July 29, 1999

EPA-SAB-EEC-99-COM-003

The Honorable Carol Browner
Administrator
United States Environmental Protection Agency
401 M Street, SW
Washington, DC 20460

SUBJECT: Environmental Impacts of Natural Hazards: The Need for Agency Action

Dear Ms. Browner:

The Environmental Engineering Committee of the Science Advisory Board recommends that EPA develop programs to deal with environmental impacts of natural hazards and their effects, including human health. The Committee first raised this issue in its 1995 report *Future Issues in Environmental Engineering* (SAB, 1995) and is renewing its recommendations at this time because some natural hazards have increased in frequency and severity, mostly due to the indirect influence of human activities. Floods and wildfires are in this category. The enclosure briefly summarizes some recent natural hazards and their impacts.

This EEC commentary results from a series of activities at publicly announced meetings. In February, 1998, colleagues from the National Science Foundation, U. S. Waterways Experiment Station, and the Mitigation Directorate of the Federal Emergency Management Agency discussed with the Committee, current and anticipated environmental impacts, relevant literature and the ability of both Agency and external programs to effectively assess and control such impacts. In December 1998, staff from the Office of Chemical Emergency Preparedness and Prevention briefed the Committee about relevant EPA activities. Committee members considered the environmental impacts of a variety of natural hazards, such as floods, earthquakes, hurricanes, landslides, tsunamis, wildfires and droughts.

**1. Findings on the Agency's Capacity to Address Environmental Impacts**

After reviewing reports on natural hazards within and outside the United States, being briefed on a variety of federal programs, and the collegial discussions mentioned above, the Committee reached the following findings and recommendations.

a) Impacts of natural hazards such as floods, earthquakes, hurricanes, landslides, tsunamis, wildfires and droughts on both human health and the environment are significant in most ecosystems. Such impacts include erosion and silting of wetlands; washout of waste treatment and storage facilities; dam failure and resulting inundation of wildlife habitats; spreading of disease causing vectors; and release and transport of chemical contaminants.

b) Both frequency and severity contribute to the intensity of natural hazards, severity being a measure of the event itself, such as the Richter scale for earthquakes. The meaning of the word “impact” varies by context. It can be used to describe the primary event, structural damage, public health risks, or ecological damage.

Some kinds of natural disasters have been more frequent in recent years than would be expected on the basis of the historical record; however, experts disagree over whether this difference constitutes a trend. While these observations are not yet fully understood, the apparent increase in frequency is one of the factors that motivated the American Society of Civil Engineers to operate the Council on Natural Disaster Mitigation and the United Nations to designate the 90s as the International Decade for Natural Disaster Mitigation.

Impacts can be measured in different ways. Mortality and property damage are common measures. However, the environmental impacts associated with natural hazards have not been adequately investigated nor has the potential for such impacts to exacerbate other environmental problems. While an increase in intensity suggests that the impacts on human health, property and the environment will also increase, this is not always the case. In the United States, for example, mortality from hurricanes has decreased markedly, while property damage has increased.

c) In the context of natural hazards, the U.S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), Federal Emergency Management Agency (FEMA) and the U.S. Army Corps of Engineers focus on some preventive and mitigative activities. However, these agencies only tangentially address environmental impacts. EPA’s efforts are relatively small and focused on emergency response activities for contaminant spillages. There is no national program to address the totality of environmental and public health impacts of natural hazards.

d) The impacts of natural hazards in other countries can both jeopardize U.S. interests and threaten public and environmental health in the United States. For example, El Nino-driven wildfires in Central America and Mexico have generated smoke that could affect public health in the southern portion of the United States.

**2. Recommendations on Program Needs**

a) Develop a Program to Provide National Leadership on Research

The Committee recommends that EPA provide national leadership for research on the assessment and mitigation of environmental impacts arising from natural hazards because the major unaddressed issues fall within EPA's area of expertise and existing elements of EPA's research programs are compatible with the issues that need to be addressed. Such research would be, for example, consistent with the primary goal of the U.S. Global Change Research Program (USGCRP), for example, is to "determine the local, regional and national climate change and variability in the context of other existing and potential future stresses on human health, the environment, society and the economy." One approach would be to expand the scope of the Global Change Research Program to include a research program on extreme events (natural hazards).

b) Develop Hazard Zoning Schemes in which Environmental Sensitivity is a Key Parameter

Facility siting and structural design considerations vary with the nature of the facility, intensity of extreme events and the vulnerabilities of the ecosystem(s) involved. The Committee recommends EPA help public officials and the private sector make decisions on siting and design by developing environmental sensitivity information at various spatial scales. and presenting it in conjunction with existing frequency-severity indices for various hazards. (There are new data visualization techniques for both spatial and temporal information which make these relationships easier to understand.)

This initiative would contribute to resolving long-standing Agency concerns about facilities in sensitive environments. The initiative is consistent with SAB's recommended model for futures analysis. This analysis combines the use of scenarios with an analytical framework, such as the ecorisk framework, to provide systematic approach for assessing future environmental risks. Finally, this initiative is consistent with the draft recommendations of the Risk Reduction Options Subcommittee (RROS) of the SAB's Integrated Risk Project on the screening, selection and implementation of environmental risk reduction options.

c) Revise Current Design Approaches for New Facilities that may be Located in Vulnerable Areas

At this time, the impacts of transient stresses from natural hazards are not adequately considered in the design of waste management facilities such as surface impoundments, waste piles, and landfills. Currently, designers who wish to address the effects of transient events find it difficult to do so because the Agency's technical guidance manuals generally describe design methods based on deterministic rather than probabilistic models. The Committee makes these observations based on the participation of members in the *Review of the Office of Solid Waste's Proposed Surface Impoundment Study* (SAB, 1998) and in a Consultation on Alternative Approaches for Disposal of Federal Low-Activity Radioactive Wastes (SAB, 1998).

Because designers have difficulty using Agency manuals to address transient stresses that may cause catastrophic failure or accelerate gradual failure, the Committee recommends that EPA revise its design methodologies to cover the reliability of structures in hazard-prone locations. Such methodologies could be connected and extended to ecosystem and human health risk assessments through estimates of probable contaminant release quantities and concentrations and their effects.

d) Require Consideration of Facility Vulnerability to the Location-Relevant Natural Hazards During Environmental Impact Assessments

The Agency can reasonably expect that natural hazards will continue to occur, that there will be impacts on the environment and human health, and that it is possible, in general, to both anticipate the ramifications of extreme events to prevent or reduce them. The Committee recommends that Agency expand its activities to reduce environmental impacts of natural hazards. A range of options is available to the Agency including research, communication, education, guidance, permit requirements, etc. For example, if permit applicants for facilities in high risk areas were required to address this topic in their applications, the analysis could be articulated in the form of a hazards summary directed at each particular event and its environmental effects, arrayed in terms of magnitude, importance, and estimated probability, fortified by pertinent commentary that could be drawn from antecedent knowledge and experience.

e) Collaborate with other Agencies Programs at Various Levels

Several regional, national and international agencies currently operate programs on natural disasters and sustainable development. Among these agencies are the World Health Organization, the United Nations Environment Program and the World Bank. Virtually every federal department plays a role in economic or technical aspects of disaster management. This issue provides an opportunity for EPA to partner with federal (and state) agencies with management responsibilities for natural resources, such as the Fish and Wildlife Service, National Park Service, and Forest Service.

In the United States, implementation of disaster management programs occurs at the state and local level. Without their support, programs designed by federal agencies, including EPA, cannot be effectively implemented. Therefore, the Agency should develop a coordinated plan for defining its sphere of activities and appropriate level of collaboration with other organizations to implement an integrated natural hazards program that goes beyond the current focus.

In this context, it may be worth making an analogy to the prevention rubric used by most public health problems which classifies prevention actions as primary (preventing or lessening impacts), secondary (mitigating effects which have occurred), and tertiary (keeping things from getting worse). Currently, most disaster management activities would be considered secondary or tertiary. This commentary advocates increased attention to primary prevention, that is the proactive efforts where EPA could exercise useful leadership.

The Environmental Engineering Committee looks forward to increasing its interaction with the Agency on approaches to minimizing adverse environmental impacts of natural hazards and to a written response to the recommendations in this commentary.

Sincerely,

/signed/
Dr. Joan Daisey, Chair
Science Advisory Board

/signed/
Dr. Hilary I. Inyang, Chair
Environmental Engineering Committee
Science Advisory Board

/signed/
Dr. Frederick G. Pohland, Co-Chair
Subcommittee on the Environmental Impacts of Natural Hazards
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Ms. Lynne Preslo, Co-Chair
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# APPENDIX - A BRIEF SUMMARY OF RECENT NATURAL HAZARDS AND THEIR IMPACTS

## 1. INTRODUCTION

Natural hazards are extreme environmental phenomena that may occur at various magnitude levels and spatio-temporal scales, often causing direct and indirect disruption of physical facilities, infrastructure, and environmental and socio-economic systems. The principal classes of natural hazards are earthquakes, floods, hailstorms, hurricanes, landslides, tornados, tsunamis (tidal waves), volcanic eruptions, wildfires, droughts and storms. Popular thinking, born out of review of historical records and recent observations, is that the severity and frequency of natural hazards are increasing at an alarming rate. The issues involved with natural hazards encompass a broad array of constituent events that may be triggered or driven by the coincidence of such events with a vulnerability situation. Vulnerability varies in time and space, thus making it necessary to develop and use hazards severity/frequency zoning maps for scaling hazards for location-specific risk assessments. Vulnerability is interactively determined by its anthropogenic and natural components.

## 2. PATTERNS OF OCCURRENCE AND ENVIRONMENTAL IMPACT GENERATION

The categories of factors that interact to exacerbate or attenuate the impact of natural hazards are illustrated in ***Figure 1***. Natural activity systems are phenomena that occur without significant enhancement (in intensity) by anthropogenic systems. The latter may be intense enough at a location to magnify the effects of the natural phenomena into a hazard. For example, excessive development of a Florida lowland can magnify the effects of a rainstorm into a flood. Essentially, there is a threshold intensity, defined by both magnitude and frequency of a phenomenon, above which the natural environment of the specific site or location can not attenuate negative impacts without human intervention. From the illustration in ***Figure 1***, the Florida lowland could still not be vulnerable to the flood if adequate flood control schemes are in place. Control schemes which range from structural schemes such as levees to facility siting controls, provide a management opportunity for minimizing the impacts of natural hazards on lifelines (such as power and telephone lines, water mains, sewers), structures, environmental and socio-economic systems, and public health. Disasters often occur only when control schemes are inadequate.

Anthropogenic activity systems such as those listed in ***Figure 1*** are directly proportional to population for most regions.  Considering that population has increased rapidly in most countries, hazards and impacts have also increased. Within countries, population redistribution to coastal areas also tends to increase the frequency of natural disasters.  About 50% of the U.S. population lives in coastal states; including 34 million people in Texas and Florida where hurricanes are frequent (J. Golden in Parfit and Richardson, 1998).

Meteorological hazards tend to be more intense in coastal regions and island communities.  A combination of location, dense population and inadequacy of hazard control schemes, such as those described by Wright et al. (1993), has made southeast Asian countries very prone to natural disasters.  In general, it is estimated by the World Bank (as reported by Showstack,1998) that about 95% of deaths caused by disasters globally occur in developing countries. Nevertheless, during the period 1975-1994, the United States spent about $0.25 billion per week on meteorological disasters alone (Forrest and Nishenko, 1996).

The large size of the United States, which spans near-tropical and temperate zones, exposes it to several hazards.  An elaborate analysis and illustration of the severity and spatial distribution of historical data on natural hazards in a recent issue of National Geographic magazine (Parfit and Richardson, 1998) reveal the following patterns: several volcanoes that have been active within the past 2000 years (the time frame often identified with high risk of eruption) are located on the Pacific Coast of the United States; earthquake hazards are highest in the western one third of the United States as well as the mid-western region around New Madrid, MO, and Charleston, SC; Florida, Texas, Louisiana and the  Carolinas bear the brunt of hurricanes, which peak in August and September each year; the frequency of tornadoes which sweep through the United States is 800 - 1100 per year, and exceeds the frequency in any other country; tornadoes are restricted largely to the eastern half of the United States; and since 1930, the major droughts have been more severe in Utah, Wyoming, Colorado, New Mexico, California, Oklahoma, northern Texas and the western portion of the Dakotas.

## 3. GENERAL DAMAGES AND LOSSES

Annual damages to physical infrastructure and socioeconomic costs of natural disasters are staggering.  For the period between August, 1992 and December, 1995, statistics (NSTC, 1996) show the following structural losses from natural disasters in the United States: Hurricane Andrew, $25 billion; Hurricane Iniki,

$12 billion; March 1994 blizzard, $6 billion; 1993 Midwest floods, $30 billion; 1993-1994 winter storms, 1994 spring floods and summer wildfires, $25 billion; 1995 spring floods, $7 billion; and 1995 hurricanes, at least $6 billion.

A recent report by the Associated Press in the New York Times (Monday, November 30, 1998, pp. A-18) indicated that the 1998 hurricane season was the deadliest in 200 years in North and Central America and the Caribbean: more than 10,000 people were killed. The averaging effect reduces the national burden per community, but the loss in the specific disaster areas may be very significant. For example, direct losses from the 1993 Northridge earthquake was about 3% of the California Gross State Product (Forrest and Nishenko, 1996). Globally, 85% of all insured losses of property are attributable to natural disasters, a realization that has prompted the United Nations Environment Program (UNEP) to develop an Insurance Industry Initiative (III) for mitigative action.

## 4. ENVIRONMENTAL DAMAGES AND RISKS

Environmental damages that result from natural hazards are often less dramatic than structural damages to lifelines (such as power and telephone lines, water mains, sewers) and buildings. Environmental damages also may be linked in series to structural damages as direct consequences. The slower manifestation of environmental damages relative to lifeline damages has resulted in neglect of complete environmental impact assessments beyond actions needed for contaminant spill response when natural disasters are analyzed. One of the problems is the difficulty of establishing causal links from a manifested non-immediate environmental damage back to the catastrophic event in a multi-hazard situation. Also, beyond initial efforts to rehabilitate and restore damaged lifelines and structures, the continuous monitoring of the affected area, which is needed to identify and characterize human and environmental impacts, is often not conducted. Nevertheless, despite the general lack of data on the environmental impacts of natural hazards, a few analyzed events have exemplified the environmental and human health risks that can result from uncontrolled impacts of natural hazards.

Floods can induce significant negative ecological impacts. The SAB (1995) has presented a natural hazards sequence tree to help summarize damages inflicted by floods (shown in ***Figure 2)***. The 1993 Midwest Floods washed out several waste treatment and storage facilities, as discussed by Inyang (1994a). Salinity, toxins and zebra mussels were spread downstream. Reportedly (NSTC, 1996), ecological impacts were observed as far away as the Gulf of Mexico. In the summer of 1992, Hurricane Andrew left more than 20 million cubic meters of debris in its wake in the Florida Keys, challenging the waste disposal system capacity of the area (Keck, 1996). The scale at which floods can affect ecosystems is illustrated by the 1998 Chinese floods which inundated about 64 million acres of land around the Yangtze River.

Between May 25 and June 28, 1998, wildfires destroyed valuable ecosystems in about 218,000 acres in Florida. During the same time frame (Boston Globe, May 7, 1998, pp. 17), wildfires raged across the Canadian prairie, destroying about 360,000 acres of grass and timberland. Sometimes, environmental and public health effects may impact another country, when the source of the initiating phenomena is external. For example, during mid-1998, smoke drifted into Texas, Oklahoma and Florida from a belt of El Nino-driven wildfires in Central America and Mexico. As reported in U.S. News and World Report (June 1, 1998, pp. 38), the resulting air pollutants also produced dramatic increases in asthma and other respiratory ailments in Central America.

## 5. EMERGING MONITORING SYSTEMS AND PROGRAM NEEDS

Although the impacts of natural hazards have been recognized, preparedness and mitigation strategies have not adequately addressed environmental effects. Since the declaration of the decade of the 1990's by the United Nations as the International Decade for Natural Disaster Reduction (IDNDR), several international and national programs have been developed. In the United States, responsibility for relevant activities is shared at the federal level by several agencies as described by NSTC (1996). The principal agencies are the Federal Emergency Management Agency (FEMA), National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), U.S. Department of Energy (USDOE), U.S. Environmental Protection Agency (U.S. EPA), U.S. Department of Health and Human Services (USHHS), the U.S. Department of Housing and Urban Development (USHUD), the Federal Energy Regulatory Commission (FERC), and the National Science Foundation (NSF).

Advances in telecommunications, data management and visualization methods, and sensors within the past ten years have provided new opportunities for data acquisition and interpretation for prediction of natural hazards and development of environmental and public health disaster prevention and mitigation strategies. Earth observation satellites can attain spatial resolutions of a few meters, while others have high observation frequencies (about 0.5-6 hours). The U.S. LANDSAT 5 satellite has a spatial resolution of about 5 meters, although resolutions are increasing as military technology is adapted to civilian uses.

Multi-spectral sensors such as those on LANDSAT can provide spatial distribution information on wetlands, population centers, waste treatment and storage facilities, and roads/bridges. Radiometer sensors such as NOAA's Advanced Very High Resolution Radiometer (AVHRR) sensors mounted on meteorological satellites have a relatively low resolution, but their measurement repetition makes them useful for flood and wildfire monitoring.

Data obtained from these satellites and other ground-based methods, such as those summarized in ***Table 1*** (NRC, 1989), have utility beyond their primary purpose. Secondary use of such data in environmental risk characterization, planning and mitigation requires the development of linkages among different analytical techniques that are traditional to various professional disciplines, each of which covers narrow segments of this problem. Relevant technical issues include hazard (geologic and meteorological/climatic) event prediction; hazard control options selection methodologies; environmental damage/impact assessment for probable events; waste management facility design reliability analysis; ecosystem and facility monitoring system design; and linkages of event probabilities and facility/ecosystem physical damage to ecological and human health risk levels. The SAB (1995) has described how network analysis can be applied to natural hazards problems.

Approaches that could be adopted to control environmental pollution that could be caused by damages of fixed waste management facilities include choice of suitable sites, structural design conservatism and incorporation of external redundancy. These approaches are discussed in greater detail by Inyang (1991, 1992, 1994a, and 1994b). ***Figure 3*** shows the probable damages that an earthquake may cause on a waste landfill. Such damages which could be internal, may not be readily/initially detectable unless monitoring schemes such as those illustrated in ***Figure 4*** are implemented. The operational mechanisms of the sensors range from fiber-optic sensing to sensor cable swelling and consequent voltage drop upon contact with contaminants.

Contaminant source term concentrations which are usually computerized for risk assessments may become significantly erroneous as release mechanisms change from permeation of barriers to flow through flaws in the structural system that result from natural hazards. Traditional and innovative monitoring techniques that could be used in hazard-prone environments are summarized in ***Table 2***. Advances in electro-chemical sensing have increased the capacity to continuously monitor contaminants in surface and subsurface environments. These monitoring systems need to be used more widely.

Current design methods for waste containment systems are mostly based on deterministic mathematical expressions. Considering that natural hazards enlarge performance uncertainties, probabilistic analyses should be used in design, at least for facilities in hazard-prone environments. Among the techniques that could be assessed for use are Cause-Consequence Analysis (CCA), Event Tree Analysis (ETA), Fault Tree Analysis (FTA), and Failure Modes, Effects and Criticality Analysis (FMECA). Some of these techniques are being used in the analysis and design of nuclear power plants against accidents and natural hazards.

Natural hazards are producing environmental impacts that may coalesce with other traditional stressors to enhance environmental degradation rates. It is difficult to decouple post-disaster impacts from those that are attributable to ever-increasing anthropogenic activities. Nevertheless, environmental aspects should be addressed adequately in the emerging programs. Components should include, research, education, technical guidance, technology transfer and collaboration between public agencies and the private sector at appropriate levels. For example, at the federal level, the National Disaster Reduction Initiative (NDRI) an interagency program developed by the National Science and Technology Council (NSTC) has a funding level of about $155 million for the 1999 fiscal year. Other programs such as the U.S. Global Change Research Program (USGCRP) started in 1997, and the Public Private Partnership 2000 (PPP 2000 of NSTC) provide additional opportunities. The U.S. Environmental Protection Agency, with its mandated mission of protecting the environment and public health, should provide leadership for these important programs related to natural hazards.

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**Table 1. Applications of information-gathering and communication systems for natural hazards mitigation (NRC, 1989)**

**TABLE 1 AVAILABLE IN HARDCOPY ONLY**

**Figure 1.** **Schematic illustration of the interaction between natural events and anthropogenic systems relative to hazards and disasters**

**FIGURE 1 AVAILABLE IN HARDCOPY ONLY**

**Figure 2. Natural Hazards Sequence Tree**

**FIGURE 2 AVAILABLE IN HARDCOPY ONLY**

**Figure 3.** **Schematic of a landfill showing potential deformation of leachate collection pipes by seismic stress (landfill geometric details are not provided. (Inyang, 1992)**

**FIGURE 3 AVAILABLE IN HARDCOPY ONLY**

**Figure 4.** **An illustration of external monitoring systems using point, linear and areal sensors, that could be configured to detect damages in sensitive environments (adapted from Inyang et al, 1996).**

**FIGURE 4 AVAILABLE IN HARDCOPY ONLY**

**Table 2.** **Examples of traditional and innovative monitoring techniques for specific waste containment problems, for possible use in high hazard situations. (Inyang, 1994b)**

**TABLE 2 AVAILABLE IN HARDCOPY ONLY**

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