The Department of Defense Kuwait Oil Health Fire Risk Assessment (The "Persian Gulf Veterans' Registry")

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OTA BACKGROUND PAPER

THE DEPARTMENT OF DEFENSE KUWAIT OIL FIRE HEALTH RISK ASSESSMENT

(The "Persian Gulf Veterans' Registry")

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OTA Review

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INTRODUCTION

Even before the end of Operation Desert Storm, the Department of Defense (DoD) began to assess the likely health impacts of the conflict's most visible icon--billowing smoke from 600 burning Kuwaiti oil wells, ignited by retreating Iraqi troops. Then, just as the last fires were extinguished, the Congress made its own specific demands for information about health risks to each smoke-exposed military participant (in Public Law 102-190 and later expanded on in Public Law 102-585). DoD responded with the Kuwait Oil Fire Health Risk Assessment, the heart of which is a computer-based geographical information system (GIS). The completed part of the risk assessment is based on actual measurements of contaminant levels taken while troops and smoke coexisted in the Persian Gulf. An ongoing part will eventually produce estimates of health risks based on "modeled" contaminant levels where and when no actual measurements were taken.

The Office of Technology Assessment was directed in Public Law 102-585 to assess whether DoD's project "meets the provisions of the law under which it was mandated," to assess its "potential utility . . . for scientific study and assessment of the intermediate and long-term health consequences of military service in the Persian Gulf theater of operations during the Persian Gulf War, " and to address some other related questions. A requirement that OTA assess the Department of Veterans Affairs Persian Gulf War Veterans' Health Registry (which was mandated in the same public laws as the DoD effort) was met by a report in October 1993.1

This Background Paper describes briefly the work on DoD's Kuwait Oil Fire Health Risk Assessment to date, including the results of a pilot study of health risks, and then answers the questions addressed to OTA in PL 102-585. This review relies heavily on the work of a consultant expert in chemical risk assessment who studied the DoD project for OTA (the consultant's report is available from OTA).[2] His work is based on a variety of contacts with the U.S. Army Environmental Hygiene Agency (EHA; recently renamed the U.S. Army Center for Health Promotion and Preventive Medicine, but referred to in this report as EHA), which has major responsibility for this task within DoD, except for determining troop locations. That latter task falls to the U.S. Army and Joint Services Environmental Support Group (ESG), the Army's experts on military records. OTA's consultant (and OTA staff) gathered information from ESG on their activities relevant to this review.

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[1] U.S. Congress, Office of Technology Assessment, "The Department of Veterans Affairs Persian Gulf Veterans' Health Registry, 1993.

[2] Risks of Radiation and Chemical compounds, "The DoD Persian Gulf Oil Fire GIS Modeling Project: A Review and Evaluation, " submitted to OTA September 1994.

SUMMARY OF OTA'S FINDINGS

DoD have designed a GIS capable of producing individual estimates of risk resulting from exposure to oil fire smoke (and for smoke plus ambient background concentrations of toxic substances using measurements of air samples over a nine-month period) for each person who served in the Persian Gulf region, in response to the Congressional mandate. The system will be fully operational when the exposure information is all placed into the GIS (some time in 1995) and daily location data for each unit stationed in the region during the conflict are completely abstracted from original military records (some time in 1996). The risk assessment framework adopted by DoD is a logical and well-executed response to the mandate, based philosophically on the way the Environmental Protection Agency (EPA) conducts risk assessments under various environmental health laws. This type of risk assessment, because of a desire to protect public health, inherently overestimates risks to health.

In its *Final Report: Kuwait Oil Fire Health Risk Assessment*, EHA reported estimated health risks that were extremely low: an estimated upper limit of lifetime cancer risk of two in a million (possibly rising to three in a million when exposure is extended to the entire period during which the fires burned, and possibly somewhat higher at some places where measurements were not taken), and a low probability of noncancer health risks (not quantified in the same way as cancer risks). These risk levels are similar to estimates for a person spending the same amount of time in a U.S. city, calculated in the same way. Under existing risk assessment scenarios, these risk estimates would be considered so low that, in most cases, they would be dismissed. Scientifically, there is no added value to actually generating (or being able to generate) risks for individuals, all of which would be below these upper limits (or slightly modified upper limits not expected to be much different from these) and would, in any case, not be very accurate. Risk assessment methods have generally been designed to apply to groups of people and not to estimate precise risks for any one individual. Since all estimated risks would be very low, they could not be used to identify any particularly "high risk" cohorts that might benefit from medical surveillance or other intervention.

The GIS may have uses other than generating oil fire health risk estimates. It is a versatile and powerful analytic tool that might be put to use in epidemiologic studies of other exposures in the Persian Gulf, but only if sufficient information on those other exposures were available and could be described accurately in time and place. (OTA is unaware of efforts to systematically catalog exposures in this way.) This type of use will depend on ESG completing its troop location inventory, independent of the needs of the oil fire risk assessment.

The important conclusion that OTA draws from DoD's report on oil fire health risk assessment is that, using state-of-the-art risk assessment methods, the risks to health from exposure to the smoke and the background air contaminants in the Persian Gulf are likely to be extremely small. If aspects of the Persian Gulf experience are causing illness, they are likely to be other than oil fire smoke, according to DoD's risk assessment.

When completed, DoD's GIS and its associated risk assessment system will meet the Congressional mandate for individualized estimates of exposure from Persian Gulf oil fires. The troop location and atmospheric data related to the smoke will be easily accessible indefinitely once they are all entered into the system. **The scientific value of the program, however, lies in what already has been accomplished, which establishes that overall risks to health from oil fire smoke are very low.** Additional scientific value may come from its use in evaluating other exposures that are suspected of causing health problems among Persian Gulf veterans, but this depends on having detailed information about other potentially harmful exposures. **Actually being able to generate individual exposure estimates, which is required by the law, is of very low value as it relates to learning anything about veterans' health.**

THE OIL FIRES IN KUWAIT

As Iraqi troops withdrew from Kuwait at the end of the Persian Gulf conflict, they destroyed more than 700 oil wells in four major oil fields, and about 600 were burning at the end of February 1991. Other wells were gushing oil and some of the resulting "oil lakes" also burned. When all the fires were burning, perhaps 5 million barrels of oil were consumed each day. Before the last fire was extinguished in early November 1991, 800 million barrels of oil may have burned.

The fires released copious smoke that rose to altitudes of one to four kilometers and moved mostly to the south and west under the influence of prevailing winds. Some fires released predominantly white smoke, indicating large quantities of water vapor; some released very black smoke, indicating high soot content; and some released smoke intermediate in color. Plumes from the individual fires merged as they moved downwind into a "super-plume" that could be tracked from satellite images of the Persian Gulf region. The super-plume was dense enough to block out most sunlight when it was overhead.

The plumes contained both oil combustion products and unburned chemicals originating in the oil, along with minerals associated with soil or water carried aloft by the fires. Significant quantities of the more volatile chemicals in crude oil also were released to the atmosphere by evaporation from gushing oil wells or crude oil pools.

Nearly 700,000 U.S. troops were deployed to the Persian Gulf region and many were in the region while the fires were burning. When a plume was overhead in the vicinity of the troops, there was a potential for exposure, although the densest part of the plume was generally well above the surface.

Soon after the fires began, speculation arose that exposures might cause acute health effects in some people. Measurements of pollutant concentrations and records of health complaints did not reveal a widespread short-term problem, but the possibility remained that smoke exposures could cause diseases, including cancer, later on.

THE CONGRESSIONAL MANDATE TO DOD

The first Congressional mandate came in the National Defense Authorization Act for Fiscal Years 1992 and 1993 (Public Law 102-190, Section 734), passed in December 1991. The law calls for the Secretary of Defense to:

> establish and maintain a special record relating to members of the Armed Forces who, as determined by the Secretary, were exposed to the fumes of burning oil in the Operation Desert Storm theater of operations during the Persian Gulf conflict.

This "registry" was to include the name of each exposed individual and "a description of the circumstances of each exposure of that member to the fumes of burning oil . . . including the length of time of the exposure. "

About a year later, in the Veterans Health Care Act of 1992 (Public Law 102-585, Section 704), the Congressional mandate for information was expanded to all who served in the Persian Gulf during the conflict, not just those known to be exposed to oil fire smoke. The new mandate called for information (to the extent it is available) on the location and circumstances of each person's service including "atmospheric and other environmental circumstances in such locations. " Public Law 102-585 also directs OTA to assess the mandated DoD "registry," as described in the law.

THE KUWAIT OIL FIRE GIS MODELING PROJECT

Status of the Project

As of September 1994, a preliminary version of the GIS had been completed and tested in a pilot project, described in EHA's *Final Report: Kuwait Oil Fire Health Risk Assessment.* EHA's report was made available to OTA in August by the Office of the Assistant Secretary of Defense for Health Affairs for the purpose of completing this Background Paper, but otherwise has not been released by them.

EHA are still working on completing the GIS database, but the basic structure of the system is in place. The main tasks remaining are to define the smoke plume boundary for each day, which is a well-defined activity but one that requires intensive work, and to determine "emission" rates for each toxic substance in the smoke (discussed later). Once this is complete, in early 1995, the system will be ready to generate health risk estimates for each individual who served during the period of the oil fires.

ESG have made considerable progress in computerizing the daily troop locations, but project that it will be another two years before the task is complete. Locations are abstracted on a unit-by-unit basis, so ESG already are able to provide EHA with daily locations for some units and will be able to add units as they progress. In addition, they have once-per-month locations for most of the Army units that served in the Persian Gulf (most units did not move around very much, so these locations probably represent relatively well the dispersion of troops).

Description of the Project

The GIS is a computer-based system designed to capture, maintain, and analyze information about troop exposures to the oil fire smoke and any risks to their health that might result. The information needed for an ideal assessment includes:

- the location of each service person on each day of service in the Desert Shield/Storm theater of operations,
- the location of every smoke plume on each day smoke was in the air,
- the inventory of toxic substances entering each plume,

- the concentrations of those toxic substances at the location of each service person on each day,
- the conditions of each person’s exposure (e.g., the rate at which each person is inhaling air), and
- the inherent toxicity (including all diseases) of each substance to which each person is exposed.

In spite of its relatively straightforward purpose, the Kuwait Oil Fire GIS is a complex and resource-intensive undertaking. It requires a great many assumptions and procedures that are not demonstrably correct or incorrect. The GIS shares with most other risk assessment systems the need to deal with substantial uncertainties about both toxicity and exposure. As with many such assessments, the GIS copes with uncertainty by using assumptions that overestimate rather than underestimate risk; in the jargon of risk assessment, they are “conservative” assumptions. Both the values for toxicity and the exposure scenario parameters (such as the duration and intensity of exposure) are chosen to minimize the possibility that risks will be underestimated. EHA have generally followed the lead of the EPA in these areas.

For each person, two risk numbers may be produced: the risk of cancer (all cancers combined), which is expressed as a fraction (e.g., one in one million) and the risk of all other chronic diseases (the nature of which are not specified), given as a “hazard index, ” expressed as a multiple of one, which is set at a level at which no toxicity is likely to occur even after years of exposure (discussed in more detail below).

Information on the toxicity of chemicals found in the smoke comes from various EPA sources and is “generic” (i.e., the same toxicity relationships are applied regardless of the source of the chemical, so the ones used are not specific to these chemicals as constituents of smoke). Information on the levels of those constituents to which troops were exposed is specific to the Persian Gulf experience and comes from a variety of data sources on the oil fires. Troop location data come mainly from written military records. Each component of the system is discussed below.

Troop Identification and Location

The identity of nearly all the 696,000 individuals who served in the Desert Shield/Storm theater of operations during the Persian Gulf conflict have been available since the early development of the GIS. The Defense Manpower Data Center has supplied this information to ESG (including 64 data elements for each person). It is a simple matter to pinpoint the dates of service in the Persian Gulf and the unit with which each person served; these two pieces of information are all that is needed to enter the GIS on an individual basis.

The extent to which military personnel were exposed obviously depends on where people were in relation to the smoke. The whereabouts of each service member at each moment he or she was in the Persian Gulf cannot be known precisely, of course, but accepting a few basic assumptions, locations that in most cases will be reasonably close can be assigned. This aspect of the GIS involves fewer assumptions and less estimating than do others.

For the purposes of the GIS, a location for each company-level unit (most representing about 150 people) will be determined for each day of the Persian Gulf era (not just the period of burning oil fires, following the expanded mandate of PL 102-585). This information for each such unit was recorded on paper in their daily records. Abstracting these data points requires actually reading through the records for each of these approximately 13,000 units and transcribing each point (by latitude and longitude). The points captured in the records came from automated locators that use satellite contact to calculate position. To the extent the record keeper read the instrument and entered the numbers correctly, the locations should be quite exact.

The most important assumption about the location coordinates is that all members of the unit are assumed to have been at the same place. This clearly is not true. In general, however, it is probably true that troops were relatively near their unit location most of the time. As it turns out, the resolution of other parts of the GIS is not so great as to make locations that might be off by even 15 kilometers a big problem. In addition, it appears that the smoke plumes did not vary a great deal over short distances, so all in all, the troop location data will be sufficiently precise for nearly all individuals. There undoubtedly were times when people were distant from their unit for particular reasons. One can conceive of scenarios in which location away from an individual's unit might be important, but it is unlikely to be a major problem.

Smoke Measurements

The level of risk associated with the oil fire smoke depends on what the various compounds are that made up the smoke and on the levels of each one when and where troops were exposed. One could imagine a map of the smoky region blanketed with numbers that describe the concentrations of each relevant smoke constituent for each day the fires burned (assuming that conditions did not change appreciably over the course of a day). It might then seem a simple matter to describe the level of exposure to each person on the ground in contact with all the various substances. EHA's task in this area is to develop the blanket of numbers from data that are rather limited, in both place and time. They are going about this using two independent methods: first, using measurements from air monitoring in the Gulf while the fires were alight; and second, mathematical modeling of smoke dispersion using meteorological data and information on smoke emissions from the fires. These approaches, which give rise to quite different estimates, are described in the following paragraphs.

EHA sampled air in the Gulf area from early May through December 1991, which includes about a month of sampling after the last fire was extinguished. Using methods recommended by EPA, about 4,000 samples from eight sites (four in Kuwait and four in Saudi Arabia) were taken and analyzed, The sample locations were chosen primarily on the basis of major troop concentrations, and included areas where the smoke was considered heaviest . Samples were analyzed for all toxic substances reasonably anticipated to be in smoke from an oil well fire involving Kuwait crude oil, as well as for other potentially toxic substances. Airborne concentrations can result from the vapors of volatile organic compounds or from less volatile compounds attached to fine particles of smoke or dust. These measurements represent the combined concentration of substances in the smoke and background levels of those substances.

Using the air monitoring data, individuals are assumed to be exposed to the concentrations at the monitoring site closest to their company's location on each day. Estimates will also be made using the HY-SPLIT model (see below) for those locations during the early period of burning oil wells, before monitoring began, from February to April 1991. (These estimates will differ from the monitored levels because they will not include background concentrations.)

In the second approach, the National Oceanographic and Atmospheric Administration (NOAA) used a mathematical model, “HY-SPLIT,” to estimate for each “grid point” the average daily concentrations that would be caused by burning oil wells. HY-SPLIT is a state-of-the-art “trajectory” model that uses information on wind speed and direction along with particle settling and diffusion rates to simulate the movement of “packets” of particles over time. The model was calibrated using measurements from air samples taken in “flythroughs” of the super-plume by the National Center for Atmospheric Research, the National Aeronautic and Space Administration, university groups, and EHA’s ground measurements. A third piece of information on smoke concentrations--satellite imagery of the plumes--is being used as well. By combining this visual “truth” with the boundaries of the HY-SPLIT model plumes, even better location of the smoke with time is possible.

The GIS modeled data from the period when some measurements were available (which has the advantage of calibration with the data from air monitoring) will be used to predict smoke-related concentrations for locations and days when there were no measurements, especially the period before field measurements began. For all periods, the modeled concentrations estimate only the contribution from the smoke itself, and therefore will be lower than the estimates from the ground measurements (which include other sources of pollutants, such as auto emissions). Exposures are assigned based on the nearest grid point to an individual’s company location. Because the spacing of the grid points is relatively fine in comparison to the plume dimensions, these modeled exposures are not likely to be misestimated substantially even if a person was not near the grid point all day, as long he or she was closer to that grid point than to any other.

A weak link of the HY-SPLIT procedure is currently in the estimation of “emissions” for each constituent of the oil smoke. Only emissions of sulfur dioxide ($S0_2$) and soot are known with any certainty because the sulfur and carbon content of the oil can be estimated and because some cross-calibration was possible with measured concentrations in the plumes. For other substances, the estimates are less firm. Even for the metals, which are neither created nor destroyed by the fire, estimates are difficult because of the range of metal content in the crude oil from different wells and uncertainties about the fraction of each metal that reached the plume. Some of the metals would remain in oil pools and never enter the atmosphere, while another portion would attach to large-diameter particles falling out of the smoke early and not reaching the main plume altitude used in the modeling. For volatile and semivolatile organic compounds present in the oil, emission rates are even more speculative. Conversely, the rate of formation of hazardous substances during combustion is very uncertain. EHA are in the process of collecting information on the chemical composition of oil from each oil well field and on the total amount of oil released, to aid in determining appropriate emission rates.

The two types of concentration estimates generated by EHA have one fundamental difference: the measured concentrations provide a way to estimate total exposure for troops located at or near one of the eight sampling sites for any day during which measurements were taken. The modeled concentrations provide a way to estimate Smoke-related exposures at any gridded location on any day the fires were burning, but provide no information on the contribution to total exposure from local, non-fire sources (e.g., auto emissions, airborne soil).

Personal Exposures

The juxtaposition of people with smoke makes for exposure. EHA included three routes of exposure in their risk analysis: direct inhalation of smoke, incidental ingestion of soil particles with smoke constituents attached to them, and dermal absorption of smoke constituents from soil adhering to the skin.

Inhalation is by far the most important exposure route (accounting for more than 90 percent of the total risk). The airborne concentration estimates described above form the basis for inhaled exposures. To determine how much exposure took place, EHA assumed a breathing rate based on 20 hours of relatively strenuous activity every day and four hours of sleep. Multiplying the total volume of air inhaled daily and the average daily concentration gives an estimate of the total amount of substance inhaled on that day. Dividing by body weight provides an estimate of the inhaled “dose” (milligrams of substance inhaled per unit body weight per day).

Soil is ingested when it sticks to food or fingers and is then eaten. Soil ingestion occurs under very ordinary conditions, and probably occurred to a substantial degree in the dusty Persian Gulf where hand-washing was not always feasible. EHA have assumed that each person ingested 300 mg of soil each day (a relatively high estimate). Soil concentrations have been determined from measurements at each of the same eight sampling sites as for the air concentrations.

Absorption through the skin depends on how much soil adheres to the skin, how much skin is exposed, and the fraction of each constituent that migrates out of the soil and through the skin over a day of exposure (which varies from chemical to chemical). EHA have assumed that one milligram of soil adhered to each square centimeter of exposed skin each day, that on average 4,270 square centimeters of skin were exposed (about 20 to 25 percent of total skin area), and that from 1 to 5 percent of each compound was absorbed.

The exposure assessment, consistent with other aspects of the model, has been deliberately “high-sided,” so the exposure numbers coming from these calculations should represent the uppermost plausible level of exposure.

Estimating Risk

Estimates of health risk are calculated by applying generic information about the risks of each toxic substance (toxicity values) to individual quantitative estimates of exposure (discussed above) using some standard formulas. EHA used toxicity values from EPA’s Integrated Risk Information System (IRIS), considered to be that agency’s most thoroughly reviewed source of toxicity information. Because IRIS has not released toxicity summaries for all the substances of possible interest in the smoke from the Persian Gulf oil fires, other sources of information (mainly from other EPA programs) were used when necessary. Nearly all the toxicity values are based on data from animal experiments. Information on the toxicity of only some metals and a few other compounds is known directly for human beings.

Once toxicity values have been decided on, risk calculations are quite straightforward in the approach taken by EHA. For these calculations, exposures were expressed as average daily doses over the period of exposure.

For noncarcinogens a “hazard quotient” (HQ) is calculated by taking the ratio of the estimated average daily dose to a “reference dose” (RfD). An RfD is a daily dose that is unlikely to cause any health effect in most people even if they are exposed at that level indefinitely. If the estimated daily dose is less than or equal to the RfD (i.e., the HQ is less than or equal to 1.0), no health effects of any kind would be expected. If the estimated daily dose is higher than the RfD (i.e., the HQ is greater than 1.0), then there is some possibility of a health effect; the probability, the severity, or both increase as the HQ rises further above 1.0. However, neither the probability nor severity is quantified and doses slightly exceeding the RfD may be inconsequential. On a more practical level for the exposed individual, the HQ does not refer to any specific disease, but to health effects in general.

To take account of possible additive effects among chemicals that affect the same organ systems, a “hazard index” (HI) is computed by adding together the HQs for every chemical affecting that system. If the HI is above 1.0, some health effects are possible.

RfDs (and the HQs and HIs based on them) represent the best estimate of health risk after long-term exposure to a substance (long enough for the concentrations of the substance inside the body to have stabilized even with continuing exposure). Generally, shorter periods of exposure, like those in the Persian Gulf, will be associated with lower risks, but except in those few cases where a “subchronic” RfD has been defined, the RfD cannot be “adjusted” to account for that lesser risk. Therefore, troops who remained in the Persian Gulf for only a few weeks or months are probably not at as high a risk as would be predicted by their HI, but a quantitative adjustment cannot be made. HQs and HIs are, in the end, rather crude measures.

With carcinogens, the approach is different. Any exposure is assumed to carry some risk of cancer, and the risk is assumed to increase linearly with total exposure. The proportional linear increase of risk with exposure is called the “cancer potency slope factor” which, when multiplied by an average daily dose, gives an estimate of the lifetime probability of developing cancer because of that substance assuming a lifetime of exposure at that dose. If exposure does not continue for a lifetime, as in the case of the Persian Gulf troops, an adjustment is made to scale back the risk proportionate to the length of exposure. The probabilities are usually expressed in some natural unit, such as three chances in a million. The resulting estimate must then be held up to a standard of “acceptable risk. ” The notion of what is acceptable derives from a combination of science and policy and depends on the context of the risk estimate.

The cancer slope factors and the exposure estimates are calculated with “conservative” assumptions, so the resulting risk estimate is usually described as a plausible upper limit on the probability of developing cancer. The estimate is “plausible” in the sense that none of the individual assumptions is so conservative as to be beyond belief. In the vast majority of cases assessed in this way, the estimated risks will be greater than the true risks, sometimes by large margins. In a few cases, the estimated risks will be approximately correct, and in a very few cases, they will be too low.

Predicted Health Risks from the Oil Fires

EHA used the measurements at the eight ground monitoring sites to estimate the risk to hypothetical individuals assumed to have been present at those sites from May 5 through December 3, 1991, which was the monitoring period. (These risks, therefore, exclude the risk from exposures before monitoring took place, from February through early May.) The eight sites include both areas very near the fires, including one (Al Ahmadi Hospital) that was only about a mile from a burning oil field, and areas more or less unaffected by them.

The predicted excess cancer risk during the seven-month monitoring period ranged from a low of four in ten million to a high of two in a million, including all routes of exposure. Benzene, one of commonest air contaminants everywhere, mainly from the combustion of gasoline, is the main “driver” of cancer risk in these estimates. The risk levels differed little among the smokier monitoring sites in Kuwait and the “cleaner” ones in Saudi Arabia. The total predicted risk of all noncancer chronic conditions ranged from an HI of 0.5 to an HI of 5,0. The HIs were higher than 1.0 (i.e., some potential for chronic disease) at all but one site. Inhalation of volatile organic compounds, particularly benzene, accounted for more than 99 percent of the noncancer risk.

Generating Individual Health Risk Estimates With the GIS

The Kuwait Oil Fire GIS was designed to respond to the Congressional mandate for individualized information on health risks from oil fire smoke for each person who served in the military during the Persian Gulf conflict. As currently conceived, EHA would provide a complete database of daily contaminant levels over the region to ESG. When a request is received to estimate an individual’s risk, ESG (using similar GIS software) would enter the appropriate identifying information and the program would link an individual to his or her unit, and then calculate an aggregate exposure and risk over the time the veteran was in the Persian Gulf. ESG would then communicate risk levels to the veterans who have asked for their exposure information. The format for that communication has not yet been worked out, though this issue has been discussed among various parts of DoD.

Two questions arise in evaluating the utility of individual risk estimates: how accurate will the information be and how should it be presented to maximize its usefulness to the veteran? As to accuracy, it is clear that the risk estimates will not be very accurate for an individual. The preference for conservative assumptions will mean a consistent bias toward overestimation of risk, while uncertainties about an individual’s location with respect to his or her unit will mean an additional random uncertainty.

The raw estimates of risk that will be generated by the GIS are not easy to understand in relation to an individual’s health. What does a cancer risk of one in a million mean? Will use of the words “cancer” and “chronic toxicity” themselves induce fears? Alternatives to reporting these raw estimates would be to describe a gradation of *exposures* (low, medium, high) or to use the average risk as a reference and report an individual’s risk in relation to it, though the interpretation of these relative terms may also mislead. These issues have not yet been taken up by DoD, but presumably they will require attention if the system proceeds as planned.

OTA EVALUATION

The GIS

The estimation of troop exposures to oil fire smoke might have been handled by any number of computer-based systems, including relational databases or spreadsheet programs. But these types of systems are severely limited in both their analytic and display capabilities. The decision to use a GIS was based on its ability to capture, manage, manipulate, analyze, model, and display spatial data. The key to a GIS, setting it apart from other software (such as computer-aided mapping) is the "topology" that allows the user to query, analyze, and display the data with respect to the connectedness of elements with spatial features (e.g., grid points, lines, or polygons).

The GIS is an essential tool to achieve the objectives of the risk assessment project, cast narrowly to estimate exposures and risks to troops operating in the Persian Gulf. However, the purposes of the project beyond this have not been stated clearly. Neither the types of reports that will be generated for individual veterans nor their formats are well described. It is clear that ESG will use the system to respond to veterans' requests, but no other particular uses (i.e., for research) have been specified. If multiple users are contemplated, there should be more coordination in designing the system to meet their needs.

In principle, the GIS could be used to investigate exposures and risks from any other events or activities involving hazardous substances that could be located by geographic coordinates and date. Some exposures that have been mentioned are spraying of pesticides, use of diesel-fueled heaters in tents, chemical or biological agents deployed by Scud missiles, and depleted uranium used in projectiles and tank walls. OTA learned of no attempts to develop a database for any such exposures. Although it seems feasible to develop a database of location and time for some of these exposures and therefore to identify troops that were nearby, developing quantitative "exposure" estimates would be difficult or impossible. Given the extremely low estimates of risk from the oil smoke itself, using the GIS to aid in investigating other exposures might give added value to the investment that already has been made.

Information on Oil Fire Constituent Levels

EHA has made efficient use of the ground measurements of air during the period that monitoring took place. But there are limits to those data, which will affect EHA's ability to predict health risks over the entire area occupied by troops and over the entire time during which smoke was in the air. The principal limitations of the measured values are:

- **The restriction to eight sampling locations that may not be representative of the distribution of troops.--Four of the locations are clustered tightly around Kuwait City and the four** in Saudi Arabia represent only a portion of the area that was affected by the oil fire plume. Because monitoring sites were chosen on the basis of troop concentration, however, this is probably of little importance.

- **The restriction to the period May through November (and to shorter periods for most of the** stations) .--Concentrations of smoke-related substances could have been higher during the period February through April when more fires were burning.

- **The inability to separate smoke-related contributions from those related to natural background or other non-smoke sources.**--The dominant source of both cancer and noncancer risk is benzene and it is not clear whether or not this is mainly smoke-related. The variation of chemical concentrations with distance from the fires is often inconsistent with a smoke source; for example, neither chromium nor benzene concentrations were significantly different between the Kuwait and Saudi Arabia stations (although this may bean effect of the super-plume). The degree of overestimation of smoke risk is difficult to evaluate but is probably substantial.

- **The use of one-half the detection limit for the concentration of every chemical reported as** below the detection limit. --Although the inability to detect a chemical in a sample is no assurance that it is not present, it may not be present or may be present a level well below one-half the detection limit. Using one-half the detection limit is appropriate where good reasons exist for assuming the chemical is present, but is questionable when few samples show detectable levels. EHA has followed EPA policy on this point, however.

- **Disposition of "non-target analytes." --At every sampling location, the total concentration** of "non-target analytes" (everything not specifically measured) among the volatile organic compounds was much greater than the total concentration of the target analytes. Some description is needed of the composition of the "non-target analyte" fraction and an explanation of why the detected substances were not target analytes.

- **Lack of consideration of particulate matter--- Although it includes a section discussing generally** the health effects of inhaled particulate, EHA did not formally assess the potential toxicity of particulate (other than "soot," or carbonaceous particles) independent of the chemicals associated with the particles. Respirable particulate matter, which apparently came not from the smoke but mainly from background dust, is considered a health hazard at concentrations lower than some of those measured by EHA.

Exposure estimates based on the HY-SPLIT model are not yet possible because EHA has not fixed on a procedure for estimating emissions of each substance from the various burning wells. Without these emission rates, no modeled exposures can be calculated (but by design, they must be lower than the measured values, which include ambient substances).

Toxicity Information

EPA is widely perceived as the most authoritative source of information on environmental health hazards, so EHA's decision to use EPA toxicity information is well justified. EPA's mandate to protect human health from environmental hazards means, however, that its estimates of the toxic potencies of chemicals are conservative, i.e., tend to err on the side of overestimating risk when the true values are uncertain. This conservatism may or may not be appropriate, depending on how the estimates are to be used.

EHA's use of the RfD to evaluate noncancer risks (in calculating HIs and HQs) may have been unavoidable (no other set of risk relationships is available for a wide range of substances) but it presents significant problems in interpretation. The RfD is intended as an exposure level that is without any risk of toxic effect, even if the exposure continues indefinitely, but somewhat higher doses are not necessarily risky either. Most RfDs embody uncertainty factors of between 100 and 1,000, so they represent values far above those for which toxic effects may ever have been observed. For nearly all compounds, a true "threshold" for toxic effects in humans is unknown. This great uncertainty even under conditions of continued exposure is compounded by the fact the RfDs cannot be adjusted for assessing the shorter exposures experienced in the Persian Gulf. In order to understand the potential for noncancer effects, the nature of the health conditions that make up the risk should be examined for each substance so that judgments can made about their plausibility.

Interpretation of the Health Risk Assessments

The levels of cancer risk reported by EHA are considered to be below the level of concern under virtually every environmental or occupational regulatory proceeding. If the missing three months of exposure were considered, the highest risk might rise to about three in a million. A risk of one in a million has been considered unacceptable in some risk management decisions, but usually only when large populations are exposed.

The highest noncancer risks suggest that some chronic health effects from these exposures are possible. EHA have pointed out that the estimates contain so many conservative assumptions about both exposure and toxicity that they are likely to be substantial overestimates and may not imply any health risk at all, The addition of the three unmonitored months of exposure might increase the HIs somewhat because more fires were burning then, and the average daily exposure might have been higher. Because calculation of the HIs assumes exposures continuing indefinitely, the extra time itself would not affect the HIs.

The risks reported by EHA were from measurements of the air at ground level, so they represent background plus smoke-related contributions. No risk estimates were reported for modeled concentrations, which would, of course, be lower, because the background would be eliminated. If this risk of total exposure in the Persian Gulf is seen as an appropriate measure of impact on service personnel, then one might also ask what the risk would have been had the person spent eight months in the United States. The lifetime cancer risk of spending that time in the San Francisco Bay area, calculated in the same way as the risks for the Persian Gulf, is in the vicinity of 5 in a million--about twice the calculated risk in the Persian Gulf.

Comparisons such as these maybe criticized as trivializing the Persian Gulf experience, and it may be difficult for the troops who were in the Persian Gulf, as well as the public who daily witnessed massive, billowing smoke plumes blocking the sun in Kuwait, to accept the results. But stating them is important to place the risk in some context. It should also be understood that, like the risks predicted from exposure to Persian Gulf oil smoke, risks predicted from monitoring in the United States are overestimates based on conservative assessment methods and are still far too low to be confirmed or disproved by epidemiologic observations in the exposed populations.

Uses of the GIS and Related Information

DoD's mandate from Congress was to describe each individual's exposure to oil fire smoke in the Persian Gulf. EHA has taken this a step further by creating a capability to translate exposures into health risk estimates. EHA's system, relying on the GIS, should be fully functional once the system contains all the relevant atmospheric data (sometime in 1995) and the daily locations for each unit have been entered (sometime in 1996 or possibly sooner). Depending on whether the measured values of substances (from ground monitoring) are used or the modeled concentrations (from HY-SPLIT) are used, the risk will represent either total risk (in the former case) or the incremental risk of exposure to oil fire smoke. Which is preferred is a question of policy rather than science.

Whichever source of risk is chosen, the actual predicted levels will be very low. The figures reported by EHA in their report, which represent risks from both background and smoke (from ground monitoring measurements) ranged only as high as two in a million for lifetime cancer risk. Because of the highly conservative assumptions embodied in the RfDs and their unsuitability for predicting effects of short-term exposure, the highest HI (5.0) is probably of little health consequence. While it is not clear that these estimates represent the absolute worst case, it would be surprising to find exposures much higher anywhere in the Persian Gulf theater of operations. EHA might consider carrying out a "plausible" worse case risk estimate based on existing knowledge of where troops were and the known contaminant levels. Although complete troop location data will not be available for perhaps two years, ESG already has monthly location data for a large number of Army units that served in the Persian Gulf. Using this information now could provide a reasonable estimate of troop dispersion and perhaps identify a confluence of troops and relatively heavy smoke for purposes of estimating the highest of risks.

The question that can't be ignored is whether it is worthwhile to go ahead with a system that will generate extremely low risk numbers for everyone---numbers that are virtually uninterpretable (and not very accurate on an individual basis) in terms of one's health. The numbers generated will undoubtedly change over the years as the best information on risk changes (some upward, some downward), but it would be almost unthinkable that the risks would change by, say, a factor of 10.

Are there other uses for this system? As mentioned earlier, any risk that can be located in place and time is amenable to inclusion in the GIS. Complete information on suspicious exposures of virtually any kind are going to be hard, but not impossible, to come by. Once mapped, they could be matched up with the troops near them spatially and temporally, perhaps as the basis of choosing cohorts for an epidemiologic study. Such studies would require careful planning and cooperation and coordination between the researchers and EHA. (It should be noted that the exposures and resulting risks from the oil fire smoke are, as currently estimated, too low and too small in range to support epidemiologic studies.) If it is decided that the GIS should be available to assist in some of these studies, it would be important to complete the troop location component of the project, and to maintain the GIS as an analytic tool.

If the Congressional mandate to produce individual exposure estimates remains intact, DoD would be compelled to complete the GIS as it is doing, and eventually, the individual information would be available to veterans, whether or not it signifies anything about their future health (or more than would be signified by telling them that no one's risk is above a certain level). Scientifically, this exercise appears to have limited value in terms of the veterans' health if the reported risk numbers are confirmed and it is accepted that the risks from oil fire smoke are negligible. In terms of the veterans themselves, they may want these estimates. According to the Director of ESG, providing individual exposure assessments (along with an explanation of what they mean) may help allay the fears of Persian Gulf veterans concerning their exposures, and there may be value (other than scientific) in that.