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Standard Practice for Development and Use of Oil-Spill Trajectory Models[1]

This standard is issued under the fixed designation F2067; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice describes the features and processes that should be included in an oil-spill trajectory and fate model.

1.2 This practice applies only to oil-spill models and does not consider the broader need for models in other fields. This practice considers only computer-based models, and not physical modeling of oil-spill processes.

1.3 This practice is applicable to all types of oil in oceans, lakes, and rivers under a variety of environmental and geographical conditions.

1.4 This practice applies primarily to two-dimensional models. Consideration is given to three-dimensional models for complex flow regimes.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Terminology

2.1 *Definitions:*

2.1.1 *trajectory model*—a computer-based program that predicts the motion and fate of oil on water as a function of time.

2.1.1.1 *Discussion*—Input parameters include oil properties, weather, and oceanographic information. There are four different modes: forecast, hindcast, stochastic, and receptor.

2.1.2 *contingency planning*—planning of several types to prepare for oil spills.

2.1.2.1 *Discussion*—This planning can include modeling such as described in this guide, to predict where oil spills might go and what the fate and properties of that oil would be.

3. Significance and Use

3.1 Trajectory models are used to predict the future movement and fate of oil (forecast mode) in contingency planning, in exercises and during real spill events. This information is used for planning purposes to position equipment and response personnel in order to optimize a spill response. Oil-spill trajectory models are used in the development of scenarios for training and exercises. The use of models allows the scenario designer to develop incidents and situations in a realistic manner.

3.2 Oil-spill trajectory models can be used in a statistical manner (stochastic mode) to identify the areas that may be impacted by oil spills.

3.3 In those cases where the degree of risk at various locations from an unknown source is needed, trajectory models can be used in an inverse mode to identify the sources of the pollution (hindcast mode).

3.4 Models can also be used to examine habitats, shorelines, or areas to predict if they would be hit with oil from a given source (receptor mode).

4. Modelling Methods

4.1 Models simulate the movement of oil on water, calculates the various weathering processes and considers the interaction of the oil with the shoreline. The input data needed by the model includes area maps, oil properties, and spatial and temporal vectors of wind and ocean currents. In some models, there are separate programs for advection and fate. In some cases, the fate models calculate weathering on the total mass of the oil rather than on individual particles. Some models include response strategies (skimming, burning, dispersing, and so forth) and the effect of these on the mass balance.

4.2 The computer model calculates the surface fate of the oil using physical and chemical properties of the oil and weathering algorithms.

4.3 The output of a model is a map showing oil-slick locations as a function of time, and graphs and tables of the weathering of the oil and mass balance.

4.4 The output of the model is subject to uncertainties, primarily caused by uncertainties in the input data from forecast winds and predicted ocean currents. The model should include an estimate of the magnitude of these uncertainties. It

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[1] This practice is under the jurisdiction of ASTM Committee F20 on Hazardous Substances and Oil Spill Response and is the direct responsibility of Subcommittee F20.16 on Surveillance and Tracking.

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should be recognized that models are only a tool and thus outputs should always be confirmed by ground-truthing.

5. Input Modelling Parameters

5.1 In order to generate a georeferenced output, it is necessary to have a suitable base map. This map should have a resolution in the order of 100 m near shore and 1 km in the open ocean. The base-map data should be in a common mapping format. The map should be vector-based in order that the output can be scaled to be consistent with the extent of the trajectory. The data on the map should be organized in layers, with ocean current, wind fields, and trajectory information available as separate layers. Other common layers are resources at risk, sensitive habitats, water intakes, socioeconomic parameters, and so forth.

5.2 The physical and chemical properties of the oil are needed in order to calculate the weathering of the oil. This data should be derived from readily available distillation data curves and other standard oil-industry crude descriptors. Catalogues are available that include parameters used in oil-spill trajectory models. The need for the determination of model-specific parameters should be avoided where possible.

5.3 The spatial and temporal distribution of wind fields is required to drive the advection terms of the model. These wind fields should be input as a time series of vectors, with separate inputs for each wind-data source. The modeling program should have methods to interpolate the data from the individual wind observations. In some cases, weather data would be available as large-scale synoptic charts. The computer program should be able to translate these maps into the required wind fields.

5.4 The ocean current regime can be divided into three components: wind-driven currents, tidal currents, and residual currents.

5.4.1 The vector sum of these three currents is the spatial and temporal driving force that moves the oil on the ocean surface. The total ocean current equation must obey the continuity equation so that the model does not generate artificial sources and sinks. The wind-driven currents are directly mapped from the wind field, with a factor of about 3 to 3.5 % commonly used to convert the wind vector into the corresponding surface ocean-current vector.

5.4.2 The ocean-current vectors that are produced by tidal action are strongly dependent on the bathymetry and shoreline shape of the area involved. Tidal currents follow the tidal period, with strong spatial changes depending on the tidal cycle. There are many schemes that have been derived to compute such currents. Hydrodynamics models are sometimes used to generate oceanographic data. Real time oceanographic data from buoys provides both current and winds of high accuracy.

5.4.3 The residual currents are strongly spatially dependent but remain constant in time over the duration of most spill model calculations. This may not be true for stochastic calculations that have time periods of months to years.

5.4.4 In estuaries, there are very complex currents, which are difficult to predict using available models.

5.4.5 The computation of ocean currents is complex and should be supplemented by actual measurements using drifter buoys and oceanographic current meters. In many situations, simple current measurement using floating objects can be used and are better than no measurements.

5.5 River and complex hydrology regimes are driven primarily by current which is constrained by shoreline boundaries and geomorphology.

5.5.1 The complexity of river modeling varies with user needs and can vary from simple time and distance calculation to 3D grid models.

5.5.1.1 Time and distance calculations are used for response plans to determine planning distances. Stream flows should be taken from monitoring networks or a representative measurement in the absence of a monitoring network.

5.5.1.2 In areas where the potential for releases is high, more complex finite element models are required. These complex models require tight boundary-fitted coordinate system to account for shorelines and varying channel shapes (geomorphology). The models should include the ability to follow changing river stages, degrees of icing and oil & particle deposition on the riverbank and the stream bed. Many rivers are sediment laden and deposition of oil-sediment particles may be a consideration.[2,3]

5.5.2 Complex hydrology regimes include estuaries and straits. Waterflow can be influenced by large and conflicting vectors: for example, streamflow, tides and wind. 3D models are needed to accurately account for the hydrodynamics in combining and split flows, circulating flow and reversing flow. These advanced models include the fate and effects of oil and often are a compromise between river models and ocean models which use non-uniform grids.

5.6 There are many limitations to the ability of models to predict oil movement and fate, and the output should be regarded as guidance rather than an absolute prediction.

6. Model Characteristics

6.1 Most models divide the slick into a number of particles, each of which is advected and weathered separately. These particles are treated as moving elements. The real slick is continuous and not quantized. If insufficient particles are used by the model, then anomalous results are generated. The total number of particles in the model should be greater than 100 at all times.

6.2 The model should include the weathering of the oil with time. Essential processes are:

6.2.1 Evaporation,
6.2.2 Emulsification,
6.2.3 Dissolution,
6.2.4 Natural dispersion, and
6.2.5 Sinking.

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[2] Great Lakes Science Advisory Board's Science Priority Committee, Potential Ecological Impacts of Crude Oil Transport in the Great Lakes Basin, International Joint Commission, Ottawa, Ontario, 41 p., 1999.

[3] LimnoTech, 2018. Impacts of unrefined liquid hydrocarbons on water quality and aquatic ecosystems of the Great Lakes Basin, available at http://www.ijc.org/