final Risk Scores

Based on the preceding plenary session discussion, each group should be asked to reconsider their scores in cases where significant differences exist. Hopefully, the discussion will allow you to resolve the differences; if not, then that is acceptable. They indicate areas where uncertainty is a critical issue, and that is important to know. Present these unresolved issues to the risk managers for discussion and indicate in the final matrix by cross-hatching or stippling.

> *You may want to leave some time after the preliminary rankings for participants to research particular concerns.*

You may want to complete the initial discussion of the differences at one meeting, and then allow participants to consider the implications and collect any new information they might like before you ask for a final score. In other cases, the change may be obvious and the change can be made right away. *Either way, make sure someone documents the changes and the reasons behind the modification.*

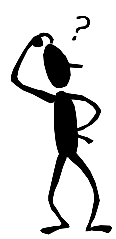
At the end of this process, you should have completed three products, the risk ranking matrix (Sample Form 5), the preliminary risk matrix (Sample Form 6), and the final risk matrix (Sample Form 7).

The revised risk-ranking matrix will be used to develop the discussions about relative risk in the next activity.

Once you complete the final summary risk matrices, you need to complete "sub-habitat summary worksheets." The sheets will identify the critical points discussed for each sub-habitat of concern. Each sheet will include brief statements on the following topics:

- Sub-habitat distribution (regionally and locally)
- Key species
- Key ecological role
- Sensitivity to oil
- Key assumptions in the risk ranking (for each response)
- Consequences of incorrect assumptions (if critical)
- Adequacy of data for the analysis
- Data needs

The best way to do this is to have individuals volunteer to prepare drafts for the sub-habitats with which they are the most familiar.



Where Can I Find More Information?

Pond, R.G., D.V. Aurand, J.A. Kraly (compilers). 2000a. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the San Francisco Bay Area. California Office of Spill Prevention and Response.

Pond, R.G., D.V. Aurand, J.A. Kraly (compilers). 2000b. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the Galveston Bay Area. Texas General Land Office, Austin, TX.

Activity 9: Evaluate the Relative Risk for the Response Options Under Consideration

SUMMARY

This activity focuses on the summation of the information now available to the participants. The risk to individual resources or from individual response options is presented, as is the relative risk related to all of the response options.

In order to complete this Activity, you will need to accomplish the following tasks:

- Complete individual summary tables for each sub-habitat type
- Complete the summary table of risk scores for the scenario
- Summarize the relative risk (based on natural recovery) for each response option
- Prepare summary discussions for each sub-habitat type
- Prepare consensus conclusions based on the scores for each option as well as their relative level of effects

Specific suggestions as to how to accomplish these tasks are provided in the following sections. When you finish reviewing this background material, complete the sub-habitat summary table and the relative risk summary matrix in Appendix A (Sample Form 8 and 9).

Defining the Risk – Comparing Effects

By now, you have the information necessary to complete the analysis, but it must be compiled in a meaningful fashion. Therefore, there are two objectives in this activity:

1. Examine the results for each individual option and see if it improves recovery, relative to natural recovery.
2. Compare the response options relative to each other to determine the best utilization of all of the options.

Develop Sub-habitat Summary Tables

In order to easily discuss the habitat-specific consequences of the various alternatives, and to make the data easier to present, complete an individual table for each sub-habitat (Sample Form 8). Table 9-1 shows a sample table taken from the

Galveston Bay ERA (Pond et al., 2000b). Note that there are two scenarios represented in this example. This table and the sub-habitat summary worksheets developed in Activity 8 provide the basis for the final comparative analysis.

Table 9-1 Risk Rankings for Water Surface [Surface Microlayer], Relative to Natural Recovery developed during the Galveston Bay ERA (Pond et al., 2000b)

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	2C	3C	3C	2B	4B	4B
On-water Recovery	3C	3C	3D	2C	4B	4B
Shoreline Cleanup	2C	3C	3C	2B	4B	4B
Oil & Dispersant	4D	4D	4D	3C	4C	4C
On-Water ISB	3C	3C	3D	2C	4B	4B

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern.

Preparing the Relative Risk Summary

While the results for individual sub-habitats are important, the real goals of this assessment are:

1. Determine if any options exist that are clearly more beneficial than others
2. Decide if any options present an unacceptable level of environmental risk

You will accomplish these two things by comparing the potential response options to the baseline, natural recovery (i.e., no response). For example, if the risk from a particular option is the same as natural recovery, then there is no relative risk to using the technology, but no benefit either. However, if the risk from a response option is relatively lower than natural recovery, then a net environmental benefit is expected. As you work through the analysis, you will notice that some individual scores in the risk matrix increase, while others decrease, making interpretation more difficult. Obviously, this is more important when the level of concern is moderate to high. *This is where the local knowledge of the resource managers is critical*, because they can guide the group in weighing and interpreting the results.

To complete this activity, participants need to compare the risk scores for all habitats and response options for the scenario. The scores for natural recovery represent the baseline against which they need to evaluate the other options. The risk ranking matrix used to rate the level of concern is resource independent (see Figure 8-4 for an example). In other words, the matrix is driven by considerations that apply equally to all resources (recovery time and level of effect from individual to community). This provides, to some degree, a common basis for comparison between habitat types. Table 9-2 presents an example of a completed summary risk table taken from the Galveston Bay ERA (Pond et al., 2000b).

Table 9-2 Example of a completed summary of risk scores for the 500 barrel spill scenario, Galveston Bay ERA (Pond et al., 2000b)

Habitats	Terrestrial	Shoreline/Intertidal			Benthic Subtidal					Water Column			Surface
SUB-HABITATS:	Terrestrial	Marsh/Tidal Flat	Sand/Gravel Beaches	Riprap Manmade	Shallow <3 feet	Open Bay 3 to 10 feet	Channel >10 Feet	Reef (not intertidal)	SAV	Top 3 feet	Bottom 3 feet (in depths of 3 to 10 feet)	Bottom 3 feet (in depths greater than 10 feet)	Surface (microlayer)
Natural Recovery													
On-Water Recovery													
Shoreline Cleanup	c	c	c										
Oil + Dispersant										c	c	c	
ISB													

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern. Cells with lines indicate concern with intermediate between moderate and low. Note that there were no high concern ratings in this scenario. Cells with a "c" indicate normally minimal concern, but incident specific circumstances need to be examined.

Develop Conclusions and Recommendations

At this point, your assessment is almost complete. Now you need to decide what your results really mean to your oil spill planning effort. Do this activity as a group, and then address consensus recommendations of your group concerning issues such as the following:

- environmental acceptability of each response option
- the best ways to use the response options (alone or in combination) to limit environmental damage
- the implications of the analysis for the use of new response technologies
- the limitations to the analysis
- new issues that were identified and need to be addressed, and
- the utility of the ERA process in response planning

You may find that there are additional general topics relevant to your planning area - this section should include everything you want to communicate to your response manager and to the other stakeholders in the response planning process. The final section of that report, i.e., making sure that the limits of your information are clear, is the subject of the next activity.

Where Can I Find More Information?

Pond, R.G., D.V. Aurand, J.A. Kraly (compilers). 2000a. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the San Francisco Bay Area. California Office of Spill Prevention and Response.

Pond, R.G., D.V. Aurand, J.A. Kraly (compilers). 2000b. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the Galveston Bay Area. Texas General Land Office, Austin, TX.

Activity 10: Understanding and Explaining the Limits of the Analysis

SUMMARY

There is always an element of uncertainty in this type of analysis. If this had been a large-scale, detailed risk analysis, it would be possible to develop some quantitative estimates of uncertainty for elements of the assessment. Even then, however, there are always some sources of error that cannot be clearly measured. In this case, the ERA is very qualitative and largely based on expert opinion; therefore, the uncertainty cannot be quantified. That does not eliminate the need to address the issues that might affect the conclusions of the analysis. In this activity, participants are asked to summarize the potential sources of error, and to provide a consensus evaluation of their importance.

In order to complete this Activity, the participants will need to accomplish the following tasks:

- List and describe the major sources of uncertainty in the analysis
- Complete a subjective evaluation of general data adequacy
- Identify any portions of the analysis where there is a consensus that data was possibly inadequate
- Determine what affect these inadequacies can have on your analysis
- Determine what kind of data could resolve the critical uncertainties

Specific suggestions as to how to accomplish these tasks are provided in the following sections. When the participants finish reviewing this background material, complete the data adequacy summary sheet (Sample Form 9) in Appendix A.

Conducting the Analysis – Defining Limits

Uncertainty can enter all phases of an ERA. In detailed risk analyses, considerable effort is put forth trying to quantify the sources of uncertainty. In oil spill planning applications, however, this analysis must remain qualitative because the events cannot be defined precisely. The major areas of uncertainty are as follows:

- Conceptual model formation
- Information and data
- Natural variability
- Mistakes by participants

A detailed discussion of the problem of uncertainty and the ways it can be addressed is included in Appendix B.

A finished assessment should represent the best estimate of ecological risk. Remember to discuss uncertainties associated with the estimate explicitly in your report. In order to address those concerns in this assessment, you need to address the following four issues for each sub-habitat assessment summary:

1. What were the essential assumptions behind the risk rating?
2. What are the consequences if these assumptions were incorrect?
3. What was the overall data adequacy for determining the risk rating?
4. Were there any recommendations for data collection that will improve the analysis?

At this time, use that information to write a short summary paragraph for each sub-habitat type. Then, review the paragraphs with your team for consensus and approval. As you develop the paragraphs, make a list of the concerns that appear to be the most critical. For each concern, prepare a short paragraph addressing the implications of that issue for the analysis as an example. Table 10-1 lists the issues that were raised in both the Galveston and San Francisco Bay ERAs (Pond et al., 2000a,b).

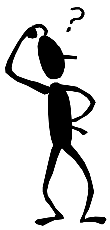
Summarizing the General Level of Adequacy for Data Used in the Assessment

While you are certain to have specific concerns about data elements in the analysis, you need to decide, as a group, if they interfered significantly with the results of your analysis. You can accomplish this by having the assessment team complete a general data adequacy summary, using the sample format presented in Appendix A (Sample Form 9). In this process, the group, by consensus, decides if the data quality associated with each of the matrix cells was 'high' (4) to 'low' (1). You will need to decide as a group what adjectives to use to describe the numerical scores.

Table 10-1 Areas of Uncertainty, Texas and California ERAs (Pond et al., 2000a,b)

Galveston Bay	San Francisco Bay
Assumptions about efficiency	Assumptions about efficiency
Modeling the fate of oil and dispersed oil in the environment	Modeling the fate of oil and dispersed oil in the environment
	Effect of salinity on dispersant efficiency
Uptake of dispersed oil by sediments	Uptake of dispersed oil by sediments
Effect of dispersed oil on birds	Effect of dispersed oil on birds
	Thresholds for dispersed oil
	Consequences of the ISB smoke plume
	Definition of the extent of the 'resource' or 'population' being considered

In both the Galveston Bay and San Francisco Bay ERAs (Pond et al., 2000a,b), the assessment teams were generally confident in the validity of the analysis, but both groups did identify a few instances were data adequacy was at an intermediate level. Such instances need to be discussed by the group and their importance to the analysis explicitly addressed. Table 10-2 shows a portion of the data adequacy table from the San Francisco Bay ERA.



Where Can I Find More Information?

American Petroleum Institute (API). 1986. The Role of Chemical Dispersants in Oil Spill Control. Pub. No. 4425. Prepared by Spills Technology Issue Group, Dispersant Task Force. API, Washington, D.C.

API. 1999. Fate of Spilled Oil In Marine Waters: Where does it go? What does it do? How do dispersants affect it? Pub. No. 4691. API, Washington, D.C.

API. 1999. A Decision-Maker's Guide to Dispersants. Pub. No. 4692. API, Washington, D.C.

Table 10-2 Example of Estimations of Data Adequacy, San Francisco ERA (4 = excellent, 3 = good, 2 = fair, 1 = poor) (Pond et al., 2000a)

Habitat	Response Action				
	Natural Recovery	On-water Mechanical Recovery	Shoreline Cleanup	Dispersant Use	On-Water ISB
Terrestrial	4	4	4	4	4
Water Surface	4	4	4	3	3
Marsh	3	3	3	3	3
Mudflats	4	4	4	1-2	2
Sandy Beach	4	4	4	4	1
Rocky/Riprap/ Sea Walls	3	3	3	3	3
Pier Pilings	4	3	3	2	2
Benthic Bay / Shallow Softbottom (< 35 ft)	4	4	4	2-3	4

Activity 11: Documenting the Risk Assessment

SUMMARY

The Assessment Coordinator's job is to always keep a record of the data your participants develop, the results of the analytical process, and the conclusions of the assessment. Without at least a minimal level of documentation, it will be difficult to convince response managers and other concerned parties of the value of your effort. In this section, some methods for record keeping are suggested.

Why do You Need to Prepare a Report?

Without a written record of the results of your analysis, much of your effort will be wasted. Your objective in conducting this analysis is to examine opportunities to improve response planning. The best way to do that is to provide material to others that explains the logic behind your recommendations.

Who Is Going to Do This?

Ultimately, the assessment coordinator is responsible for completing this report. It is unlikely, however, that he or she will be able to do so without the active support of volunteers from the assessment team. He or she should approach the job as one of coordinator, and encourage maximum participation from the group. Previous experience has shown that many people can be counted on to develop sections related to activities within their area of expertise.

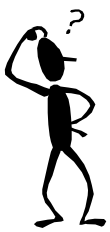
What Kind of a Report do You Need to Prepare?

In all of the various activities you, your team, and your participants were asked to complete, you were presented with sample forms to compile data and the results of your analysis. You were asked to prepare descriptive or summary paragraphs for certain elements of the analysis as well. This material is the basis for your report, and can be presented in the same sequence used in this guidebook. The level of detail is up to the assessment management team, under the guidance of the assessment coordinator. If you have completed the forms, and created the suggested summaries, then you have the basic information already collected. Text to explain the process can be extracted from this guidebook or referenced, as you desire. The best way to use the sample forms is to create computerized spreadsheets based on the design provided, and complete the forms as you work through the assessment. That way, when you come to the end of the analysis, most of the material can be easily assembled into a report.

You can also review a copy of the ERAs from Galveston Bay or San Francisco Bay (Pond et al., 2000b, a) for examples of the various sections. Those documents were prepared with the help of a dedicated project team. Your own report will probably not be as detailed.

Preparing a Report is a Lot of Work - Do You Have to Do This Every Time?

One of the objectives of this initiative is to complete a basic assessment, and then vary the scenario to examine the effects of elements such as the volume or type of oil, the time of the year, the weather, or the nature of the release. For most of these, you will be able to use much of the same descriptive material, and will need only to change the analytical and summary tables, along with any text associated with them. In essence, each new modification can be presented as an attachment to the original report, resulting in less work with each successive assessment. If the new scenario affects new geographic regions, or examines new response options, then you will need to prepare additional descriptive material, but it will not be nearly as much work as the first.



Where Can I Find More Information?

Pond, R.G., D.V. Aurand, J.A. Kraly (compilers). 2000a. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the San Francisco Bay Area. California Office of Spill Prevention and Response.

Pond, R.G., D.V. Aurand, J.A. Kraly (compilers). 2000b. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the Galveston Bay Area. Texas General Land Office, Austin, TX.

Activity 12: Using the Results to Improve Planning

SUMMARY

This activity presents some suggestions about how you and your participants can use the results of the assessment to influence future oil spill response planning decisions. The two primary means for accomplishing this objective are 1) the written project report and 2) summary presentations to response managers, local, regional, and Federal. The results should also be summarized and presented to other stakeholders as well. While the results of the first assessment will be of interest to all parties, future discussions may be more effective if the results of a range of conditions can be presented and compared at the same time.

Congratulations, you're almost finished! All that remains is a team decision regarding how you will apply this information to improve response planning in your area. The following is a list of suggestions that may help you in this effort. In the end, it is up to all participants to make sure this doesn't become just another stack of paper sitting on a shelf somewhere.

- Prepare a short summary report (4 to 8 pages) to distribute to stakeholders
- Develop a briefing using overheads or slides suitable for a short presentation to response managers
- Discuss the analytical approach and results with other response managers at your agency or in other agencies not involved in the analysis
- Hold a short session at your next RRT or Area Committee meeting to discuss the results
- Make presentations to local or regional environmental groups and encourage them to provide feedback or to participate in future efforts
- Prepare papers for technical meetings
- Review your port or area response plan and see if it is consistent with your recommendations. If not, develop suggestions as to how you can change it
- Work within the project team to implement projects and collect new data that will improve future efforts
- Stay focused on your goal - the best possible response to minimize overall environmental damage

Appendix A

Sample Forms

Sample Form 1 - Scenario Summary

Location	
Target:	
Oil Type:	
Spill Size:	
Weather:	
Date or Time of Year:	
Time of Discharge (and Tidal Stage):	
Nature of the Spill:	

Sample Form 2 - Response Option Summary (Complete for Each Response Option Considered)	
Response Option	
Use	
Logistics	
Limitations	
Effectiveness	

Sample Form 3 - Resources At Risk Matrix

Zone (if needed)	Habitat	Sub-habitat	Resource Category	Example Organisms

Sample Form 4 - Conceptual Matrix

Zones:																				
Habitats:																				
Sub-Habitats:																				
RESOURCES:																				
STRESSORS:																				

These hazards represent changes from oil only scenario.
Shaded zones indicate areas of emphasis for the risk analysis

Hazards:

NOTE: This is a sample-sized example matrix. When creating one yourself, be sure to make it large enough to include all your Ecological Resources of concern. You may replicate this example as many times as you need to include all of your resources, or you may want to create your own spreadsheet to track this information.

Sample Form 5 - Risk-Ranking Matrix

Recovery Scale

Slow → Rapid

Magnitude Scale: High → Low

	1 ________	2 ________	3 ________	4 ________
A. ________	A1	A2	A3	A4
B. ________	B1	B2	B3	B4
C. ________	C1	C2	C3	C4
D. ________	D1	D2	D3	D4
E. ________	E1	E2	E3	E4

Sample Form 6 – Preliminary Risk Matrix Form

Indicates high level of ecological concern

Indicates moderate to high level of ecological concern

Indicates moderate level of ecological concern

Indicates low level of ecological concern

Sample Form 7 – Final Risk Matrix Form

Zones:																					
Habitats:																					
Sub-Habitats:																					

Indicates high level of ecological concern
Indicates moderate to high level of ecological concern
Indicates moderate level of ecological concern
Indicates low level of ecological concern

Sample Form 8 - Individual Sub-habitat Summary Table

Response Action	Scenario ____________ Score by Group		
	A	B	C

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern.

Sample Form 9 – Relative Risk Summary Matrix

Habitats																				
SUB-HABITATS:																				
Response Options																				

Coding: Use dark gray cells to represent a "high" level of concern, gray cells to represent a "moderate" level of concern, and clear cells to represent a "minimal" level of concern. Use lines to indicate levels of concern between moderate and low. Use cross-hatching to indicate levels of concern between high and moderate.

Optional Coding: Use a "c" in cells to indicate normally minimal concern, but incident specific circumstances that need to be examined. Use "+" or "-" to indicate a change in score in which the risk to the resource changed within a level of concern.

Sample Form 10 - for Estimations of Data Adequacy

Scale (4 = __________ (high), 3 = _________, 2 = _________, and 1 = _________(low)).

Habitat	Response Action				

Appendix B

ERA Fact Sheets

DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

The Use of Conceptual Models

What is a Conceptual Model?

A conceptual model is a written and diagrammatic description of the predicted responses by ecological resources of concern after exposure to stressors. The model must include ecosystem processes that influence the potential responses. Conceptual models consist of two principal products:

1. A set of risk hypotheses that describe predicted relationships between stressor, exposure, and assessment endpoint response.

2. A diagram that illustrates the relationships defined above.

What Should it Focus On?

The model should focus on the ecosystem or ecosystems at risk, using individual species only as representative elements of the system. When it is applied to oil spill response planning, the model must be a comparative analysis of the risks and benefits of all of the response options, not individual risks and benefits.

How Detailed is it?

The model need only be complex enough to provide the information necessary to support informed conclusions. The systems, which are to be affected, must be well enough described so that the major consequences of the perturbations can be defined. This does not mean that effective analysis cannot proceed without an in-depth knowledge of all components of the local environment, in fact it means just the opposite. It is the primary responsibility of the planning team to develop a conceptual understanding of the basic structure and functioning of the systems so that research can focus on key components rather than just on the collection of environmental or physiological data which will not facilitate the decision process.

What Factors Need to be Considered?

While there is no "cookbook" methodology to develop a conceptual model, a list of basic characteristics of ecological systems relevant to oil spill response planning follows:

Complex Linkages. Ecosystem effects may be both direct and indirect, and the response planner must be sensitive to the possibility of unexpected consequences. The best way to approach this problem is through the development of conceptual models, which show the pathways connecting the various ecosystem components. There are a variety of approaches that can be used. Energy flow, food webs and nutrient or mineral cycling have all been used and are in the basic ecological literature. In oil spill response planning, it is probably most appropriate to develop a model using trophic linkages and/or physical habitat requirements.

Density Dependence. Some effects may vary depending on the population density of the species in question or, more frequently, either the oil or the response countermeasure may affect the density of a particular species, with unexpected consequences for the ecosystem as a whole.

The possibility for and consequences of a dramatic change in population density for a particular species should always be examined.

Keystone Species. In all ecosystems there are certain species which play a major role in the structure of the system. In some cases this may be direct and obvious (the role of framework corals in coral reefs, or large, dominant tree species in mangrove forests), in others less so (predators which limit the population of an otherwise dominant species). It is essential to identify such species during the analysis, because changes in the population of keystone species can have major effects on the rest of the ecosystem in question.

Time and Spatial Scaling. In order to characterize the ecosystem at risk an assessor must understand the role of time and space in the system. For example, some ecosystems are naturally patchy, others are continuous. Seasonality may be an overriding consideration. Some marine and coastal communities essentially exist for only a few weeks or months and change rapidly, while others may exist for centuries with only minor modifications unless perturbed.

Uncertainty and Variability. All ecosystems contain elements of randomness and uncertainty as well as variability, which make the prediction of exact consequences impossible. This does not mean that general trends and overall structure cannot be discerned, but it does mean that the assessor must be alert to unexpected events or consequences, and be prepared to deal with them as they are identified.

Cumulative Effects. Oil spills, and oil spill response often occur in polluted areas or in combination with other environmental stresses and cumulative or synergistic effects are always a possibility. This must be considered before models are developed. For example, a coral reef stressed by high sediment load, or a rocky intertidal zone subjected to thermal stress from an effluent discharge, cannot be expected to respond in the same way as a similar, but unstressed community. A history of multiple spills or other sources of oil in the environment could also be a factor.

Population versus Community Dynamics. The assessor must consider both protection of valuable (for whatever reason) species and whole communities. It does no good to rescue individuals of an endangered or threatened species, only to return them to a community or habitat which can no longer support them.

Definition of System Boundaries. In order to correctly characterize an ecosystem, the area that operates as a functional unit must be correctly defined, both in space and time. If this is not done correctly, unexpected consequences are more likely to occur. It is also a crucial factor in the subsequent risk evaluation, because it places the affected resources in the appropriate context for the entire system.

Who Should Participate?

Common sense limits the model to the information that is essential to the analysis, and the best way to ensure that this occurs is to involve a wide spectrum of individuals in the process. In addition, the model will be of little value if it is incomprehensible to the planning community, and so the needs of the risk managers must be considered throughout the model's development.

Referenced by Ecosystem Management & Assoc., Inc. from materials in the following:
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DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

The Use of Endpoints

What is an Endpoint?

An endpoint is an explicit and measurable expression of an environmental value that is to be protected. The use of defined endpoints is a key element in the assessment process, and must be agreement as to what constitutes an appropriate endpoint prior to the development of the conceptual model.

What Types of Endpoints are There?

The U.S. EPA terminology recognizes one type of endpoint, assessment endpoints. "Assessment" endpoint refers to effects at the population level or higher that are of ecological importance within the system under evaluation. It includes both an ecological entity and specific attributes of that entity. For example, it might be determined that a reproducing population of a particular commercial fish species is a critical assessment endpoint. Some literature on ecological risk assessment recognizes a second type of endpoint, the measurement endpoint. The EPA approach defines this as one type of "measure" used to evaluate the assessment endpoint.

How are Data Used to Evaluate Endpoints?

Assessment endpoints are often difficult or even impossible to measure directly, especially in advance of the action under evaluation. In that case, "measures" must be identified to evaluate the risk hypotheses related to the assessment endpoints. These are identified in the analysis plan. One of these, measures of effect, equates to the term measurement endpoint. It refers to data that can be measured in the laboratory or the field, and then used to estimate the assessment endpoint. Toxicity data for a single species (which can then be combined with life history and distribution information to estimate population effects) is an example of a measurement of effect.

What Factors Enter into Assessment Endpoint Selection?

Assessment endpoints should have biological and societal relevance, an unambiguous operational definition, accessibility to prediction and measurement, and susceptibility to the hazardous substance. Assessment endpoints may include habitat loss or physical degradation of habitat below some effects threshold, as well as biological effects. All participants in the assessment process must accept the endpoint definitions for endpoints of both types.

How do you Determine if a Proposed Endpoint is Really Ecologically Significant?

Determination of the ecological significance of an event requires that it be placed in the context of:

- The types of other anticipated events associated with the stressor.
- The magnitude of the other events caused by the stressor.

- Its role in the structure and function of the system in question.
- Its relationship to other events within the system (cumulative analysis).

What Is Meant By Susceptibility?

Susceptibility has two components, sensitivity and exposure. Sensitivity refers to how readily an ecological entity is affected by a particular stressor. It is related to the proposed mode of action of the stressor as well as to individual and life history stages. Exposure refers to co-occurrence, contact, or the absence of contact, depending on the nature of the stressor and the properties of the ecological entity in question. It is a central assumption of risk assessment that effects are directly related to exposure. Life history considerations are often very important in determining susceptibility, and can be very complex. Delayed effects must also be considered.

How Are Management Goals Considered?

Consideration of management issues is critical because, ultimately, the value of the risk assessment is determined by its ability to support quality management decisions. Managers find it easier to use the information if it is based on values or entities that people know about and understand. With planning, such considerations can be integrated into the assessment without compromising its relevance to the ecological system in question.

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Appendix C

Using Toxicity Data in Oil Spill Response Planning

USING TOXICITY DATA IN OIL SPILL RESPONSE PLANNING

by
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WHY SHOULD YOU CARE?

Toxicity data have two major values to the oil spill response planner. The first is to allow for the screening of potential chemical response agents. The second is to estimate the ecological effects of the use of a chemical response agent in the field.

In the first instance, standard toxicity data will allow the ranking of chemicals in order of their desirability, provided that the test conditions and the species used are equivalent. This is a much easier conceptual issue than the latter, but it still requires care on the part of the user. The questions that need to be asked in order to ensure that the tests are comparable are discussed in a later section.

With respect to the second issue, no one associated with oil spill response planning really needs to know laboratory toxicity values per se. What is of interest is the ability to decide whether or not a proposed action is likely to result in the death or injury of marine organisms or damage to ecological systems of concern. Decision-makers (and resource managers) would prefer to have access to ecological field data on local organisms and communities under circumstances similar to that expected during a spill response, so that they would be comfortable with their recommendations. Regrettably, that kind of information is essentially never available, and so decisions must be based on interpreting other kinds of information and applying that to the situation which exists at the spill. Studies or observations at other spills, controlled ecological studies on oil spills or oil spill countermeasures effects (either in the environment or in the laboratory) and laboratory toxicity data are all types of data that can be used to address the environmental concerns. Laboratory toxicity data are probably the most common, and so they are routinely introduced for consideration when questions about environmental effects of oil, or chemical oil spill countermeasures, are raised.

SO WHAT'S THE PROBLEM?

There are four major issues associated with the use of toxicity data, which relate to its quality as well as extrapolation into real world situations. These are:

- How do you determine the general quality of the data being presented?
- How do you interpret data between species?
- How do you interpret data between different types of tests? and,
- How do you use toxicity test data to estimate ecological effects in the environment?

Each of these issues is examined in this paper.

IS THERE ANY INFORMATION THAT CAN HELP?

There is a great deal of information that can be used, too much, in some respects. This paper attempts to summarize the essential elements of the toxicological literature, and defines some basic concepts that can be applied to the oil spill response planning scenario. An implicit assumption in all of the material that follows is that decisions must be made on the basis of the available information. While it will be obvious that additional information would be useful for some topics, the paper emphasizes simple methodologies that can be applied without additional data. There are some basic terms that must be understood, and these are explained in the glossary at the end of this paper. The paper attempts to develop the most simple, yet defensible, approach possible. More complex procedures should only be adopted if they are necessary for accuracy, or if they substantially improve the quality of the decision-making process.

Types of toxicity tests Toxicity tests, and the resulting data, are often referred to as being acute or chronic. Acute tests are used to determine the concentration of a toxicant that produces harmful effects on test animals during a short-term experiment under controlled conditions (Rand and Petrocelli 1985). "Death" is the most commonly used response because it is easy to assess, and the test is then referred to as an acute lethality test. Most acute lethal responses occur within a short time period, so 96 hours has been chosen as a standard exposure time (although other exposure times are often reported) and the concentration is generally reported for 50% response of the population. Therefore a 96-hr LC_{50} is the concentration of toxicant that results in death of one-half of the test animals when exposed for four days. Usually, this test is performed under a steady state concentration of a toxicant. It is designed as a comparative tool to study relative effects of one toxicant over another. The conditions under which an acute LC_{50} test are run are strictly controlled, and as a result, generally do not give the researcher direct information about how the animal would respond in the field. This is primarily because the exposure in the laboratory is rarely representative of likely field exposures. Other acute tests that are designed to assess the lower limit effects of a toxicant on an animal, such as the Lowest Observed Effect Concentration (LOEC) and the No Observed Effect Concentration (NOEC) also make use of steady state exposure to the toxicant.

In addition to acute toxicity tests, there are several longer-term (chronic) tests that can be used to assess effects of the toxicant over multiple lifestages of an animal. Chronic tests are generally designed to expose the test animals for longer periods of time in order to study the long-term effects of the toxicant on the animal. These tests often evaluate the reproductive cycle and the ability to produce healthy offspring. In addition to life cycle tests, partial life cycle tests and early lifestage tests may be run. The latter two were originally developed for use with fish, where a complete life history study may take many months. They are generally conservative estimators of effects since they emphasize the most sensitive stages. For aquatic invertebrates with a short generation time, it is usually almost as convenient to run a complete life cycle test

Both acute and chronic test results are usually reported in parts-per-billion (ppb) or parts-per-million (ppm). These refer to the amount of toxicant that is in the water and represent an exposure value. One ppb is equivalent to one microgram of toxicant in one liter of water; one ppm is equivalent to one milligram of toxicant in one liter of water.

Exposure time By far the majority of the toxicity data available is for exposures that were 96 hours in duration. This is an arbitrary, but logistically convenient convention that has become a standard. Other time intervals, especially 48 or 24 hours, are also used, but not nearly as often. In terms of assessing the relative toxicity of a chemical to different species, or of different chemicals to the same species, the actual duration is less important than is consistency, and so the 96-hour standard is appropriate. This is not true when trying to interpret ecological effects in the field, where exposure may be much longer (near a waste discharge, for example) or much shorter (such as the use of a chemical during an oil spill response). The former situation is often addressed by chronic toxicity studies, while the latter can be addressed by studies using very brief exposure times, although such data are uncommon.

Toxicant For our purposes, the toxicant (a substance being tested which produces an adverse effect) could be any chemical oil spill treating agent. Since many are complex mixtures of compounds, and may have proprietary formulations, it is not always clear exactly what is being tested. This is particularly important if the compound, or elements of a complex formulation, have varying volatilities and solubilities in water. Likewise, oil, which needs to be evaluated as well as the treating agent, is not a single entity. It is a complex mixture of hundreds of different components, all of varying volatilities and solubilities, but ôoilö does not like to mix with water. These factors make preparing oil media for toxicity tests in the laboratory a very tricky process. The amount of oil that you add to the water to prepare the test media does not all ôdissolveö. In fact it may remain on the surface, evaporate, or enter the water column as oil droplets of various sizes, or be in solution. Different mixing energies, times and conditions change the proportion of all of these. To date, very few laboratories have used the same procedure for preparing the oil-in-water test media. As a result, different labs may or may not be exposing the animals to the same oil-in-water mixture. The same can be true for a treating agent, and so it is important to know how exposure concentrations were prepared whenever toxicity data are used. The best studies will provide some analytical measure of the actual concentration of oil or treating agents in the test solution at intervals throughout the experiment, rather than rely on nominal (estimated) concentrations.

Obtaining LC_{50} values from an acute exposure requires that the animals be exposed to different concentrations of the toxicant. For water-soluble toxicants, these different concentrations are prepared by dilution. Because of properties just described, a 10-fold dilution of an oil-in-water or chemical treating agent-in-water solution may or may not result in a solution that is one-tenth the strength. Therefore laboratories that have used a dilution process of their test media may not be using the concentration of oil that one might expect. For this reason, whenever an LC_{50} value is presented, it is critical to know how the test media were prepared.

Test conditions Laboratory toxicity tests are performed under very controlled conditions. This means that elements of the experiment such as water temperature, salinity, pH and oxygen levels are set and held constant for the duration of the test. Although there are standards for test conditions for some animals, researchers often deviate from these standards. Other conditions in the experiment might also vary, such as the use of artificial sea salts to create the test water, the lighting conditions used in the lab during the test, and the presence or absence of food for the animals. Variations in these conditions may result in different LC_{50} values for the same animal, even with the same lifestage and toxicant. It is therefore important to collect as much information as possible about the specific conditions under which a particular test was performed.

Before any comparisons of toxicity data can be made, the compatibility of the toxicity test conditions must be confirmed. Since there are a number of different methods to expose an animal to a toxicant, an LC_{50} for a given animal and toxicant is not a value ôset in stoneö. As mentioned above, time of exposure is one factor that can vary. Although 96 hours is the standard exposure period, other exposure times can be used, and it is essential that the length of exposure associated with the LC_{50} value be specified. There are other test conditions that can affect the concentration of the exposure. Aquatic test may be performed in open or closed containers, which is an important issue when considering evaporative losses of the toxicant and water. The tests may be either static (where the animals sit in the same water for the entire test) or flow-through. The level of the toxicant in the test chambers may be held steady (constant concentration) throughout the experiment, or the test may be designed to initially expose the animal to a toxicant, and then dilute the test chambers with clean water over time (spiked exposure).

It is important to understand that both time and concentration affect exposure, and that all of these different test conditions must be understood before attempting to evaluate the meaning of a given LC_{50} value. Collecting detailed information about the conditions of a toxicity test allows more accurate extrapolation of the data from species to species.

Endpoints Although LC_{50}'s are one of the most commonly reported values, there are other ways to report toxicity results. Among these are the No Observed Effects Concentration (NOEC) and Lowest Observed Effects Concentration (LOEC). Both of these are ways of reporting data about an animal's response to lower concentrations (relative to the LC_{50}) of a given toxicant. Another commonly reported value is the effective concentration (EC_{50}). An EC_{50} value is a more generic term and reports the concentration that causes 50% of test animals to respond in a particular way. Whereas the LC_{50} value assesses mortality as the endpoint, an EC_{50} value can report any endpoint that the researcher chooses. If EC_{50} values are reported, in addition to knowing the test conditions, the endpoint that was used in place of mortality must be known. Commonly used EC_{50} endpoints for acute tests include immobilization or loss of equilibrium for the animal.

These endpoints are calculated from averaged observations that were recorded during the toxicity experiment. It is therefore useful to know how much variation existed within the experiment. These endpoint values should be reported with a confidence interval, which describes the amount of variation in the experiment, and tells you how much precision was involved with the test. A large confidence interval (CI) suggests that there was much variation within the experiment, and that the endpoint value may fall anywhere within this CI range.

Standard test species There are a group of standard test species that are commonly used for toxicity testing. Some of the basic considerations made when selecting standard animals include seasonal availability and ease of culturing under laboratory conditions. The past use of the animal for toxicity tests, and most importantly, the commercial and ecological importance of the animal for a given region, are other factors that are considered. Much laboratory work has been done with these species, and as a result , there are large databases of information already available on them. Agencies such as the American Society for Testing and Materials (ASTM) and the US EPA encourage the use of these species in interlaboratory comparisons in order to enhance our knowledge about them (Widdows 1993)

Standard test organisms have been designated within most of the major taxonomic classifications of animals. These include both freshwater and saltwater animals that live in the water column, on the bottom surface, and within the sediment layer. Some of these species are widespread within most geographic regions of the U.S., while others tend to be localized within specific areas. Common marine species used in the United States include:

Acartia tonsa (copepod)
Artemia salina (brine shrimp)
Crassostrea virginia and *C. gigas* (oyster) (embryos or larvae)
Mysidopsis bahia (mysid)
Fundulus heteroclitus (salt marsh killifish)
Cyprinodon variegatus (sheepshead minnow)
Menidia beryllina and *M. menidia* (inland and Atlantic silversides)
Atherinops affinis (topsmelt)

Sensitive species The choice of species for assessing a particular toxicantÆs impact in a specific area must be considered carefully. Some species can tolerate exposure to toxicants much better than others. Certain species are well-known for being able to survive very harsh conditions. Toxicity data on these animals may not help you to decide how more sensitive animals in the area would be affected by the same toxicant.

In general, the term "sensitive species" can refer to biological, ecological, or commercial sensitivity. A biologically sensitive animal is one that displays harmful effects to low concentrations of a toxicant relative to other species. Ecologically sensitive species are ones that are considered vital to the ecosystem of a given area. Similarly, commercially sensitive species are those that play a key role in the local economy. When considering how relevant toxicity data are to a particular area, you must consider if the species is considered "sensitive" in one or more of these ways. Extrapolation of species to species data can be made with more confidence if the species fulfills one of more of these "sensitive" roles.

Life history stages Every species has particular lifestages that it undergoes during development. In general, early stages of development are considered more sensitive than later stages. Chronic toxicity tests often assess the effects of a toxicant across the animal's complete life cycle. Unfortunately, for many species this is a very time and cost intensive process. Early lifestage tests, which expose the animal during its early (more sensitive) lifestages, can shorten this process and provide you with information about the most sensitive stages of a particular species.

Acute toxicity tests, because of their short duration, generally only expose the animal during one lifestage. It is important to know what lifestage of an animal was used when you are presented with an LC_{50}. An LC_{50} value for a juvenile stage of a fish would present a more sensitive indication of the effect of the toxicant on that species than an LC_{50} value for an adult stage of the same fish.

VERIFICATION OF THE QUALITY OF AVAILABLE DATA

Table 1 lists a series of questions that should be answered every time a toxicity data set is considered. If the answers to these questions are not known, then there is a significant chance that the data may be misinterpreted or misapplied. While there is no absolute criteria for acceptance or rejection of a particular data set, the lack of direct estimates of toxicant concentration for hydrophobic chemicals, and/or the lack of sufficient detail to repeat or verify the test, will generally mean that the data should be rejected or used only with great caution.

EXTRAPOLATION OF TOXICITY DATA FROM ONE SPECIES TO ANOTHER

Why is this an issue? It is expensive and time consuming to run laboratory toxicity tests. In addition, there are only a limited number of species that are generally used. There are good reasons for using only a small suite of test animals, and it is an advantage when the goal is to screen compounds for their relative toxicity, which is the most common situation. However, when the intent is to estimate effects on populations or communities of animals in the field, extrapolation between species becomes more important.

It is not intuitively obvious how to apply data collected on one species to another. One consequence is a tendency on the part of regulators to want to develop their own, unique set of test organisms for use in their geographic region. While this has some obvious attractions, it is generally not practical to collect laboratory data on all species that might be of concern. A second approach is to look for test data on sensitive species, or for sensitive life history stages, which will provide a conservative estimate to protect the populations of concern. Finally, there are a variety of statistical or mathematical methods to estimate the range within which an unknown value might fall. Such formulas are the basis for most ecological impact models. Even so, there is no clear consensus as to the best approach.

Taxonomic extrapolations and Uncertainty Factors There are a variety of methods that have been proposed for dealing with this issue. A common suggestion is to use a "sensitive species" on the assumption that it would provide protection for less sensitive organisms. The difficulty here, of course, is in determining that the test species is in fact "sensitive" enough to fulfill its assigned function. In addition, it appears that there is no consistently most sensitive aquatic animal when dealing with different toxicants (Suter 1993). While this approach has obvious limitations, it is clear that there are general tendencies within and between taxonomic groups and when enough data sets are available, using values for the most sensitive species may be useful. Another approach to dealing with differences between species is the use of uncertainty factors. This approach has been most commonly used to extrapolate from mammalian test species to humans. Essentially, it involves the statistical estimation of an appropriate range factor which, when applied to an LC_{50} value (or other endpoint) from a test species, would be likely (at some statistical level of confidence, usually 0.95) to include the LC_{50} value for another species of concern. Calabrese and Baldwin (1993) reviewed this approach, but it has not been used with any frequency in ecological risk assessments. Given the fact that the ecological assessment problem is significantly larger than trying to protect a single species (humans) the limited use of this approach is not surprising. Nevertheless, there is some appropriate literature, which is reviewed in their discussion. While the data are heavily skewed towards fish species, taxonomic relationships do appear to be inversely related to the size of the uncertainty factor. They conclude that a factor of 10 is appropriate for species to species comparisons within a genus, while comparisons of orders within a class require approximately a 100-fold factor to achieve a 0.95 confidence level. Comparisons between taxonomic groups at intermediate levels (for example, families within orders) should be assigned intermediate values, while comparisons for classes within a phylum or between phyla are much higher. For the Environmental Protection AgencyÆs Water Quality Criteria (Suter 1993, Calabrese and Baldwin 1993), development of the ôFinal Acute Valueö (a regression generated number which should protect 95% of the species present) requires data for at least eight species form at least eight different families. This would rarely be possible with the existing oil spill chemical data, except for selected dispersants.

What is the best way to deal with species to species interpretations? With respect to initial selection of potential response agents, decisions can be based on results obtained for the standard EPA test species, for example, *Fundulus heteroclitus* (salt marsh killifish) and *Artemia salin*a (brine shrimp). These data adequately identify the **relative** toxicities of the various compounds, as long as equivalent test conditions were used in all tests. Regulators should select compounds for further consideration which are the least toxic while still demonstrating an acceptable level of effectiveness. This is, however, only the first step in the evaluation, and does not mean that a chemical is acceptable, only that it appears to be more acceptable than the other available options.

The second issue, estimation of toxicity for species of concern in the field, is more complex and the data available for *F. Heteroclitus* and *A. salina* are rarely adequate, depending on the circumstances. In any case, all of the available data ought to be identified and used in the analysis. The easiest approach, if appropriate data are available, is to estimate the toxicity threshold of interest from the use of species pairs. If data on two species exist for one chemical, but only for one species on a second chemical, the unknown toxicity for the second species can be estimated by use of an application factor. If this cannot be done, the following steps should be followed:

1. Demonstrate that the available data sets for the different species are essentially equivalent, i.e. do the test conditions, especially duration and nature of exposure, correspond in the various tests and did they use the same endpoint ? If not, eliminate inappropriate data sets from further consideration, or correct for the differences. Exposure concentration is not critical, as long as the range was appropriate to elicit a response. Endpoints should include confidence intervals as a measure of the variability observed within the test.

2. Organize the available data into taxonomic groups. Apply an appropriate uncertainty factor to the data set to obtain a range of values likely to pertain to the species in question, if test data are not available. For example, if the only available data are for a fish, and the species in question is a coral, then a factor of more than 100-fold would need to be applied, and little could be said with respect to the sensitivity of the coral. On the other hand, if the species are closely related (two cyprinid fish, for example) only a 10-fold correction should include the unknown value. This approach is not particularly sensitive, but it can be used effectively in the case of substances that have a very low toxicity.

COMPARISON OF TOXICITY DATA FROM DIFFERENT LABORATORY TEST METHODS

Why is this important? There are two potential uses for toxicity data in oil spill response decision-making. The first is to ensure that chemicals approved for use are the least toxic of the effective options. The second is to estimate the possible consequences of the release of the chemical into the environment. For the former, standard acute 96-hour toxicity tests are clearly appropriate, but the user of the information must verify that the tests are equivalent or can be standardized through the use of some correction factor. The situation is not as straight forward in the latter case, and most available toxicity data are not appropriate for direct application to circumstances in the field.

WHAT CAN BE DONE TO STANDARDIZE BETWEEN TEST METHODS?

Although many different test conditions can be used, and several different endpoint values can be reported, there are ways to relate data from one test to another and between endpoints. Differences in the salinity, pH and temperature that were used for experiments are not cause for concern unless the animals were under obvious stress. During a toxicity test, the only stress that the animal should undergo is from exposure to the toxicant. As long as the conditions were suitable for that species, these variations are acceptable. The salinity and pH of the experiment should ideally be ecologically relevant ones (e.g.- should be close to field conditions for that species).

Conversion from short-term acute endpoints to chronic values can often be accomplished by means of application factors. Application factors are a way of predicting one endpoint result from another based on other known toxicity data for a particular species, and are calculated by dividing the NOEC and the LOEC by the 96-hour LC_{50}. They are reported as a range and can be multiplied by the median lethal concentration (LC_{50}) of a chemical from a short-term toxicity test to estimate an expected no-effect concentration (NOEC) under chronic exposure (Rand and Petrocelli, 1985). If differences between test protocols are too great, however, the data should not be combined.

EXTRAPOLATING DATA FROM THE LABORATORY TO THE FIELD

This is the most important comparison that needs to be developed. It is crucial to any decision about the use of oil spill response chemicals, and is the most controversial.

Why can't laboratory results be applied directly to field situations? Toxicity data are most useful when relative comparisons are made, under constant conditions, between species or among life history stages. The most appropriate (and common) use is to screen chemicals for their relative toxicity, in order to identify the least (or most) toxic compounds. Comparisons among species, life history stages and/or various toxicants or combinations of toxicants are difficult when there are significant differences in the analytical procedures used. This means that, while standardization of laboratory tests has been a critical issue, selection of test conditions that mimic those in the field has not. The standard acute toxicity test, which uses a continuous exposure for 96 hours (sometimes less) is a very poor estimator of episodic, short duration events followed by rapid dilution, which is the case for even relatively large spills. If the rapid dilution observed in the field to date is accurate, static 96-hour tests would over-estimate oceanic exposures by more than 100-fold (Aurand 1995). Peterson *et al*. (1993) used the concept of body burden in fish to explain the physiological basis justifying the significance of this difference. In their results, it was clear that short-term exposure tissue burden was dependent on toxicant exposure duration. The use of acute 96-hour tests has remained common, however, since it is often the only data available, and its use is rationalized by the fact that it is a conservative estimate of real world exposure. In most cases, the users do not realize how significant this over-estimation can be, and fail to appreciate the consequences of concluding that there is an acute toxicity problem, when, in fact, none exists (Suter 1993).

ppm-hour Toxicity data are usually available for a range of concentrations, but less frequently for different time durations, even though both are known to play a role in toxic response. If tests of different duration are available, they may be extrapolated through the use of the ratio of the two test endpoints. If a larger data set is available, then regression analysis can be used to estimate general temporal relationships (Suter 1993). Care must be observed in either case not to over-extend the data set, and to ensure that no other test conditions influence the results. This is the basis for the concept of the ppm-hour (Anderson *et al*. 1981, 1984), where the two factors are considered to be direct multipliers (Suter 1993). Experimental evidence for this approach has been obtained, but is somewhat limited, and, intuitively, there are limits beyond which the concept does not apply. The approach has been assumed valid for time periods of 1 hour to 4 days (National Research Council 1989). Mackay and Wells (1983) presented a very detailed analysis of the use of this approach with respect to dispersants and dispersed oil, and the approach has recently been used in the background material in support of the Federal Region VI Regional Response Team's "RRT VI FOSC Preapproved Dispersant Use Manual".

Moving into the real world by understanding exposure Laboratory toxicity tests are conducted under unnatural conditions, in the sense that the goal is to provide easily controlled, standardized conditions so that comparisons can be made between tests. Real-world conditions are not totally ignored, of course, because they are reflected in the environmental tolerances of the test species. On the other hand, laboratory exposure regimes for the toxicant are driven more by the need to ensure that a range of responses is observed during the test than by a desire to duplicate field exposures. When the exposure in question is chronic, for example, a marine benthic community in the vicinity of a wastewater discharge, the comparison between the laboratory and the field can be relatively direct, but this is not the case for oil spill response.

Estimating exposure Interpretation of laboratory toxicity results is affected by the assumptions, either explicit or implicit, that the user makes concerning the concentrations of treating agent and/or treating agent and oil which are likely to occur in real spill situations. Field data suggest a rapid decline to values of less than one or two percent of the initial level within two or three hours when dispersant is sprayed on test slicks at sea. This would equate to a half-life of approximately 0.5 hours (Aurand 1995). Such field data are not extensive and is based on relatively small crude oil releases, but consistently shows this pattern. Undetectable or background levels were attained within several hours after the slicks were dispersed, and this situation should apply to small or moderately sized accidental spills.

Field data and laboratory data have shown that, while slicks at sea are highly variable in terms of distribution and thickness, 0.1 mm is a reasonable estimate for the average thickness of an unemulsified oil slick, and this value is usually used when planning for dispersant use. Assuming that a 0.1 mm thick oil slick is totally dispersed and evenly mixed into the top 1 meter of the water column, then the resulting concentration would be 100 ppm. The standard planning factor for dispersant application, based on a dispersant to oil ratio of 1:20 at this slick thickness, is 50 liters per square kilometer (6 gallons per acre) yielding a 5 ppm concentration. Under most circumstances, these concentrations would not be maintained for more than tens of minutes, based on the expected rate of turbulent mixing (Figure 1).

In spiked exposure tests with a half-life of 2.5 hours using Corexit 9527 on four California test species, embryonic red abalone (*Haliotis refescens*) exhibited a No Observable Effect Concentration (NOEC) of 5.3 to 6.6 ppm (Singer *et al*. 1991). The other test organisms, newly released spores of the giant kelp (*Macrocystis pyrifera*), 4-day-old juveniles of the mysid (*Holmesimysis costa*), and 10-day-old larvae of the top smelt (*Atherinops affinis*), all yielded higher NOECs, 12.2 to 16.4 ppm, 8.4 to 20.5 ppm, and 31.0 to 89.8 ppm, respectively. As would be expected, concentrations found to be toxic in the spiked tests were higher than those in constant-concentration trials of the same duration (Singer *et al*. 1990). Unfortunately, no consistent conversion factor that could be used to relate constant exposure to spiked exposure tests was found (Singer *et al*. 1991). This type of data is not generally available, and in fact still represents an over-estimation of field exposure in open ocean situations, although it may be representative of situations with restricted exchange and/or mixing. The issue then, becomes how to compare an extremely short, one-time event to the results of a 48- to 96-hour toxicity test. While LC_{50} values are appropriate for use in relative comparisons, for oil spill response planning LOEC or NOEC values are most appropriate. Even if these are not reported in the reference, they may be derived from the test results if sufficient detail is presented.

Despite its limitations, the most appropriate method currently available appears to be the ppm-hour concept. In the following sections a simplified approach to the use of this concept is presented. More precise mathematical calculations of concentrations, etc., are possible, but should only be used if clearly justified. All of the assumptions presented in the following sections are based on "representative" values, and can be adjusted to fit local conditions.

Defining consequences The final step in the evaluation of the toxicity of a proposed chemical treating agent is to determine the likelihood of significant toxicity being observed in the field, based on an evaluation of the available data relative to the expected concentration. The following steps should be followed for water soluble compounds:

1. Estimate the field dilution pattern. Assume no evaporative loss and 100% mixing into the water column. For applications over or on the water column assume that instantaneous mixing occurs to a depth of 1 meter (unless available data suggest a better number), and that subsequent vertical dilution occurs at a rate of 50% per 15 minutes. Ignore horizontal diffusion. If it is an open water area with good mixing and the bottom is encountered during mixing, decrease the dilution rate to 50% per 30 minutes after the bottom depth is reached. For applications to the shoreline with subsequent runoff into an open water body with significant wave action, assume that the initial quantity per meter of shoreline is mixed into a cubic meter of water within 15 minutes, and then estimate subsequent dilution as above. It is not acceptable to use this simplified approach in quiescent, shallow areas with limited mixing.

2. For a species of concern which is restricted to the near surface of the water column, calculate an estimated exposure level based on the initial concentration and the assumed dilution rate by summing the concentrations in the top one meter for the first hour of exposure (Figure 1 & 2). This will account for 97% of the exposure at this dilution rate. If the dilution rate must be changed to fit the circum-

stances, then this time interval must be adjusted. For example, an application rate of 50 liters per square kilometer (standard rate for dispersants) would give a 5 ppm concentration at time 0, a 2.5 ppm concentration at 0.25 hours, 1.25 ppm at 0.50 hours, 0.63 ppm at 0.75 hours, and 0.32 ppm at 1.0 hours. This is equal to 9.70 ppm-hour.

3. For a species of concern which occurs at depth or is a benthic species, select an appropriate water depth, determine the earliest time an exposure might occur at that depth and at what concentration, and then complete a similar calculation to that above. For example, if the species of concern is a benthic organism and the water depth is 8 meters, then in the above example exposure would begin during the 0.50 to 0.75 hour interval, at an initial concentration of 0.63 ppm. The exposure for the next two 15 minute intervals would be 0.32 ppm, (because of the assumed decrease in dilution rate), and 0.16 ppm for the fourth 15 minute interval. This would estimate a cumulative exposure of 1.43 ppm-hour.

4. Estimate the range of available laboratory data in terms of their ppm-hour concentration, including whatever uncertainty factors were appropriate, based on the species of concern. For example, if the 96 hour LC_{50} for a test species is 100 ppm, then the value in ppm-hour is 9,600 ppm-hour. If the uncertainty factor to be applied is 10, then the lowest toxicity value of concern would be 960 ppm-hour, two orders of magnitude above the exposure level for the hypothetical organism in the top one meter of the water column, and 650 times the exposure of a benthic organism at an 8-meter water depth.

5. Based on the obvious oversimplifications in this approach, and the inherent uncertainty with respect to the ppm-hour concept, assume potential effects if the laboratory and estimated field values fall within one order of magnitude.

6. After evaluating the effects of the treating agent, similar calculations can be made to estimate the effects due to the oil itself. Any concerns with toxicity related to the oil as a result of the use of a treating agent must be weighed against those which would result even if the oil were not treated.

Table 1 Questions that should be answered for all toxicity tests prior to a determination as to whether or not the test data are relevant for the scenario under consideration.

1. What species is used?
    - Is it the species of interest?
    - Is it closely related taxonomically?
        - What conclusions can be drawn between taxonomically close species?
    - Is it a freshwater, estuarine or marine species?
2. How sensitive is this species?
    - Is it used as a standard test organism by any agencies?
    - Are there other toxicological data on this organism?
3. What lifestage is used?
    - Is it a single lifestage test?
    - Is it a complete or partial life cycle test?
    - Is this a sensitive lifestage(s)?
4. What endpoint is reported?
    - Is it an acute test (LC_{50})?
    - Is it a chronic test (EC_{50})?
        - Is the effect quantifiable?
        - Is it reproducible?
        - Is the effect biologically significant (to the species of interest)?
5. Was the species checked against a reference toxicant?
6. Was the test repeatable?
    - Were controls used?
    - Are confidence limits reported?
    - Were adequate sample sizes used?
    - Were replicates performed?
7. Were concentrations of the toxicant measured or estimated (nominal)?
    - What method was used?
    - At what points during the test were chemical samples collected?

Figure 1. A schematic diagram of a 0.1 mm thick oil slick evenly dispersed along a vertical axis down to 1.0m, 2.0m, 5.0m and 10.0m depths. Concentration of oil and oil treating agent are shown assuming a 1:20 ratio of treating agent to oil.

Figure 2. Dilution curve for a 0.25 hour half-life. The estimated exposure for 1 hour is calculated by summing the concentrations represented by the bars.

Glossary

Acute Toxicity - adverse effects that develop in response to short-term exposure (relative to the animals life cycle) to high toxicant concentrations. Lethal endpoint (LC_{50}) tests fall within this category.

Chronic Toxicity - adverse effects that develop over long-term exposure (relative to the animals life cycle) to low toxicant concentrations. Life cycle tests and early lifestage tests generally fall within this category.

EC_{50} (Median Effective Concentration) - the amount of a toxicant that produces a specified effect in 50 % of the test population over a given time period. The effect that is used as the endpoint can be behavioral, physiological, cellular, etc. and is chosen by the researcher conducting the experiment. Endpoints that can be quantified (such as growth rate) are much more useful than those that cannot be precisely measured (such as erratic swimming).

Embryo - an embryo is an early lifestage for many animals, and is considered to be a sensitive lifestage with respect to toxicity testing.

Egg - the egg is considered the first lifestage in the development of an animal. Eggs are generally encased in an semi-impermeable membrane that can render them less susceptible to external factors, such as toxicant exposure, than successive early lifestages.

Exposure - the term exposure refers to the amount of toxicant that the animal encounters. Exposure takes into account both the concentration of the toxicant in the water and the duration of contact to the animal.

Flow-Through Exposure - an exposure system in which water (and the toxicant) is continuously renewed at a constant concentration. This can also be referred to as a continuous flow exposure. Flow-through tests can be good estimators of toxicity in field conditions where there is a continuous effluent of the toxicant.

Larva - this is an early lifestage for many animals that undergo metamorphism. It is a period of substantial development for the animal and is therefore considered to be a sensitive lifestage for toxicity testing.

LC_{50} (Median Lethal Concentration) - the amount of a toxicant that produces 50 % mortality to a test population over a specified period of time. LC_{50} values are generally given for 48-hour or 96-hour exposure periods. LC_{50} values are meaningless without a reported exposure time.

Lethal Endpoint - a way of assessing the effects of a toxicity test by observing the degree of mortality within the exposed test animal population. Tests that have a lethal endpoint are commonly known as acute toxicity tests.

Life Cycle Test - a toxicity test that involves exposing test animals through their reproductive life cycles. Generally, this would involve exposing and monitoring the animal from a point in one generation to the same point in the next generation (e.g., egg-larval-juvenile-adult-egg). The successful production of offspring is often used as the endpoint for assessing this type of test. Life cycle tests are very sensitive in that they expose all stages in the animalÆs life cycle. Unfortunately, they can take a considerable amount of time and, as a result, be quite costly to run.

LOEC (Lowest Observed Effect Concentration) - a measure of the lowest amount of a toxicant required to elicit some notable effect from a test animal over a given time period.

LOEL (Lowest Observed Effect Level) - see LOEC definition above.

MATC (Maximum Acceptable Toxicant Concentration) - this represents the range of toxicant concentrations that fall above the NOEC but below the LOEC.

NOEC (No Observed Effect Concentration) - a measure of the highest amount of toxicant to which a test animal can be exposed without displaying any notable effects from the exposure over a given time period.

NOEL (No Observed Effect Level) - see NOEC definition above.

ppb (part per billion) - a unit of measurement commonly used in toxicological testing; it equates to 1 microgram per liter of water (or 1 microgram per kilogram of solid material).

ppm(part per million) - a unit of measurement commonly used in toxicological testing; it equates to 1 milligram per liter of water (or 1 milligram per kilogram of solid material).

Spiked Exposure - an exposure system in which the toxicant is initially present, and is subsequently diluted with addition of clean water. Spiked exposures probably give the most realistic estimate of toxicity in field conditions where there is a release of toxicant into well-circulated waters.

Static Exposure - an exposure system in which water (and the toxicant) is not renewed during the test. Static exposure tests often over-estimate toxicity because they do not account for dilution effects that would occur in field conditions.

Sublethal Endpoint - a way of assessing the effects of a toxicity test by observing a non-lethal response of the animal (such as erratic swimming or decreased food consumption). Tests that have a sub-lethal endpoint are known as chronic toxicity tests.

Toxicant - a substance that has an adverse effect on an organism.

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Appendix D

Resources of Concern

Table D-1. Resources of concern identified by risk assessors, Galveston Bay ERA.

BROAD HABITATS	SUB-HABITATS	RESOURCE CATEGORY	EXAMPLE ORGANISMS
Terrestrial (includes dunes)	N/A	arthropods	insects; spiders
		birds	bald eagle; cattle egret; rail; Attwater prairie chicken; snipe; killdeer
		mammals	opossum; raccoon; coyote; deer
		reptiles/ amphibians	Gulf coast toad; pygmy rattlesnake; western rattlesnake
		vegetation	wire grass; shrubs, deciduous trees
Shoreline (intertidal)	marsh/ tidal flat	birds	American avocet; American oyster-catcher; black-necked stilt; great blue heron; mottled duck; roseate spoonbill; blue and green-winged teal widgeon; shovelers
		crustaceans	blue crab; grass shrimp; fiddler crab; brown, white and pink shrimp; hermet crabs
		fish	killifish; sheepshead minnow; spot; gobies; flounder
		infauna	polychaetes, amphipods
		mammals	river otter, raccoon
		molluscs	blue mussel; ribbed mussel; periwinkle; Donax
		reptiles/ amphibians	diamondback terrapin; American alligator; saltmarsh snake
		vegetation	salt marsh cord grass; wire grass
	sandy beach	birds	American oyster-catcher; black skimmer; terns; gulls; piping plover; white and brown pelicans
		crustaceans	mole crab, ghost crab
		infauna	amphipod; nematodes
		mammals	coyote; skunk, opossum; raccoon
		molluscs	common rangia
	riprap/ man made	algae	Sea lettuce;
		birds	brown pelican; double-crested cormorant; laughing gull;
		crustaceans	stone crab; blue crab; hermit crab
		fish	blennies; gobies; sheepshead; mullet
		infauna	amphipods, polychaetes
		mammals	rats
		mollusc	blue mussel; barnacle; oyster

* Indicates organism is a keystone species.

BROAD HABITATS	SUB-HABITATS	RESOURCE CATEGORY	EXAMPLE ORGANISMS
Benthic (subtidal)	shallow (< 3 feet)	algae	Grassaleria; Ruppia
		birds	roseate spoonbill; great blue heron;
		crustaceans	grass shrimp; brown shrimp; hermit crabs
		fish	southern flounder; drum
		infauna	amphipods; polychaetes
		molluscs	lightening whelk; snails; quahog; oysters
	open bay (3-10 feet)	algae	benthic diatoms
		birds	diving ducks; grebes; coots
		crustaceans	white, pink and brown shrimp; blue crab;
		fish	southern flounder; drum; mullet; hardhead
		infauna	amphipods; polychaetes
		molluscs	lightening whelk; snails; northern quahog; oysters; clams
	channel (> 10 feet)	crustaceans	blue crab; pink, brown and white shrimp
		fish	southern flounder; drum; Spanish mackerel; bluefish; pinfish; sheepshead
		infauna	amphipods; polychaetes
		molluscs	oysters
Benthic (subtidal) (cont.)	reef	algae	benthic diatoms
		birds	American oyster-catcher; gulls; terns; white and brown pelicans; wading birds
		crustaceans	stone crab
		fish	pinfish; sheepshead; flounder; gobies; blennies
		infauna	amphipods; polychaetes
		molluscs	oyster*; oyster drills; barnacles
	SAV	algae	??
		birds	great blue heron; diving ducks;
		crustaceans	white shrimp; blue crab;
		fish	killifish; sheepshead; sheepshead minnow; spotted seatrout; spot; seahorse; pipefish
		infauna	amphipods; polychaetes
		molluscs	northern quahog; lightening whelk; snails
		seagrass*	eelgrass; American seagrass; ruppia

* Indicates organism is a keystone species.

BROAD HABITATS	SUB-HABITATS	RESOURCE CATEGORY	EXAMPLE ORGANISMS
Water column	top 3 feet	algae	??
		birds	osprey; gulls; terns; cormorants; diving ducks; common loon; migratory water fowl
		crustaceans	blue crab; white, brown and pink shrimp
		fish	bay anchovy; gulf menhaden; redrum; inland silverside; striped mullet; drum
		jellyfish	cabbage head; sea comb; sea nettle; man-o-war
		mammals	bottlenose dolphin; stennelid dolphin
		phytoplankton	diatoms; dinoflagelates
		reptiles	American alligator; Kemp's ridley seaturtle; loggerhead seaturtle;
	top 3 feet (cont.)	zooplankton	larval crustaceans; larval molluscs; copepods; fish eggs and larvae
	bottom 3 feet (in depths of 3-10 feet)	birds	loons; diving ducks
		crustaceans	blue crab; white, brown and pink shrimp
		fish	black drum; redrum; sand seatrout;
		reptiles	American alligator; Kemp's ridley seaturtle; loggerhead seaturtle;
		zooplankton	larval crustaceans; larval molluscs; copepods; fish eggs and larvae
	Bottom 3 feet (in depths > 10 feet)	birds	loons; diving ducks
		crustaceans	blue crab; white, brown, pink shrimp
		fish	black drum; redrum; sand seatrout;
		mammals	bottlenose dolphin; stennelid dolphin
		reptiles	Kemp's ridley seaturtle; loggerhead seaturtle;
Surface	N/A	algae	sargassum
		birds	olivaceous cormorant; least tern; herring gulls; mallard; brown pelican; white pelican
		crustaceans	sargassum shrimp*, sargassum crabs*
		fish	sargassum fish*, file fish; sea horse
		mammals	bottlenose dolphin; stennelid dolphin
		microlayer asso-ciated plankton	fish eggs and larvae
		reptiles/ amphibians	sea turtles

* Indicates organism is a keystone species.

Table D-2 Resources of concern identified by risk assessors, San Francisco Bay ERA.

ZONES	HABITAT	SUB-HABITATS	RESOURCE CATEGORIES	EXAMPLE ORGANISMS
Terrestrial	Upland and Supratidal		Vegetation	American dune grass; threatened and endangered dune plants; lichens; algae; vascular plants
			Mammals	raccoon; fox; humans
			Birds	waterfowl; seabird colonies; snowy plover; least tern; raptors
			Reptiles/Amphibians	SF garter snake; red-legged frog
			Insects	mission blue butterfly
Water Surface			Mammals	cetaceans; sea otters; pinnipeds
			Birds	pelicans; grebes; waterfowl;cormorants; terns; loons; shearwater; alcids
			Reptiles/Amphibians	leatherback turtle
Intertidal	Marsh		Vegetation	saltmarsh cordgrass; pickleweed
			Mammals	salt marsh harvest mouse; shrew; voles; canids
			Birds	rails; wading birds; shorebirds; waterfowl; loons; grebes; canvasback; raptors; Suisun song sparrow
			Fish	salmonids; sculpins; surf perch; delta smelt
			Crustaceans	fiddler crabs
			Molluscs	snails
	Mud Flats		Vegetation	Gracilaria
			Birds	gulls; wading birds; shorebirds; waterfowl; canvasback
			Fish	sculpins; surf perch; topsmelt; flatfish
			Crustaceans	fiddler crabs; ghost shrimp
			Molluscs	clams
			Polychaetes	fat innkeepers; Nereis
	Sandy Beach		Mammals	raccoon; canids
			Birds	gulls; shore birds; snowy plover; sea ducks; raptors; loons; grebes
			Fish	surf perch; surf smelt; striped bass
			Crustaceans	sand crabs; crabs
			Meiofauna	unknown

ZONES	HABITAT	SUB-HABITATS	RESOURCE CATEGORIES	EXAMPLE ORGANISMS
	Rocky/Rip Rap/Sea Walls		Vegetation	sea lettuce; leafy reds; corralines; sea palms; brown algae
			Mammals	harbor seals
			Birds	gulls; pelicans; shorebirds; alcids; oystercatcher
			Fish	sculpins; surf perch; rockfish; herring (and eggs)
			Crustaceans	crabs
			Molluscs	CA mussel; gastropods; abalone
			Epifauna	pile worms; feather dusters; tube-worms; sea urchins; starfish; anemo-nes
	Pier Pilings		Vegetation	sea lettuce; leafy reds
			Birds	gulls; pelicans; cormorants
			Fish	sculpins; surf perch; rockfish; herring
			Crustaceans	crabs
			Molluscs	CA mussel; gastropods
			Epifauna	pile worms; feather dusters; tube-worms; sea urchins; starfish; anemo-nes
Subtidal	Benthic Bay	Shallow Softbottom (< 35 ft)	Vegetation	Gracilaria
			Mammals	sea lions; harbor seals
			Birds	diving ducks;loons; grebes
			Fish	demersal fish; herring
			Crustaceans	crabs; bay shrimp
			Molluscs	clams
			Polychaetes	fat innkeepers
		Shallow Hardbottom (< 35 ft)	Vegetation	red and brown algae
			Mammals	sea lions; harbor seals
			Birds	loons; grebes
			Fish	rockfish; demersal fish; herring
			Crustaceans	dungeness crabs
			Molluscs	mussels
			Epifauna	feather dusters; tubeworms; anemones
		Deep Bottom Hard/Soft(> 35 ft)	Fish	sturgeon; rockfish; demersal fish; her-ring
			Crustaceans	crab; bay shrimp
			Molluscs	clams
			Polychaetes	fat innkeeper

ZONES	HABITAT	SUB-HABITATS	RESOURCE CATEGORIES	EXAMPLE ORGANISMS
	Benthic Coastal	Softbottom (< 35 ft)	Mammals	grey whales; pinnipeds; sea otters
			Birds	diving waterfowl; alcids; loons; grebes
			Fish	demersal fish; sharks
			Crustaceans	crabs
			Molluscs	clams
			Epifauna	polychaetes; sea cucumbers; seastars; brittle stars
		Softbottom (> 35 ft)	Mammals	grey whales; pinnipeds; sea otters
			Birds	diving waterfowl; alcids; loons; grebes
			Fish	demersal fish; sharks
			Crustaceans	crabs
			Molluscs	clams
			Epifauna	polychaetes; sea cucumbers; seastars; brittle stars
		Shallow Hardbottom (< 35 ft)	Vegetation	leafy reds; corralines; brown algae; green algae; kelp
			Mammals	pinnepids; sea otters
			Birds	diving ducks;loons; grebes; alcids; pelicans; cormorants
			Fish	rockfish; surf perch; sculpins
			Crustaceans	crabs; shrimp
			Molluscs	scallops; snails; abalone
			Epifauna	tubeworms; featherdusters; sea urchins; starfish; anemones
		Deep Hardbottom (> 35 ft)	Vegetation	leafy reds; corralines; brown algae
			Mammals	pinnipeds; sea otters
			Birds	alcids; diving birds
			Fish	rockfish; sculpins
			Crustaceans	shrimp; crabs
			Molluscs	snails; abalone
			Epifauna	tubeworms; featherdusters; sea urchins; starfish; anemones
	Kelp Forest (surface to bottom)		Vegetation	kelp; brown macroalgae
			Mammals	harbor seals; sea lions; sea otters
			Birds	cormorants; murres; grebes; alcids; pelicans; gulls
			Fish	rockfish; topsmelt; anchovy; sardines
			Crustaceans	kelp forest mysid; kelp crabs
			Molluscs	snails; abalone; squid

ZONES	HABITAT	SUB-HABITATS	RESOURCE CATEGORIES	EXAMPLE ORGANISMS
			Epifauna	polychaetes; sea urchins; starfish; anemones
	Eelgrass/ Algae (Surface to bottom)		Vegetation	eelgrass; Gracilaria
			Birds	waterfowl; loons; grebes; cormorants
			Fish	surf perch; Pacific herring;
			Crustaceans	grass shrimp;
			Molluscs	snails; clams
			Infauna	polychaetes
Water Column	Bay		Mammals	pinnipeds
			Birds	pelicans; cormorants; gulls; waterfowl
			Fish	shad; Chinook salmon; sturgeon; striped bass; white croaker; steelhead; herring; anchovy
			Plankton	zooplankton; ichthyoplankton; phyto-plankton
	Coastal	Shallow Water (0.1 - 35 ft)	Mammals	pinnipeds; cetaceans
			Birds	pelicans; cormorants; alcids
			Fish	rockfish; salmon; steelhead; anchovy; mackeral
			Crustaceans	euphausids
			Molluscs	squid
			Plankton	zooplankton; ichthyoplankton; phyto-plankton
		Deep Water (> 35 ft)	Mammals	pinnipeds; cetaceans
			Birds	cormorants; alcids
			Fish	Chinook salmon; steelhead; sharks
			Crustaceans	euphausids
			Molluscs	squid
			Plankton	zooplankton; ichthyoplankton; phyto-plankton

Appendix E

Fact Sheets on Response Options

DISCUSSION PAPER

Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in Texas Waters

Natural Recovery/No Response

What is Natural Recovery and/or the "No Response" Option?

The natural recovery and/or "no response" cleanup strategy is just that–the oil is left to weather naturally; no attempt is made to remove/recover any of the floating or stranded oil. This is considered the response option of choice when there is a need to minimize the environmental impact of human intervention in a particular habitat. It is used when other response options are considered to cause more damage than the oil itself. It is also an option when there is no effective method for cleanup or the existing environmental conditions do not allow the use of existing response technologies. Although no cleanup action is taken, monitoring of the contaminated areas or resources is required.

This response strategy is applicable for all habitat types. The primary reason for using the "no response" strategy is when:

- Spills occur a great distance from shore.
- Natural removal rates are fast (e.g., the evaporation of gasoline or oil along highly exposed coastlines).
- The degree of oiling is light.
- Cleanup actions will do more harm than natural removal (as is primarily the case with salt marshes and sheltered tidal flats).
- The spilled oil is inaccessible.

In general, oil that is not recovered using conventional response techniques is left in the environment and can be considered to undergo natural recovery, whether it continues to weather, in sediments, is consumed, or undergoes natural biodegradation.

Effectiveness

Effectiveness of the natural recovery/no response option is dependent upon many factors:

- Volume of oil spilled.
- Type of oil spilled.
- Depth of penetration.
- Habitat type.
- Season.
- Climate.

The effects of the "no response" option has been studied for several large spills, e.g., the *Metula* spill in Chile, the *Exxon Valdez* spill in Prince William Sound, Alaska, and the Gulf War spill in Saudi Arabia. In each of these cases, significant quantities of oil were left to weather naturally. In the cold, temperate environment of Chile, the heavily oiled marshes where the oil was not removed by tidal/rain action are expected to be affected for decades. This is an extreme example of a slow recovery; after 20 years, little change has occurred. Sites left to natural recovery during the *Exxon Valdez* spill are considered to have nearly returned to background levels less than 10 years later.

Seven years following the Gulf War, Saudi Arabia's climate has rapidly weathered the extremely thick layers of oil coating the entire shoreline, detoxifying it and allowing for the beginnings of what is expected to be a rapid recovery.

In general, the lighter the oiling, the more rapid the recovery. Conversely, an area covered with a thick layer of oil will take longer to recover. Recovery may be on the order of several months (light oiling) to many decades (extensive oiling or penetration deep into the sediments).

What are the Potential Opportunities/ Benefits?

1. Reduces the potential impact to the habitat from other, more conventional response techniques.
2. Reduces the chance for mixing the oil deeper into the sediments where it can remain relatively unweathered for many decades.
3. Can be used for spills of very light oils and oil products (e.g., gasoline and jet fuel) that are not easily recovered using conventional cleanup technologies.

What are the Potential Challenges/ Tradeoffs?

1. Leaves the oil in the environment for a longer period than if recovered, thus increasing the chance for resource impacts.
2. May be inappropriate for areas used by high numbers of mobile animals (birds, marine mammals) or endangered species.

Referenced by Ecosystem Management & Assoc., Inc. from materials in the following:
Pond, R.G., D.V. Aurand, J.A. Kraly (compilers). 2000a. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the San Francisco Bay Area. California Office of Spill Prevention and Response.

Pond, R.G., D.V. Aurand, J.A. Kraly (compilers). 2000b. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the Galveston Bay Area. Texas General Land Office, Austin, TX.

DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

ON-Water Mechanical Recovery

What is On-Water Mechanical Spill Response?

Mechanical oil spill response uses physical barriers and mechanical devices to redirect and remove oil from the surface of the water. Where feasible and effective, this technique may be preferable to other methods, since spilled oil is removed from the environment to be recycled or disposed of at appropriate facilities. Because effective mechanical containment and removal is severely restricted by wind, waves, and currents, only a small percentage of spilled oil has historically been recovered in this manner. Mechanical removal of oil utilizes two types of equipment: booms and skimmers.

Oil Containment Booms: Spilled oil floating on the water's surface is affected by wind, currents, and gravity, all of which cause it to spread. This oil may be concentrated or redirected by deploying floating barriers, called booms. Booms come in many different shapes, sizes, and styles. They are used for concentrating oil so that it is thick enough to be skimmed, for keeping oil out of sensitive areas, or for diverting oil into collection areas. The success of booming as a strategy is dependent on currents, wind, and waves. Currents can draw the oil under the booms; waves may cause oil splash-over; wind and currents may cause the booms to sink or plane; and currents or debris may damage the boom.

Skimmers: These devices remove oil from the water's surface. They are typically used with booms that concentrate the oil, making it thick enough to be skimmed efficiently. The effectiveness of the skimmer is determined by how quickly it can collect the oil, and how much water is mixed in with it. The oil collected by the skimmer is stored in a containment tank. A wide variety of skimmers are available that use different methods for separating oil from water. Skimmer operating time is limited by the size of the storage tank, and skimmer effectiveness can be hampered by debris. Vessel-based skimming systems are utilized to remove oil from open water, while vacuum trucks are often used to remove oil that has collected near the shoreline.

Effectiveness

Boom and Skimmer Operations: Typically, estimated recovery rates range from 10 to 15% of the total spill volume with little opportunity for higher rates due to containment limitations in open water. If a boom and skimming operation is working successfully, 75 to 90% of the oil contained within the boom will be recovered by the skimmer.

What are the Potential Opportunities/ Benefits?

- Physically removes oil from the environment.
- Allows recycling or proper dis-

posal of recovered oil.

- Minimizes direct environmental impacts in open water areas.

What are the Potential Challenges/ Tradeoffs?

- Adequate storage capacity for recovered oil is often limited.
- Spreading of oil on the surface of the water; inability to contain the oil.
- Wind, waves, and currents may allow only a fraction of the spilled oil to be contained and recovered.
- Booms may fail and skimmers may clog.

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DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

DISPERSANTS

What Are Dispersants?

Dispersants are specially designed oil spill products composed of detergent-like surfactants in low toxicity solvents. Dispersants do not actually remove oil from the water. Instead, they break the oil slick into small particles, which then permanently mix (or disperse) into the water column where they are further broken down by natural processes. During periods of heavy wind and wave activity, spilled oil will often get mixed naturally into the water column, only to resurface at a later time as a surface slick when the natural mixing forces have been reduced.

By removing oil from the water surface and diluting oil concentrations in the water column, chemical dispersion:

- Prevents the small oil droplets from coming together again and forming another surface slick (re-coalescence).
- Reduces the ability of the oil to attach to birds and other animals, shoreline rocks, and vegetation.
- Reduces evaporation of volatile oil components thus reducing fire and explosion hazards.
- Provides a cleanup option when other response techniques are not effective (e.g., waves too high for booms and skimmers).
- Enhances natural weathering and biodegradation of the oil droplets.
- Removes the oil from the action of the wind that may ultimately bring a slick ashore.
- Prevents the formation of tarballs and mousse.

Dispersants may be applied to surface slicks from airplanes, helicopters, or vessels. Dispersant spray systems are designed to provide the correct droplet size and dosage, as both are important factors in effective oil dispersal. The volume of dispersant applied is a fraction of the volume of oil treated, with a typical dispersant to oil ratio of 1:20.

Where the Oil Goes

When the oil is treated with dispersants, it initially disperses within the upper 10 meters (30 feet) of the water column due to natural mixing processes. If these dispersed oil droplets are small enough (generally less than 0.01-0.02 mm diameter) the droplets will remain dispersed in the water column. The dispersed oil will be rapidly diluted due to spreading both horizontally and vertically by tides and currents. Historically, dispersed oil concentrations of 20 to 50 parts per million (ppm) have been reported in the upper 10 meters of the water column directly under the slick. These concentrations dilute rapidly as the oil moves through time and space in the water column. Within 2-4 hours, concentrations are typically below 10 ppm, which is the threshold limit below which adverse ecological effects are not anticipated. Typically, pre-authorization of dispersant use is reserved for deeper (>10 meters) waters to ensure sufficient dilution of the oil and to prevent impacts on bottom-dwelling organisms. Dispersant use can also be considered in shallower environments to minimize impacts on highly sensitive surface, shoreline, and intertidal areas that are difficult to otherwise protect.

Dispersant Effectiveness

Dispersant effectiveness is dependent on the type of oil and environmental conditions. Areas where dispersants are applied can reach 100% effectiveness in dispersing surface oil, but often this effectiveness cannot be verified because the dispersant action may occur over a long period of time, and wind and currents carry the oil from the application area. Trained observers must be used to verify effectiveness.

Approval for Dispersant Use

Because of the tradeoffs involved (i.e., relative benefits and potential negative effects), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) sets limitations on dispersant use. Dispersants must be on a national list maintained by the Environmental Protection Agency. Federal and state agency agreements establish areas where rapid decisions on dispersants may be made by the Federal On-Scene Coordinator. Use outside these areas requires the approval of additional agencies identified in the NCP.

Studies of Dispersants

The evidence from six spills treated with dispersants in United Kingdom waters since 1980 is that dispersion of oil (natural or chemical) into the water column can minimize overall environmental impacts by reducing damage to the shoreline and sea surface ecosystems. The limited environmental damage from the 1993 *Braer* incident, where large volumes of oil were dispersed naturally, provides particularly strong evidence that dispersion of oil can minimize the overall effects of a spill. Chemical dispersion in the *Sea Empress* spill in 1996 was found to reduce environmental damages and cleanup intrusiveness, cost, and duration.

What are the Potential Opportunities/ Benefits?

- Reduced impact of surface oil on shorelines, sensitive habitats, birds, mammals, and other wildlife.
- Rapid treatment of large areas.
- Reduced oil storage and disposal problems.
- Accelerated natural degradation processes.
- Use in high seas and currents is feasible.

What Are the Potential Challenges/ Tradeoffs?

- Increased oil impacts on organisms in the upper 10 meters of water column.
- Time frame for effective use may be short.
- Application equipment may be unavailable.
- Personnel trained in proper dispersant equipment use may be unavailable.

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DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

IN-SITU BURNING

What is In-Situ Burning?

In-situ burning means the controlled burning of oil "in place." On open water, burning requires specialized fire resistant boom because uncontained oil rapidly spreads too thin to sustain combustion. *In-situ* burning can be applied in some inland areas where other methods cannot be used because of limited access to the spill location or ice conditions. Since a fire boom behaves much like a standard containment boom, it is subject to some of the same wind and sea limitations as mechanical removal. However, burning rapidly removes large quantities of oil and, minimizes the need for recovery and storage.

Where the Oil Goes

The primary products of *in-situ* burning of oil are carbon dioxide and water vapor. About 90% to 95% of the carbon product is released to the atmosphere as carbon dioxide, while particulates commonly account for only about 5% to 10% of the total volume burned. In addition, about half of the particulates are soot, which is responsible for the black appearance of the smoke plume. Minor amounts of gaseous pollutants are emitted, such as carbon monoxide, sulfur dioxide, and nitrogen oxides. In addition, some polynuclear aromatic hydrocarbons (PAHs) are emitted, but the amount released is less than the amount that would be released if the oil had not undergone burning.

Field experiments have shown that most air pollutants of concern produced by an *in-situ* burn are concentrated around the area of the fire. Only one pollutant, the fine particles in the smoke, is of concern beyond the immediate area of the fire. If inhaled in high concentrations, these particulates can cause respiratory distress in the elderly or those with impaired lung function. Although these small particles from an *in-situ* burn will typically remain suspended and dilute high above the human breathing zone, monitoring plans have been established so responders can monitor particulate levels to ensure the protection of public health.

The decision to use *in-situ* burning must consider the tradeoffs involved, including:

- Impact on air quality.
- Benefit of rapid oil removal.
- Safety of the response workers.
- Risk of secondary fires.

Effectiveness

Burning is efficient. Consistently, it has been found to remove more than 90% of the oil held inside a fire boom during numerous experiments and accidental burns of petroleum on water. The small percentage of the original oil volume left unburned is typically a viscous, taffy-like material that floats for long enough to be manually removed. Because of the containment challenge, like mechanical recovery, it is unlikely that *in-situ* burning will be able to affect more than 10-15% of the total spill volume.

Approval of In-Situ Burning

Because of the tradeoff decisions involved, certain approvals must be obtained prior to use of *in-situ* burning. Use of burning agents to increase oil combustibility is regulated by Subpart J of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The State Implementation Plans required by the Clean Air Act are the primary plans that regulate air quality and pollutant sources. Agreements between state and federal regulatory authorities establish areas and necessary conditions where rapid decisions on *in-situ* burning may be made by the Federal On-Scene Coordinator and/or the State On-Scene Coordinator(s).

What are the Potential Opportunities/ Benefits?

- Reduces impact of surface oil on shorelines, sensitive habitats, birds, mammals, and other wildlife.
- Rapidly consumes oil in the burn.
- Reduces oil storage and disposal problems.
- Eliminates the air quality impacts of the volatile hydrocarbons that would otherwise evaporate.
- The products of combustion are diluted in the air above and downwind of the burn, dispersing rapidly at ground level to background concentrations.

What are the Potential Challenges/Trade-offs?

- Use limited to correct atmospheric and sea conditions or offshore areas to protect public health.
- Equipment required for burning may not be readily available.
- Time frame for effective use may be short due to difficulty of igniting weathered oil.
- Post-burn cleanup operations may be hampered if booms fail or skimmers clog with the burn residue.
- Black Smoke.

Referenced by Ecosystem Management & Assoc., Inc. from materials in the following:

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DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

SHORELINE CLEANUP

What is a Shoreline Cleanup?

The shoreline acts as a natural containment barrier for oil spilled on water. Given the right current and wind conditions, even a spill 25 or 50 miles at sea can wash ashore if not recovered or removed by on-water spill response technologies (mechanical recovery, dispersants, *in-situ* burning). On shore cleanup is very labor intensive and tends to be more acutely environmentally intrusive than any of the on-water response options. Listed below are examples of shoreline cleaning methods, many of which are used concurrently.

1. **Natural Recovery**–no action is taken, the oil is left to weather naturally.
2. **Manual Removal**–removal of surface oil by manual means (hands, rakes, shovels, buckets, scrappers, sorbents, etc.)
3. **Mechanical Removal**–removal of oil from water surface, bottom sediments and shorelines using backhoes, graders, bulldozers, dredges, draglines, etc.
4. **Passive Collection and Sorbents**–removal of floating oil by absorption onto oleophilic material placed in the water or at the water line.
5. **Vacuum**–mechanical removal of free oil pooled on the substrate or from relatively calm water.
6. **Debris Removal**–manual or mechanical removal of debris (oiled and unoiled) from the shore or water surface to prevent additional sources of contamination.
7. **Sediment Reworking/Tilling**–reworking sediments to break up subsurface oil deposits, both manually and mechanically, to expose the oil to natural processes and enhance the rate of oil degradation.
8. **Vegetation Cutting/Removal**–removal and disposal of portions of oiled vegetation or oil trapped in vegetation to prevent oiling of wildlife or chronic oil releases.
9. **Flooding (deluge)**–removal by water washing oil stranded on the land surface to the water's edge for collection and disposal.
10. **Ambient Water Washing (low and high pressure)**–removal of liquid oil that has adhered to the substrate of man-made structures, pooled on the surface, or become trapped in vegetation using ambient-temperature water sprayed at low or high pressures.
11. **Warm Water Washing (<90°F)**–removal of non-liquid oil that has adhered to the substrate or man made structures, or pooled on the surface using warm water.
12. **Hot Water Washing (> 90°F)**–removal of weathered and viscous oil strongly adhered to surfaces using hot water.
13. **Slurry Sand Blasting**–removal of oil from solid substrates or man-made structures using sandblasting equipment.
14. **Solidifiers**–chemical formulations which change the physical state of the spilled oil from a liquid to a solid for easier recovery and disposal.
15. **Shoreline Cleaning Agents**–chemical formulations applied to the substrate to increase the efficiency of oil removal from contaminated substrates using other response methods (flushing, pressure washing, etc.).
16. **Nutrient Enrichment**–a bioremediation technique that involves adding nutrients to the environment to stimulate the growth of naturally occurring oil-eating bacteria.
17. **Burning**–removal of oil from the water surface or habitat by burning the oil.

Options 14 through 17 require special approval under federal laws.

In order to determine the proper cleanup method, responders and planners consider cleanup methods in advance of a moving oil slick. Several considerations must be made before a proper cleanup plan can be initiated. First, the type and quantity of oil must be determined. Oil types vary greatly and have a major influence on the degree of impact, ease of cleanup, and persistence of the contamination. For example, lighter fuels (diesel, home heating fuel, and light crude oils) will evaporate quickly, but tend to be more toxic and penetrate the shoreline sediments to a greater degree. Heavy oils (bunker C, No. 6 fuel, and heavy crude oils) are less toxic to shoreline ecosystems and do not penetrate finer sediments, but they are very persistent, difficult to clean and may smother shoreline organisms.

Second, the type of shoreline predicted to be impacted must be identified, mapped, and ranked in terms of its relative sensitivity to oil spill impacts, the predicted rates of natural removal of stranded oil by processes such as waves and currents which naturally clean the shoreline, and ease of cleanup.

Additionally, the shoreline cleanup strategy may need to be revised in response to changing conditions or as the oil weathers.

Cleanup Effectiveness

1. The success of the shoreline cleanup response is dependent on several factors, including but not limited to the type of affected shoreline;
2. The type of oil spilled;
3. The availability of the equipment;
4. The technical experience of the cleanup personnel; and
5. Weather and sea state conditions.

Depending on the spill conditions and the response operation used, the cleanup strategy can range from 100 percent effective (e.g., manual removal) to minimally effective initially (as can often be the case in marshes and sheltered tidal flats). In marsh habitats, the activity associated with the cleanup can often be more damaging than the oil itself; the cleanup operations can drive the contaminants below the surface and make them available to the root systems of the plant and the organisms that burrow into the sediments. It is common in these environments for oil to be allowed to remain on the surface of the sediments with sorbents being placed at the edge of the water line in an effort to passively collect any oil that re-floats.

What are the Potential Opportunities/ Benefits?

Examination of the benefits and tradeoffs of shoreline cleanup are different than examining the benefits and tradeoffs of on-water response. Given the option, on-water cleanup will almost always be environmentally preferable to on-shore recovery. Therefore the potential benefits here apply to employment of one or more of the shoreline recovery options versus allowing the oil to degrade naturally on the shoreline without human intervention.

- Reduced impact on shorelines, sensitive habitats, birds, mammals, and other wildlife.
- Physically removes oil from the environment.
- Allows recycling or proper disposal of recovered oil.

What are the Potential Challenges and-Tradeoffs?

- Reduced impact on shorelines, sensitive habitats, birds, mammals, and other wildlife.
- Often labor and manpower intensive.
- Adequate storage capacity for recovered oil is often limited.
- May require special approvals under federal law

Referenced by Ecosystem Management & Assoc., Inc. from materials in the following:
Pond, R.G., D.V. Aurand, J.A. Kraly (compilers). 2000a. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the San Francisco Bay Area. California Office of Spill Prevention and Response.

Pond, R.G., D.V. Aurand, J.A. Kraly (compilers). 2000b. Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in the Galveston Bay Area. Texas General Land Office, Austin, TX.

DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

EVALUATION OF PROTECTIVE BOOMING

Background

Protective booming was not included in the matrix of response options evaluated for this exercise. The workshop participants are aware of the potential impacts associated with implementation of protective booming along shorelines and shallow water habitats. However, the group felt that protective booming would be deployed in highly sensitive areas under any oil spill response option, thus the risks would be present in all response activities considered.

When is protective booming appropriate?

Protective booming is seen as an integral part of dealing with unexpected events associated with any type of oil spill response (i.e., on water recovery, dispersant use, on-water or in-situ burning, natural dispersion without recovery). This characterization is consistent with its intended role as a contingency in case oil moves to new areas unexpectedly. It also is deployed in case planned recovery operations are not as efficient as desired or as timely as expected in deployment. The workshop participants recognized that response options that leave small residuals of oil on the water surface due to operational inefficiencies may provide a greater overall level of environmental protection when paired with protective booming. The environmental risks of those response options might indeed be unfairly characterized by leaving out the benefits of protective booming, compared to greater residual risks associated with response options that leave relatively greater residuals of oil in the water surface. For those less efficient response options, protective booming may not be sufficient to eliminate impacts of residual surface oil.

Efficiency

Workshop participants recognized that the efficiency and effectiveness of protective booming is highly variable. The degree of protection afforded depends on factors such as the type of oil, local currents and wave conditions, installation methods, boom maintenance, and the degree to which a shoreline is accessible with equipment and amenable to placement of protective booming. An additional consideration is that the efficiency of protection commonly decreases as the duration of oiling and amount of oil impinging on the boom increases. Oily boom that is not serviced on a regular basis can become a source of oil for the local area it was intended to protect. When oil does pass behind the boom, the boom can then serve as a barrier to slow the rate of oil release from the shoreline area.

Risks

Protective booming brings about a certain degree of risk of collateral damage do to physical disturbance by work crews installing, maintaining and dismantling the boom. Additionally, there are impacts of disturbance and scaring from anchoring the materials to soils, sediments or plants, along with increased erosion of shoreline and sediments while the boom jostles in place. Finally, oily booming materials that are not retrieved when the response is completed become shoreline or wetland debris.

The potential ecological risks from protective booming are considerable. However, the risks are nearly the same for any and all the response options considered in the course of the workshop, since booming would be deployed as a contingency in all cases. Therefore, it was left off the risk assessment matrix.

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DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

Bioremediation

Background

Bioremediation was not included as a response option for the Galveston Bay Ecological Risk Assessment since bioremediation is considered a final cleanup consideration or "polishing" tool. The biodegradation process is simply microbial respiration. The end products of this natural process are carbon dioxide and water. Some bioremediation products contain surfactants to break up the oil into tiny droplets, increasing the surface area of the residual oil and thus enhancing the rate of microbial degradation by enhancing interfacial exposure between oil and the microbial community. For bioremediation to be considered, incident-specific and product-specific RRT approvals are required. Given the limitations of bioremediation use, it would not be used widely in any of the defined habitats and was not included in this risk assessment.

When bioremediation appropriate?

Bioremediation is not an appropriate strategy in dealing with heavy oiling. Light to moderate residual oiling in low energy environments are potential candidates for bioremediation. Generally, some form of shoreline cleanup would be required prior to bioremediation. Workshop participants considered the application of bioremediation outside the current risk assessment matrix. That does not suggest that the workshop participants considered bioremediation inappropriate for use in the Galveston Bay.

Efficiency

Biodegradation was demonstrated in Galveston Bay during the Apex Oil spill in 1990, but observations related to effectiveness were mixed. Very little change in oil concentration appeared to be related to the addition of bioremediation agents. The objective of bioremediation is to accelerate the rate of hydrocarbon (oil) degradation by natural microbial processes to include the addition of nutrients and/or the addition of oil degrading microorganisms. Bioremediation is generally a slow process and is limited by many factors including oil concentration. For bioremediation to be effective, the oil concentration must be below the level which is toxic to the microbial community, as well as below the concentration level which inhibits appreciable biodegradation due to limited interfacial exposure between oil and oil degraders.

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