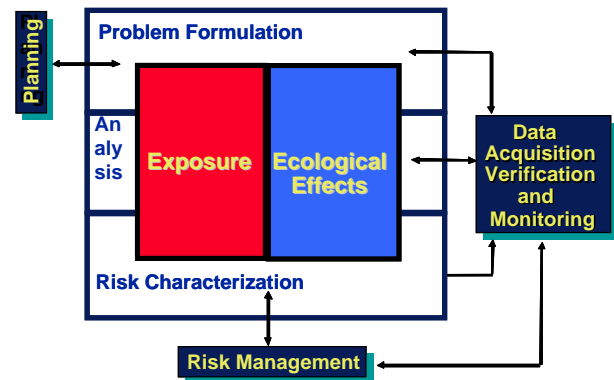


# Risk Assessment to Nearshore Marine Environment Kingdom of Saudi Arabia 1991 Gulf War

## Project Characteristics:

- *Assessment of Marine Ecological Risks*
- *Evaluate Risks of Remediation Alternatives Relative to Status Quo (Natural Attenuation)*
- *Quantification of Sediment Toxicity and Benthic Community Structure*
- *Development of Risk Framework and Rules for Risk Rankings*



The Woods Hole Group, Inc., under contract to the Environmental Consulting Bureau of the Kingdom of Saudi Arabia, conducted an assessment of risks to the northeastern nearshore marine environment of the Kingdom of Saudi Arabia from the 11-20 million barrels oil released into the Arabian Gulf as the result of the 1991 Gulf War. Some of the oil went to sea, where it either weathered or sank to the bottom of the Arabian Gulf and remains entrapped in sub-tidal sediments. The purpose of this assessment was to evaluate the ecological risks to fifty-four nearshore areas where oil is present below the sediment surface at concentrations greater than 200 ppm and to evaluate the projected potential short- and long-term ecological risks from possible remediation activities in these areas.

The study area (the offshore region from Al Khafji south to Al Jubail, of which the affected areas covered approximately 39 km<sup>2</sup>) included the nearshore sediments in Saudi territorial waters and around the Abu Ali lagoonal system and the Manifah lagoonal system (KFUPM, 2003). A sediment-sampling program at 419 sites was conducted in and around the lagoonal systems. In addition, to study the health of benthic communities in impacted sediments, benthic sampling was undertaken at five representative impacted sites and five matched controls, two in

the Abu Ali lagoonal system (Mardomah and Musallamiyah), and three in the Manifah lagoonal system (Tanajib, Balbol and Manifah). Three categories of data were used to evaluate the risk for these nearshore areas. Measures of exposure included consideration of the Total Petroleum Hydrocarbon (TPH) concentrations found in these areas, and the surface areal extent of contamination. Measures of ecological effects included both estimates of ecological toxicity from contaminated sediments and observations of impacts on benthos from the characterization of the benthic communities. Measures of diminished recovery included physical characteristics that influence the degradation and dispersion of oiled sediments (e.g., depth of oiling and wave action) and the relative level of contamination remaining in sediments.

A multi-step process was used to evaluate the current baseline risks and the potential risks from remediation alternatives (See Figure above). The first step in the process was to develop conceptual models to identify the pathways and measures of exposure and ecological effects that are going to be used to characterize and assess risk.

## Risk Assessment (continued)

The second step consisted of constructing a risk-scoring matrix that is comprised of two components: a suite of evaluative measures of exposure and ecological effects; and criteria and/or benchmarks for each of these evaluative measures that can be used to rank the risk of each measure (e.g., high, medium, or low). The third element in the process is a decision analysis framework (decision tree) that is used to illustrate how the criteria and/or benchmarks values for each risk ranking category are applied and combined across multiple evaluative parameters to derive a final risk ranking.

The results for the Nearshore Marine Assessment indicated that thirty-seven of the 54 areas proposed for remediation are ranked as high risk, covering a total area just more than 35 km<sup>2</sup>. The Mardomah study area contains the largest area scored as high risk, covering an area of more than 20 km<sup>2</sup>. Musallamiyah ranks second, with more than 7 km<sup>2</sup> scored as high risk. The total areal extent of high risk in Tanajib, Balbol and Manifah combined is roughly equivalent to the areal extent of high risk in Musallamiyah and about 37 percent of the areal extent of high risk in Mardomah.

An environmental impact analysis was conducted for each of the remediation alternatives evaluated including hydraulic and mechanical dredging and its associated berming, the impacts from sheet pilings, the removal, and treatment of sediments using thermal de-sorption. The results from these studies provides; 1) the basis for balancing the risks and benefits of active remediation with the status quo option; 2) information to assist the KSA in prioritizing those areas requiring remediation and or restoration activities; and 3) information to assist the KSA in their decision-making processes for managing risks associated with these environmental damages.

