The NOAA Trajectory Analysis Planner: TAP II

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Abstract

Trajectory Analysis Planner (TAP II) is a computer-based tool designed to investigate the probabilities that spilled oil will move and spread in particular ways within a particular area, such as a large bay or inlet with substantial ship traffic. By graphically presenting the results of thousands of oil-spill trajectory simulations, TAP II helps emergency planners understand and anticipate many possible outcomes when developing local-area contingency plans for oil spill response.

TAP II assists in the following planning tasks:

• assessing potential threats from possible spill sites to a given sensitive location

• determining which shoreline areas are likely to be threatened by a spill originating from a given location

• calculating the probability that a certain amount of oil will reach a given site within a given time-period

• estimating the levels of impact on a given resource from a spill

• analyzing shortfalls in response personnel and equipment

I. Introduction

Community oil-spill response is a complex business that typically brings together stakeholders from a wide range of disciplines, including engineers, natural resource trustees, property owners, government managers, emergency responders, maritime industry representatives, fish and wildlife experts, etc. To even begin developing a unified plan, these groups must share a common understanding of oil spills and the likely impacts of a spill in their local area. Many members of community response planning teams have little or no background in physical oceanography or trajectory analysis. The task for oil-spill modelers in support of these planning groups is to present a practical ensemble of information on potential spills and their probable consequences in relation to the various stakeholder interests represented on the planning team. A more detailed discussion of this complex task is given in Galt & Payton (1999).

Oil spill response planners must have a basic understanding of what is likely to happen.

1 What (and how much) oil might spill?
2 Where might the oil spill?
3 Where might it go? and how much?
4 Who or what might get hurt?

The first two questions can be answered by looking at the kinds and sizes of vessels that normally travel in an area, their cargo, and the types and amounts of oil they carry, as well as onshore oil handling facilities. TAP II is a tool that provides information to answer the last two questions: Given a specific spill location and type, where might it go and what might it harm?

II. Why TAP II?

The current state of the practice is *scenario-based* spill response planning, whereby a response is planned for a so-called “worst case scenario” or, in some cases, a small set of scenarios. To generate these scenarios, sets of oceanographic and meteorologic conditions are selected based on a set of assumptions about what constitutes the worst possible outcome from a given spill at a given location.

There are limitations to this approach. For example, although a particular worst case may pose the worst possible outcome from the perspective of one stakeholder, this may not be true from another perspective. Fig. 1 is a schematic of a hypothetical bay where an oil spill could occur. Depending on the conditions at the time of the spill, the oil could threaten a wildlife preserve (Scenario A), a beach with many tourist hotels (Scenario B), or a nuclear power plant with a cooling water intake (Scenario C). Different stakeholders would give very different answers as to which is the worst case. Another difficulty with worst-case scenario planning is that even if a worst case is agreed

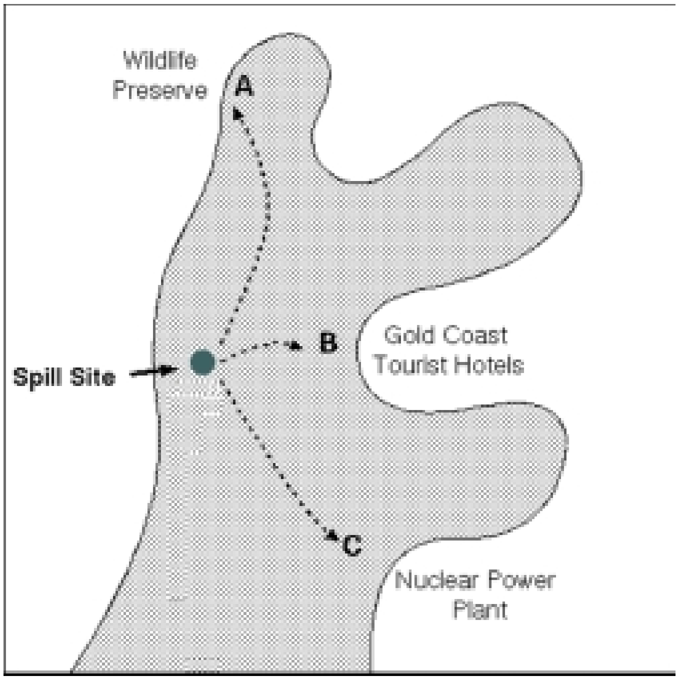

Fig. 1. Three possible worst-case scenarios of an oil spill in a hypothetical bay

upon and planned for, the likelihood of that particular scenario is often unknown. Also, a response plan formulated for a particular worst case may be inappropriate for other scenarios that would require a completely different response.

TAP II provides an alternative approach: *statistics-based* planning. *Statistical analysis* is an analysis of data derived from a sample in order to predict the characteristics of the population under study (Morris 1992). In the case of oil-spill response planning, the *population* under study is the set of all possible oil spills in a region. TAP II is the interface to a database of thousands of modeled spills, a *sample* of the *population* of all possible spills. The TAP II interface helps response planners understand characteristics of the possible oil spills in a given region. Understanding these characteristics allows responders to plan not only for *one or a few* possible high-impact events, but to determine the best overall plan for *many* events, across the entire spectrum of probabilities and levels of impact.

A. History of TAP and TAP II

The Trajectory Analysis Planner (TAP), a user-friendly tool to support spill-response planning, was developed in 1998 by the Hazardous Materials Response Division (HAZMAT) of the National Oceanic and Atmospheric Administration (NOAA). Initially developed as a pilot study for Delaware Bay and San Francisco Bay, TAP is an application and viewing engine for an area-specific database that allows the user to view graphically the probabilities that a specific oil will move from a specified spill site to a designated target location. After completing the TAP pilot project, HAZMAT (now a division of the Office of Response & Restoration) worked with response planners to evaluate their receptiveness to the product and to observe how they interpreted the information given. We also began an in-depth analysis of the statistical methods used in TAP so that we could better understand uncertainty of the information presented and the potential spatial gaps in the initial geophysical data used to generate a specific scenario set (Barker & Galt 1999, Lehr et al. 1999).

The results of this usability testing lead to the realization that TAP's configuration failed to provide some statistical analyses that would be highly useful to planners. These include distinguishing between 1) locations very likely to be oiled with a small amount of oil, and 2) locations, although less likely to be oiled, that would be hit with a large amount of oil. We also found that users often misinterpreted the information that TAP did provide. The results of these studies have lead to the reformulation of the TAP analysis procedures. The new version, known as TAP II, provides a greatly expanded and more powerful spill-trajectory database that specifically addresses major areas of concern to spill-response planners.

B. Methodology of TAP II

To provide statistics of oil spill movement, TAP II must process data from a large number of trajectories. Each trajectory is a function of the physical processes of oil movement, including—the dynamics of wind, ocean currents, and turbulent diffusion. Each trajectory is calculated using a unique set of data of hydrologic, oceanographic, and meteorologic conditions. For each location chosen (e.g., San Francisco Bay), historical wind records are examined to determine the wind field for as long a time-period as possible. Typically, at least 10 years of continuous wind records are available. In many locations, weather patterns vary substantially among seasons. To accommodate these variations, temporal parameters of the data are broken down by season, with wind and ocean patterns specific to each season. Data on historic tidal currents, river flows, and wind-driven current patterns are also computed by season to complete the geophysical dataset that defines the physical processes that move the oil.

Once the physical processes have been defined, the entire shoreline of the bay is divided into about 200 separate segments or "receptor sites." About 200 possible spill locations, or "source sites," are defined throughout the bay, covering all likely spill locations. Some 500 "start times" are randomly chosen from the time-period for which adequate meteorological records are available. For each of these start times, and for each source site, OSSM (NOAA's "On-Scene Spill Model") uses the geophysical dataset to compute a complete trajectory of the oil over a period of 5 days. As the simulated oil spill progresses, the amount of oil that passes through each receptor site is calculated. This is a massive computational task, taking about 2 weeks on 12 Macintosh 350-Mhz G3 computers.

The result of this computation is a large database of the amounts of oil from each source site that threaten each receptor site for each of 500 simulated spills. The TAP II interface is a graphical tool designed to display this data in various ways that are of interest to planners. The user interface provides four display modes, each of which summarizes the database in a different way.

III. Display Modes of TAP II

In all of the display modes the user defines the parameters of the potential spill under study.

Oil type: TAP II includes a simple oil evaporation model. The rate of evaporation depends upon the type of oil spilled.

Amount of oil released: (provided by user)

Season: The TAP II dataset is divided into seasons according to similarity of wind patterns. This could be two seasons (as in San Francisco), or up to four seasons. The user may be interested in a different season at different locations, because the environmental sensitivity of some locations may vary by season.

Time post-spill: The TAP II dataset includes data on how much oil reached each receptor site for ten different time-periods (up to 5 days) following the spill. The data for each time period is cumulative, i.e., the amount of oil that passes through each receptor site from the beginning of the spill until the selected end-point in time. By examining the data at different times following the spill, the user can determine how quickly the response must be mobilized.

Level of concern: Different shoreline types have different sensitivities to oil. The level of concern (LOC) depends on the amount of oil that would be expected to significantly impact a particular site. The LOC is the volume of oil that enters the receptor site. All the receptor sites throughout the bay are approximately the same size (~2 km of shoreline in San Francisco Bay), so that the same volume of oil would have a similar density at all sites.

A. Threat Zone Analysis

Threat Zone Analysis (Fig. 2) helps answer the question: Where might a spill occur that could threaten a shoreline location of concern? The user selects a receptor site of interest (perhaps a sensitive wetland), and is provided with a color contour map of the entire bay, indicating the likelihood of oil reaching the selected receptor site from any location in the bay. The map colors correspond to the percentage of modeled spills from each location in the bay from which the movement of oil to the selected receptor site is equal to or exceeds the LOC for that site. By repeating this analysis for a number of different receptor sites, the user can gain an understanding of the geophysical processes that move oil in the entire area.

B. Shoreline Impact Analysis

Shoreline Impact Analysis (Fig. 3) helps answer the question: If oil is spilled at a given spot, what shoreline locations are likely to be impacted? A spill source site in the bay is selected, and a color map is presented that indicates the likelihood that oil from a spill at that location will reach each of the shoreline receptor sites. The colors correspond to the percentage of modeled spills originating at the selected source site that exceed the LOC for all the receptor sites in the bay.

C. Site Oiling Analysis

Site Oiling Analysis (Fig. 4) provides a way to visualize how a particular receptor site is likely to be oiled by a spill originating at a particular location. The user selects a spill site and a receptor site and is presented with a graph showing the percentage of modeled spills that resulted in a given amount or more of oil reaching the site in the selected time-period.

D. Resource Analysis

Resource Analysis (Fig. 5) provides data on the quantity of a given resource impacted by the modeled spills, or the level of response required to adequately address the impacts of those spills. The user specifies a spill site and a resource of interest, and TAP II generates a graph that indicates the total costs of each of the modeled spills in terms of that resource. The values on this graph are the costs of oil impacting each site at greater than its LOC, summed over all the sites for which the LOC is exceeded.

The cost of a site could be the number of nesting birds at that location, or the length of boom required to protect the site, or virtually any resource of interest, in any appropriate units. The user provides data about each resource in a standard text-file format. These data include the quantity of each resource associated with each receptor site, and the LOC for that site and resource. The LOC is expressed as the amount of oil that must reach the site for the resource to be considered impacted. Because the resource data files are in a text-file format, they can be generated in a text editor, spreadsheet, or database software. Because the information required is spatial, the locations of the receptor sites are provided and can be entered into a GIS system to generate resource files from virtually any GIS dataset.

For examples of resource data files, NOAA provides files generated from our Environmental Sensitivity Index (ESI) maps (NOAA 1997). This data includes the quantity (meters) of each type of ESI shoreline found in each receptor site. For example (as shown in Fig. 5), using this data in the resource analysis mode allows the user to determine how many meters of saltmarsh shoreline are impacted by each of the modeled spills. The *y*-axis is the

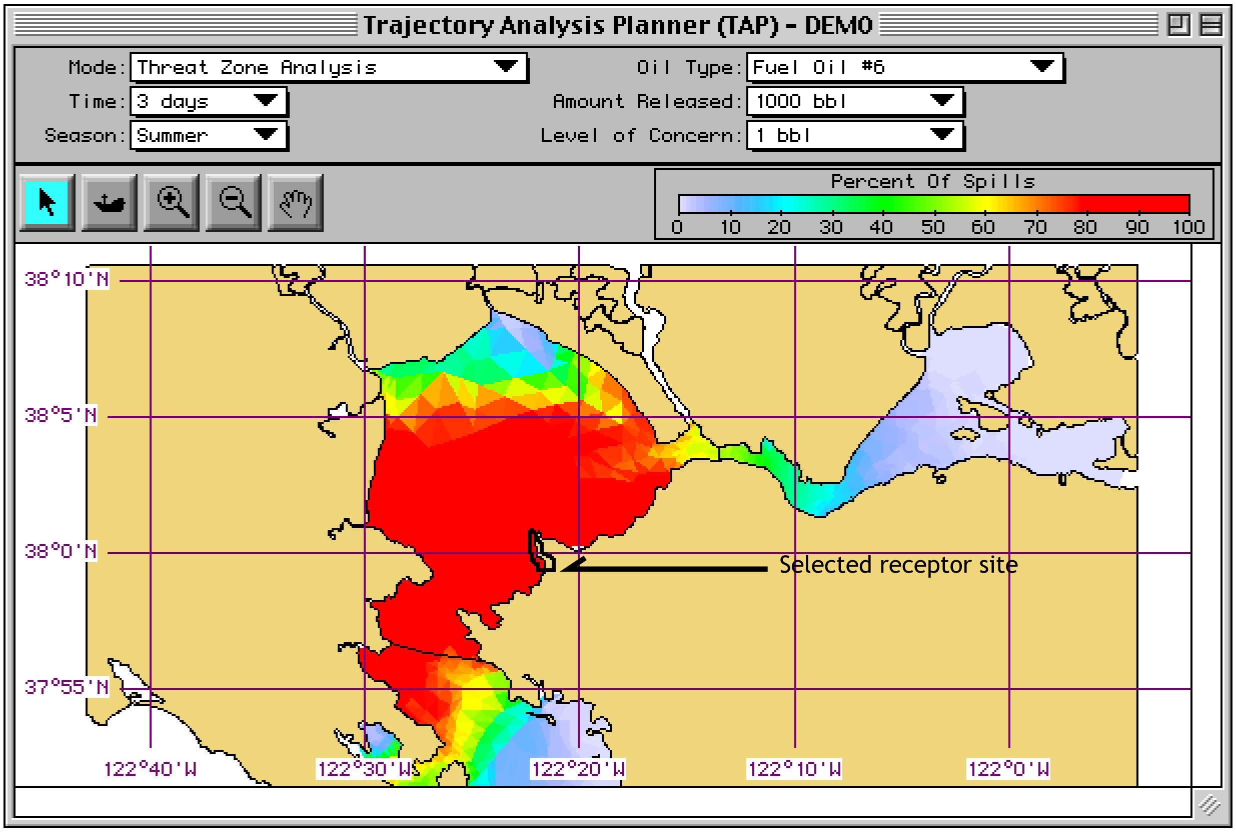

Fig. 2. Example of Threat Zone Analysis for part of San Francisco Bay. Colors indicate the percentage of modeled spills that reached the selected receptor site within 3 days

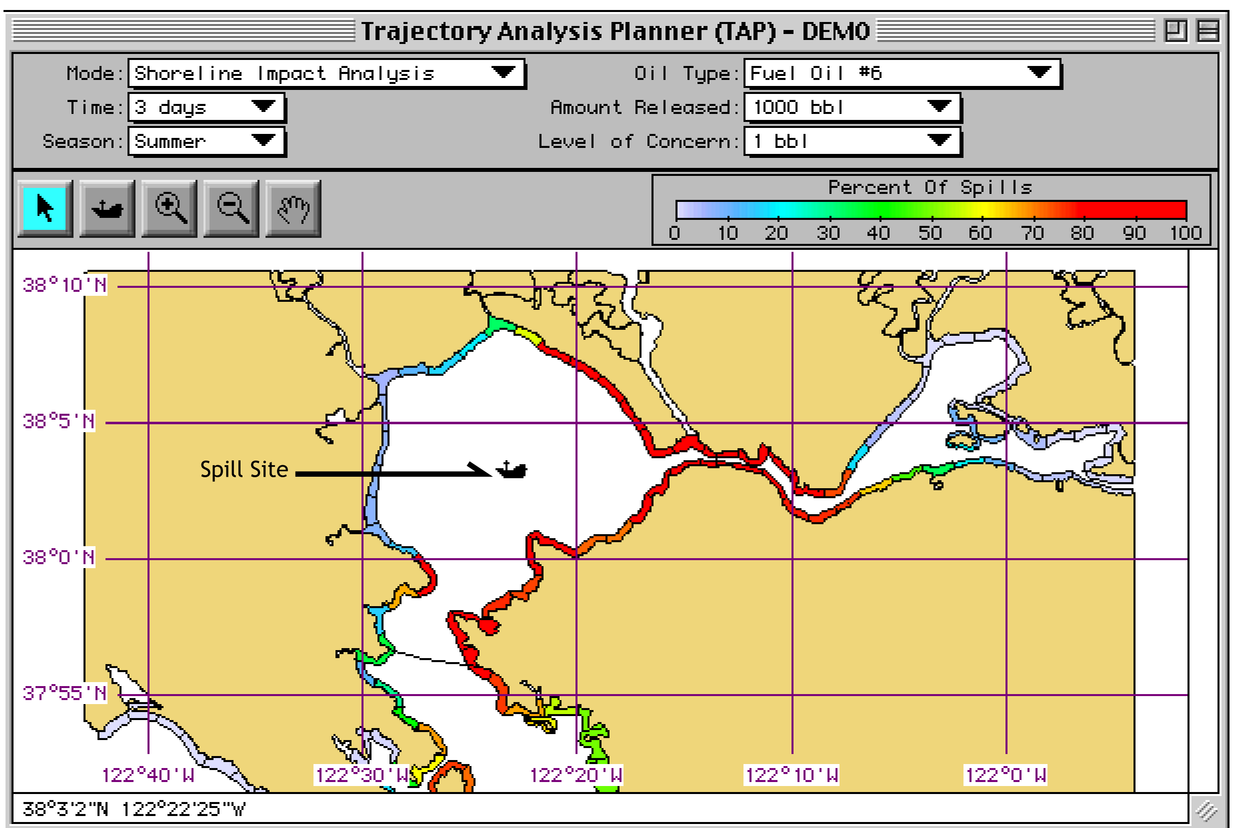

Fig. 3. Example of Shoreline Impact Analysis for part of San Francisco Bay. Colors indicate the percentage of modeled spills that exceeded the Level of Concern (LOC) at each receptor site within 3 days.

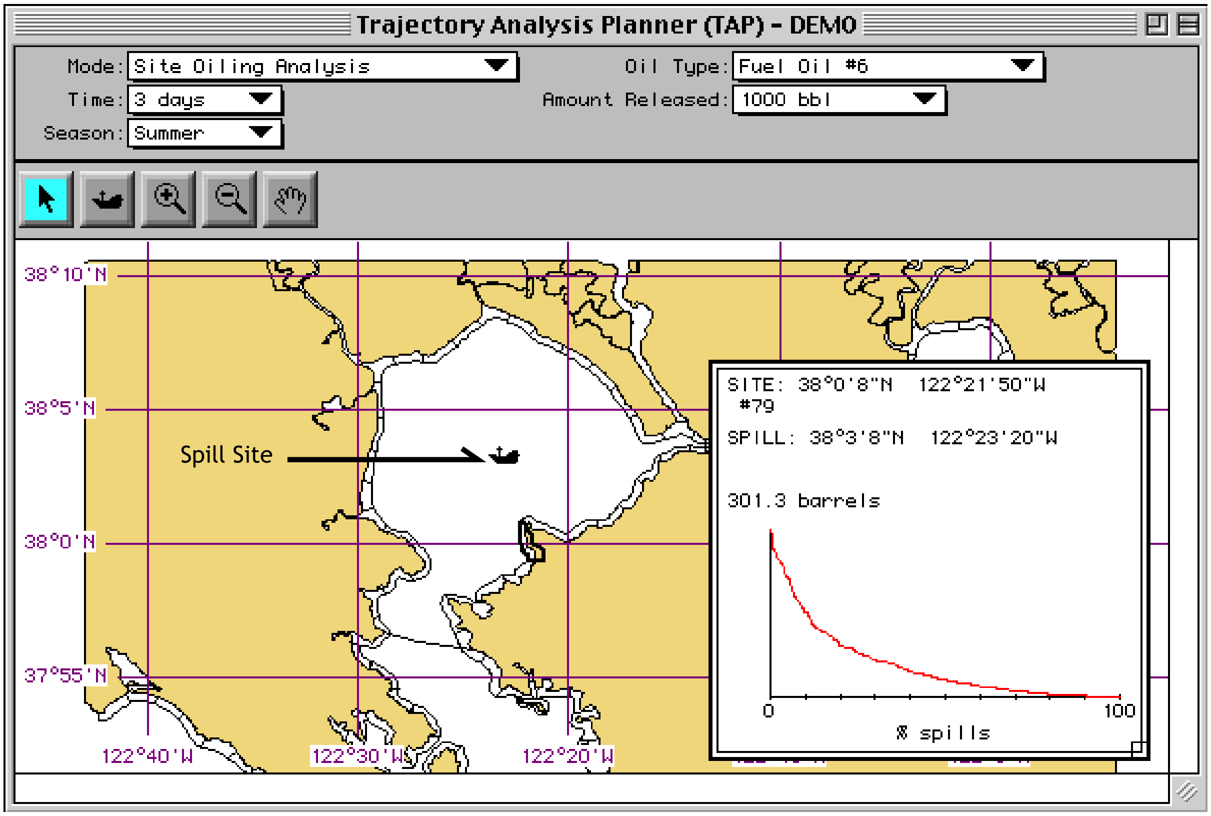

Fig. 4. Example of Site Oiling Analysis for part of San Francisco Bay. The graph plots the percentage of modeled spills in which a given amount or more of oil reached the selected receptor site within 3 days.

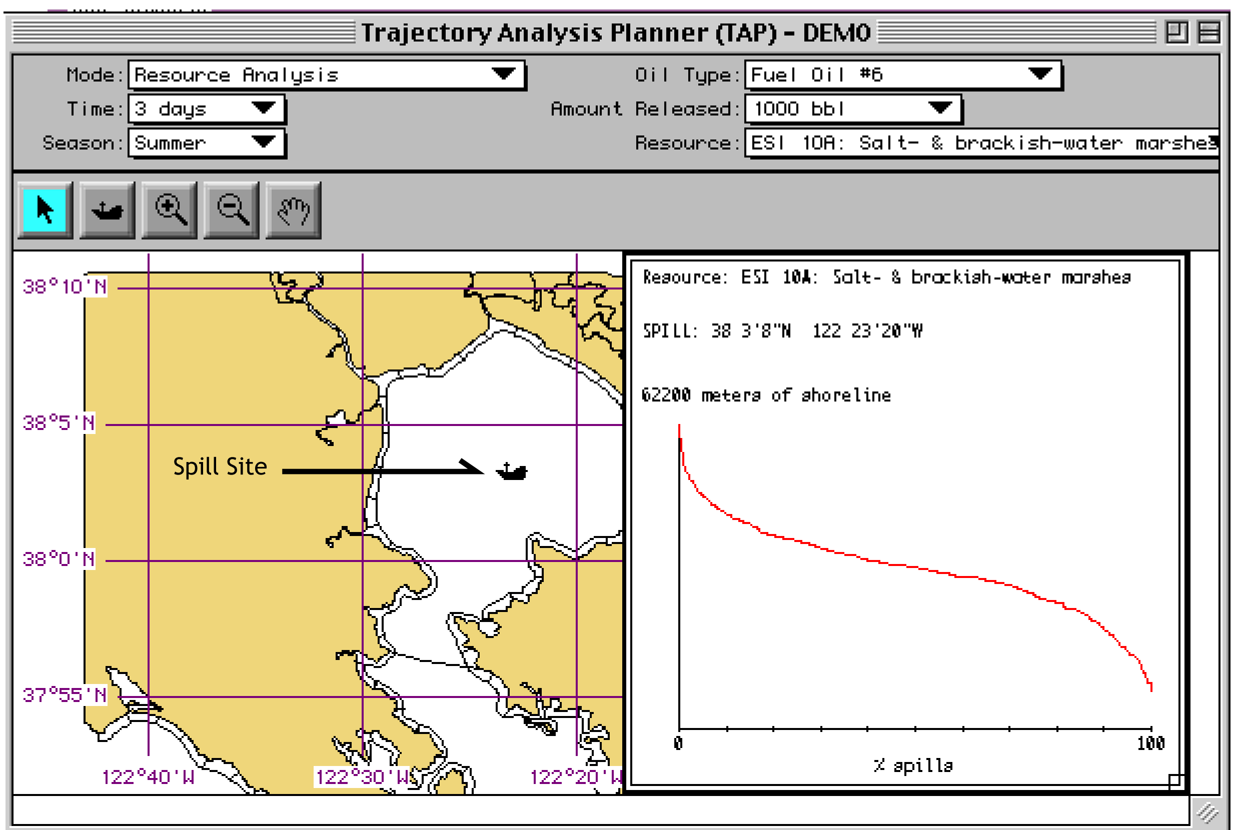

Fig. 5. Example of Resource Analysis for part of San Francisco Bay. Graph indicates total ESI type-10A shoreline (salt/brackish-water marsh) impacted by each of the modeled spills within 3 days. *y*-axis is meters of shoreline impacted; *x*-axis is percentage of modeled spills in which a given length or more of shoreline has been impacted.

length of shoreline impacted; the *x*-axis is the percentage of modeled spills for which a given amount or more of shoreline has been impacted. In this case, 0% of spills impacted more than 62,200 meters of shoreline, 50% of spills impacted about 33,000 or more meters, and 100% of spills impacted 6,000 meters or more. (Note: Fig. 5 is from an early prototype of the program. In the final product, the graph will be easier to read.)

Resource Analysis is a powerful tool for response shortfall analysis. Once a response plan for each sensitive location in a bay has been developed, the data from that plan can be entered into a resource data file, indicating, for example, the quantity of boom required to protect each sensitive site. Because it is unlikely that every location included in a plan would need protecting at the same time, Resource Analysis can be used to compute the total quantity of boom required to respond to any of the modeled spills in the database. The total costs can be computed for any of a number of different time frames, so that one could know that one quantity would be needed within 24 hours, and more within 3 days, allowing time for long-distance transport of the equipment to the site.

While, at first glance, Shoreline Impact Analysis and Resource Analysis appear to answer similar questions, they are fundamentally different. Although site A and site B may both be impacted by about 30% of the spills modeled, the two sites are probably not impacted by the same 30% of spills. In fact, it's possible that two given sites are never impacted simultaneously, such that protecting both of them simultaneously would never be required. The Resource Analysis mode computes the total cost of each spill individually, so that these two sites would not simultaneously contribute to the total cost.

IV. Conclusions

TAP II is a graphical tool designed to display localized oil-spill trajectory data in various ways that are of interest to emergency response planners. The dataset is generated using historical wind patterns and both tidal and non-tidal circulation patterns. NOAA's OSSM model uses this information for the next step, generating a series of thousands of individual trajectory analyses, each representing a different potential oil spill scenario. The results are sorted and compressed into a database that TAP II uses to generate its graphic displays. The user interface provides four display modes, each of which summarizes the database in a different way.

TAP II is now under development for the San Francisco Bay and San Diego Bay. Negotiations are underway for additional TAP II implementations. TAP II runs on Macintosh or Microsoft Windows operating systems. For more information, visit our Web site at http://response.restoration.noaa.gov, or e-mail tap@hazmat.noaa.gov

V. Acknowledgments

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